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EDITORIAL POLICY

Water Nepal is published two times a year by Nepal Water Conservation Foundation. *Water Nepal* is a publication for planners, engineers, scientists, policy-makers, and administrators engaged in water development and management. It functions as a forum for sharing experiences in different aspects of water resource development. Each issue of *Water Nepal* includes summaries of new techniques, reflections on current approaches in water development, management, research findings, and case studies of innovative practices including field experience. As a matter of policy, *Water Nepal* publishes articles not published elsewhere. But pieces that are of policy relevance for Nepal, that serve educational purposes, will be included.

Editorials, feature articles, and reports in *Water Nepal* will discuss water management problems, analysis of long-term development needs and trends, dispute resolution, impact assessment and mitigation, overcoming weaknesses and ensuring institutional learning for sustainable water development; as well as balancing water development with social and environmental objectives at the micro, meso and macro levels by understanding the interdisciplinary relationship between water use and sustainability.

Each issue of *Water Nepal* may include

Editorial: Issue and Authors – an overview of the articles and authors in the issue.

Viewpoint – a column that offers views on contemporary water development issues and provides a connecting thread to the views presented in the articles of the particular volume.

Feature Articles – detailed presentations of theory and practices in water development. Members of Editorial Advisory Board and other peer reviewers review these.

Innovation From Field – brief presentation of field experiences in water resource sector.

Reports on Gray Literature – reviews of past or contemporary public documents in Nepal and abroad.

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VIEWPOINT

THROUGH A WATER LENS: GOVERNANCE, IDEAS, CHANGE AND THE ROLE OF RESEARCH IN WATER MANAGEMENT[1]

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SETTING THE STAGE

Ideas and ideals lie at the heart of much human experience and the reflexive nature of our interaction with the natural world. Nowhere is this more true than with water, that fluid resource whose availability and dynamic unpredictability has influenced much of human history.

The roots of many societies are affected by attempts to mediate our interaction with and dependence on the characteristics and availability of water. The literal translation of shari'a or 'the way,' originally connoted 'the path to water' (Wescoat, 1995). The main bodies of Islamic jurisprudence enshrine 'the right of thirst'—a tenet founded on the realities of survival for both humans and animals in arid lands. Prophet Mohamed's saying that: "People are partners in three (things): fire, water and grass" emphasises the common nature of water (Al-Eryani, 1995). Beyond Islam, water issues lie at the heart of a fracture cutting across current conceptualisations of private and public rights in Western societies. 'By the law of nature these things are common to mankind—the air, running water, the sea and consequently the shores of the sea' (Institutes of Justinian, 2.1.1).[1] This statement by the Roman Emperor Justinian encapsulated elements of a belief system founded on the commonality of the natural world that resonates today in everything from legal battles over water in the western US to the growing global debate over whether or not a 'human right' to water should be enshrined in UN charters (Gleick, 2003; Moench, 2003; Moench, Dixit *et al*., 2003). The issue isn't, however, just one of water rights. The strands of culture which are rooted in water range across regions and societies. The flood myths at the heart of Christianity, the role of water in the concepts of cleanliness and untouchability in Hinduism, and the green lawns of suburban America all reflect aspects of the way humans define their place in the world in relation to water. Furthermore, from ancient history to modern programmes, many scholars, practitioners and politicians have recognised and, in both a literal and figurative manner, 'built on' the connections between hydraulic structures and structures of human organisation (Wittfogel, 1957; Evenari, Shanan *et al.,* 1971; Worster, 1985; Reisner, 1986; Reisner and Bates, 1990). Much as Nehru referred to dams as 'the temples of modern India,' the great society programmes and organisations of the United States in the 1930s-1970s were, in part, founded on a strong belief in scientific control over water as an engine for development. As current advertising campaigns for cement in India which show a muscular, angular jawed man holding a dam in his arm illustrate, such images continue into the present.

Such issues aren't just of interest to historians. The implications of foundational concepts are of direct relevance for immediate practical attempts to manage water resources and water systems. Moves to privatise the ownership of municipal water utilities are seen by many on both sides of current debates as a leading edge in arguments for the establishment of private water rights systems. While debates over water rights and privatisation are often cast in the 'neutral' language of management, simply as tools for society to meet common goals, they are far more than that. The debates are fundamental. They represent flash point between world views, between conceptions of human behaviour and between the rationalist, reductionist foundations of much modern science and the more recent, but also ancient, conceptions of world systems as more than the a sum of their parts. Einstein's first work was in sediment transport—perhaps there is a message in the fact that he moved on to the (more straightforward?) realm of physics.

As water professionals, we ignore the implications of foundational world views and the dynamics of human behaviour at our own peril. The best, 'most rational,' proposals for effective water management often fail and 'best practice' examples of success from one location often prove impossible to implement in other locations. Is this because politicians and decision-makers lack 'political will' or is it because currently dominant concepts of water management poorly reflect the ideas and behavioral foundations of a global society? We argue the latter and believe that substantial work linking 'practical' water management questions to wider work on ideas, knowledge generation and knowledge systems is essential in order to identify points of leverage for responding effectively to the water problems now emerging in many parts of the world. More specifically, in this paper, I intend to make and support four key points:

First: Many water related problems are a result of transformational rather than temporary changes in interlinked hydrologic, socio-economic and water use systems;

Second: Such transformations are of fundamental importance to global society because they have direct relevance for key global public goods, including poverty, health, social stability and environmental sustainability;

Third: Most conventional water management paradigms are inadequate because they fail to respond to inherent elements of human nature and on-going transformational processes within dynamic systems; and

Fourth: The identification of effective solutions requires much greater understanding of the interconnected nature of knowledge, governance and the inherently unpredictable dynamics of interlinked human and physical resource systems. Such research is important both for the immediately practical insights it provides on potential responses to water problems and as a catalytic element within the inherently political process through which society identifies problems and appropriate responses in the context of on-going transformative change.

On a lighter note, it is important to recognise that success in governing water will itself be transformational for human society. If society can figure out how to govern water effectively, we can probably figure anything out! Einstein did have a reason, after all, for leaving sediment transport and going into physics.

THE CHALLENGE OF TRANSFORMATIONAL CHANGE

Many of the changes now taking place in water resource systems are transformational. They involve fundamental changes in system parameters. Such changes represent a far more fundamental challenge to management than many, even those in the water resource profession, realise. Before exploring this idea in detail, however, it is important to recognise that transformational changes in water resource systems that are occurring parallel with similar transformational changes in human demographic, socio-economic and cultural systems. Baseline assumptions regarding the nature of society and the types of institutions required for management may, as a result, be founded on conditions that no longer exist or are unlikely to exist in the future.

What do we mean by transformational change? Irreversibility has long been a concept central to debates over environmental management, and the transformative impact of humans on environmental systems has been recognised for decades (Thomas, 1971). In many environmental fields, the impacts of human interventions are often irreversible. To take perhaps the most evident example, once a species becomes extinct you can't get it back even through more effective management! Similarly, in the water arena, aquifer compaction due to groundwater extraction is often irreversible. Transformational change takes the concept of irreversibility one step further. It involves fundamental shifts in system function or dynamics that occur as a consequence of changes in individual parameters or aggregate changes in multiple parameters. Cases involving multiple parameters are, of course, much more difficult to document and prove. Chains of causality are difficult to trace when they emerge as an aggregate result of multiple changes in multiple parameters within complex hydrologic or other systems. In addition, many transformative change processes, such as economic diversification, may be driven by multiple independent changes of causality. The reductionist methodology of most modern science is heavily challenged in the context of complex systems. Some specific examples follow:

Climatic

Current global debates over climatic change are probably the most widely known example of transformational change. In this case, human society is forced to confront the complex implications we have unwhittingly brought upon ourselves by tampering with atmospheric chemistry and physics. Despite the complexity of atmospheric science, there is an emerging scientific consensus at the Intergovernmental Panel on Climate Change IPCC that we understand the macro-implications of our action: the world's climate will, almost certainly, warm significantly. Global warming equations are, in fact, so simple that they have been given as basic problem sets for advanced graduate students as homework or end-of-term tests for more than a decade. Interestingly, while we do understand the likely macro-change in global temperatures, translating this transformational global-level change into improved understanding for regional climatic characteristics has proved difficult. Many of the world's experts in the modelling of complex systems now work on the implications of global climatic change. The net result? Although some might argue that the resolution of scientific insight is sufficiently refined to be able to predict broad regional changes, the net message for ordinary hydrologists remains impressively imprecise. In essence, we know that extreme events (floods, droughts and intense storms) are more likely, that increases in temperature appear to be having a major impact on glaciers and ice sheets, and, most importantly, that we can't trust our baselines.

Climate change is transformational. The impacts ripple through global weather and circulation patterns into regional patterns. Predicting probable impacts is, in most situations, difficult. Furthermore, the impact of transformational changes threatens the core world view on which most hydrological science has been founded—the assumption of stationarity. Most hydrological work is based on statistics. Historical data on stream flows, precipitation duration and intensity, hours of sunlight, humidity, evaporation rates and so on are the baseline measures for 'predicting' the statistical frequency of extreme events and developing the design characteristics of water supply, irrigation and flood control infrastructures. Transformational changes in climate system characteristics raise basic questions regarding the utility of historical data for projecting future conditions. Everyone, from municipal water utility districts seeking secure water supplies for burgeoning urban populations to insurance companies trying to calculate risk, is suddenly far less sure of the foundations on which his activities are based. Kaczmarek *et al.,* (1996) summarise the hydrological situation for large projects in the context of global climate change well:

> 'For hundreds of years, people have adapted their habits and economic activities to what they assumed were the natural climatic and hydrological conditions. Implicit in this assumption was that these conditions were stable. Despite the knowledge that, through dams, diversions, and water intakes, man

> has altered natural hydrological regimes, the fundamental assumption of stationarity of key hydrological processes still dominates the planning and designing of water resources development projects. This assumption may no longer be valid, because projected global environmental disturbances can cause serious alterations in the stochastic properties of hydrological time series. Moreover, the long time scales usually associated with large-scale water projects make them particularly sensitive to anthropogenic climate change.
>
> (Kaczmarek, Kundzewicz *et al.*, 1996)

Whether or not the initial assumption of stationarity was justified, those involved in water management must shift from approaches based on bounded variability to approaches capable of responding to a much larger reality involving inherent uncertainty and the limitations of current knowledge systems. The shift is challenging in psychological as well as directly tangible ways. 'Experts' and those who depend on 'experts' hate uncertainty and find it difficult to respond in an innovative manner to water problems when inherent levels of uncertainty are high. Furthermore, professional progress in a culture of experts is rarely achieved by emphasising the limitations of knowledge.

Climate debates are wonderful for illustrating the transformational nature of current processes of change. It is essential to recognise, however, that while they may be the most widely-discussed change processes influencing water resources, they are far from unique and may not be the most important. Transformative changes are occurring in many aspects of both the water resource system and the economic, cultural and institutional systems humans have founded based on that system. Specific examples of this, including changes in aquifer systems, surface hydrological systems, water quality and socioeconomic systems are discussed briefly below.

Aquifer Systems

Changes in the hydrologic dynamics of major aquifer systems brought about by the massive escalation of groundwater extraction rates that has occurred in regions such as India, China, Mexico, the Middle East and parts of Europe and the United States are often transformational (Burke and Moench, 2000). In India, the number of energised wells has increased from a few thousand in the 1950s to over twenty million (World Bank, 1998). In some regions water resources which accumulated over thousands of years are being used up in periods as short as a few decades. These changes are transformational in that they don't just affect the volume of water stored in aquifers. Aquifer compaction has long been known as a fundamental and often irreversible impact of extraction one that changes the hydraulic properties of an aquifer. Beyond this, however, the impact of changing water levels has resulted in decreased base flows in surface streams, changes in patterns of recharge and discharge across broad areas, and, in some cases, changes in regional vegetative cover and the distribution of wetlands (Burke and Moench, 2000). Groundwater extraction often transforms the hydrologic system even where there is no threat of aquifer depletion in any quantitative sense.

Surface hydrological systems

In many regions, changes in the hydrology of surface river systems brought about by changes in land structure and use have fundamentally transformed the behaviour of natural drainage systems. Decades of efforts to control flooding in the Ganges Basin have, for example, resulted in the construction of an extensive, though partial, network of embankments. These structures serve as much to block drainage as they do to retain flood waters within river channels (Rogers, Lydon *et al.*, 1989). They are paralleled by an equally massive system of diversion structures, irrigation canal networks and municipal water supply systems that move water away from river systems to points of use. In addition to large water-control structures, raised networks of roads, train tracks, field bunds, field-level canals, local water-harvesting ponds and other structures have reshaped drainage patterns in rural areas. In urban areas, the reshaping of natural drainage systems is even more dramatic. Impermeable paved areas, urban drainage channels, buildings and the increasing presence of walls around everything from housing to industrial complexes have often changed the natural drainage system beyond recognition. Transformation of regional land structures transforms hydrologic systems in complex, interacting ways. The rate at which runoff occurs, the shape and timing of stream hydrographs in response to precipitation, and the duration of flooding in specific areas all these being about change in ways that can be either subtle or dramatic. In southern New Mexico and Texas, extensive sections of the Rio Grande no longer have any flow and other sections mainly carry wastewater returns from urban areas. According to the Western Water Policy Review, a result of upstream water use and the accumulation of many such changes, 'the extensive flood plain wetlands that occupied nearly 52,000 acres of the Middle Rio Grande Valley in 1918 were reduced to just 3,671 acres (a 93-per cent loss) by 1989' (Western Water Policy Review Advisory Commission, 1998 cited Grimm, 1997). The ecosystem of the Rio Grande Basin has been transformed in fundamental ways. Similar examples are common in other parts of the world. Our own field work sections of the Ganges Basin within both India and Nepal indicates that areas once subject to brief intermittent flooding now remain underwater for many months at a time. In Rajasthan, although the monsoon was the best in a decade, almost no flow has reached the renowned, but now dry, lakes in Udayapur.[2] These changes are all the result of transformational changes in land structure as well as water-related interventions such as the construction of dams, wells and water-harvesting structures. Because of such changes, one of the most challenging tasks now facing any analytical modelling effort in surface hydrology is the re-creation of a pre-development baseline.

Water Quality

As the intensity nature of debates over water quality legislation in locations such as the United States suggests, improving groundwater quality is one of the most technically challenging tasks currently facing water managers. The challenge is directly related to the transformational changes that are occurring in groundwater quality as development, use and pollution loads increase.

Once groundwater is polluted, the task of improving its quality is extremely complex due to a combination of factors inherent in the resource base itself. Flow rates within aquifers are often three dimensional, uneven within the aquifer matrix and far less rapid than those in surface systems. As a result, pollutants tend to be extremely difficult to flush or pump out. Changes in quality related to natural constituents such as salinity are equally difficult to remedy. For example, roughly 65 per cent of the agricultural area of Haryana State in India is underlain by saline groundwater (Gangwar and Panghal, 1989), but extraction increases, even such saline sources are mobilised. Throughout much of India, water quality problems are closely correlated with areas that have experienced high levels of groundwater extraction (World Bank, 1998). This is also the case in many coastal areas around the world, where Saline Ocean water has intruded into freshwater aquifers. In both cases, quality declines due to saline intrusion are extremely difficult to reverse because they have occurred as a result of fundamental transformations in pressure gradients and the resulting flow of water within aquifers. While management is often technically possible through careful regulation of recharge and groundwater pumping, restoring water quality parameters to their original condition is frequently impossible.

The transformational nature of water quality changes may go beyond the simple physical mobilisation of contaminants. Arsenic contamination is a good example. Arsenic from geological sources has caused poisoning outbreaks in Mexico, Argentina, Chile, Taiwan, Inner Mongolia, China, Japan, India and Bangladesh (Nordstrom, 2000). The most extensively documented and well known case of widespread arsenic poisoning is in the Gangetic Basin of Nepal, India and Bangladesh. In Bangladesh, perhaps 21 million people are currently estimated to be at risk and about 200,000 cases of arsenic poisoning have been documented (British Geological Survey and Mott Macdonald Ltd., 1999). High levels of arsenic are found in water supplies underlying nearly 39 per cent of West Bengal and millions of people within the affected area, may be affected (Bhattacharya, Chatterjee *et al.*, 1996). Arsenic is also emerging as a major concern in districts such as Nawalparasi, Kapilbastu and Rupendehi of Nepal Tarai. Even at the lower concentrations found there, approximately 550,000 Nepali's may be at risk for arsenic poisoning.[3]

WHO has described arsenic as probably the most severe environmental health problem in the world.[4] In many areas arsenic is a natural constituent of sediments. Whether or not it becomes a problem for users depends on whether not it is mobilised. As a result, understanding mobilisation pathways is critical to understanding the probability of arsenic contamination in any given area. Arsenic mobilisation and speciation is heavily influenced by the redox potential at a given point and soluble forms occur under both oxidising and reducing conditions. While most work has focused on release under naturally occurring reducing conditions even those who most strongly advocate reduction as a primary cause also recognise that the oxidising conditions perhaps related to increases in pumping could be an important avenue (BGS and DPHE, 2001). The core hypothesis here is that increased pumping increase the cycling of water through an aquifer and, consequently, introduces freshly oxygenated water. This creates oxidising conditions which result in the release of arsenic. While substantial evidence indicates that reduction-related mechanisms dominate (BGS and DPHE, 2001), some evidence suggests otherwise. According to John Whitney of the USGS, 'Studies of arsenic contamination in Bangladesh (BGS-DPHE (2001) and unpublished isotope data from the International Atomic Energy Agency, Vienna, Austria) indicate that most arsenic-contaminated waters are young, less than 50 years old and that the depth of the greatest arsenic concentrations in ground water coincide with the depth to which the greatest number of wells have been installed.'[5] Whitney emphasises that 'scientists at the present time do not know whether this is a coincidence or not. However, the question of whether or not ground water pumping and extraction has an effect on the processes that concentrate arsenic in the aquifer should be investigated.'[6]

The link between current arsenic problems and the transformational nature of changes in hydrologic and human use systems is important to recognise. If additional research ultimately determines that arsenic mobilisation is related to increased groundwater pumping the problems would be a consequence of transformational changes in aquifer chemistry. The change is also a consequence of large-scale transformations in water supply systems. When the UN and other entities were supporting groundwater development as a safe source of drinking water for Bangladesh in the 1980s and early 1990s, the question of arsenic entered few people's minds. The emergence of many cases of arsenic poisoning has now catalysed awareness, but the basic scientific processes of arsenic mobilisation remain much debated (Nordstrom, 2000). It is easy to characterise this as a problem related to the failure agencies and technical support. From our perspective, however, surprises such as this are an inherent risk whenever any intervention in a complex dynamic system is made. The goal of the UN and other organisations in developing groundwater was to alleviate the devastating health impacts caused by pathogens in surface drinking water supplies. Groundwater was thought to be a clean, safe source and few thought to raise questions about the presence of potential contaminants. Society can't respond to questions that aren't asked and the questions that should have been asked are often evident only in retrospect. The development of groundwater sources for drinking was a transformational change: it fundamentally reshaped the architecture and infrastructure of drinking water supply in Bangladesh. New, returning to traditional sources may no longer be possible. Because the dynamics of both social and hydrologic systems are complex and non-linear, important issues are often counter intuitive; as a result, the task of identifying appropriate questions is challenging. Arsenic problems are emerging in locations which prior scientific wisdom would have suggested as unlikely places for mobilisation. Management requires knowing the right questions to ask, the right data to collect and the right analyses to conduct. If these factors are unknown, conventional management approaches are impossible to implement, and surprise is inevitable.

Socioeconomic and Cultural

Beyond water per se it is important to recognise that water availability and the dynamics of hydrologic systems are, in themselves, closely linked to transformational changes in socio-economic and cultural systems. Groundwater development, for example, has fundamentally changed the structure of society in many areas, and groundwater depletion is now raising the prospect of equally wrenching transformational changes in areas where it is occurring. Among the thousands of examples that could be selected, we well explore two, one in the Western US and one in India.

The San Luis Valley

The oldest water rights in Colorado are found in the San Luis Valley along with the San Luis Commons, part of the heritage of early Hispanic settlers and one of the last such common lands in Southwestern United States (NRC, 1992). The area has a deep and strongly rooted culture that derives from the Native American populations who lived there before Europeans, early Hispanic settlers and Mormon and other Anglo settlers arrived in the late 1800s. It is among the oldest permanently irrigated areas in Colorado. According to D.H. McFadden, 'By the year 1900, 1800 miles of canals, ditches and laterals had been constructed in the valley, and the streams flowing into the valley were essentially fully appropriated' (McFadden, 1989). The current culture and economic structure of the region founded is on the patterns of water development initiated during its settlement. The NRC noted the value of tradition to ethnic communities in the San Luis Valley when it commented that agriculture 'is the basis of a traditional way of life for ethnic communities that are proud of their histories and have a high level of interest in maintaining their historic way of life despite pressures for change' (NRC, 1992). It is not, however, just individual ethnic communities which depend on current patterns of water allocation to maintain their way of life: the agricultural system throughout the San Luis Valley, and, with it, a set of interlinked economic and environmental systems, are equally dependent.

Given its high elevation, the San Luis Valley is one of the most agriculturally productive areas in the United States. Since the average annual rainfall in the Valley is less than 200 mm, agriculture has always been heavily dependent on irrigation from canals and, more recently, from a large number of wells. The Valley is also a critical part of the flyway for numerous species of bird and supports the largest network of wetlands in the state. The wetlands are as a result of the Valley's unique hydrologic regime and its history of irrigated agriculture. Monte Vista National Wildlife Refuge was created entirely through irrigation and the construction of dikes, while the Alamosa Refuge was created at least partially by historical irrigation practices. As a result of these human created wetlands, the Valley boasts the largest nesting colonies of white-faced ibis and snowy egrets in the state, and one section of the Alamosa Refuge has the highest duck-nesting density anywhere in the United States (Ron Garcia, Director Alamosa Refuge, personal conversation, 24 August, 1999).

A combination of factors is now placing heavy pressure on the interlinked socio-economic, cultural and environmental patterns that have grown over more than a century of water resource development. For the last four years Southern Colorado, New Mexico and Texas, all states that receive water from the Rio Grande downstream of the San Luis Valley, have been heavily affected by drought. Tree-ring evidence suggests that precipitation levels in many areas are lower than have ever been recorded in the past 300 years. The drought has brought to a head long-running conflicts over water. Debates over water transfers from agricultural to urban uses, the need to secure cross-border flows to downstream states, questions about endangered species and tensions between farmers with surface rights and those who use groundwater all these and many other incipient conflicts are coming to a head as drought reduces the ability to fudge inherent scientific uncertainties regarding water availability and the dynamics of the regional hydrologic system.

Water management in the upper Rio Grande has been based on convenient hydrologic fictions embedded in a poorly understood scientific context. The northern San Luis Valley Basin has been seen as hydraulically separate from the southern part and managed as a separate entity despite the absence of any topographical or surface water divide (Emery, 1973; Emery, 1975; McFadden 1989). In addition, despite the well-recognised general link between groundwater extraction and flow in surface streams, the inability to specify specific impacts has hamstrung efforts to develop an integrated approach to management that considers both surface and groundwater right holders.

A major problem in resolving water management issues in the San Luis Valley stems from uncertainty over water budget estimates. Estimates of inflow have historically been approximately 453,000 af/yr higher than estimates of outflow. This imbalance may be due to inaccuracies in estimates for inflow from sub-basins, evapotranspiration from high water table areas, transient groundwater storage, or a combination of all three inflows. It may also be related to uncertainties in estimates of deep groundwater inflow and outflow. Adding to the confusion is uncertainty regarding the degree to which deep groundwater in confined and semi-confined aquifers under the Valley is hydraulically connected to surface streams and should really be treated as 'tributary' to surface water. Legal challenges to rules promulgated by the state engineer in 1975 to curtail pumping in the Valley in order to protect senior surface rights led to a court decision, that both confined and unconfined aquifers are hydraulically connected to surface streams and that withdrawals of underground water were affecting surface flows. At the same time, there was little evidence to link effects on stream flows with extraction from specific wells and there was extensive discussion regarding the role of 'non-beneficial' evapotranspiration by greasewood, rabbitwood and cottonwood.

More than a decade later, the same issues are at the center of the current legal and management battles provided by the current drought. New data on evapotranspiration rates, refined models of the San Luis Valley aquifer system, evidence about the relationship between stream flows and the survival of endangered species are the weapons of the war over the water in the Valley. Surface water users, many of whom hold 'rights' dating back to the 1880s, are blame groundwater users for depleting stream flows. Even after four decades of intensive analysis, there are still fundamental gaps in our scientific understanding of the San Luis Valley aquifer system. The battles over water are fundamentally transforming the region's socio-economic and cultural characteristics.

The Valley once vibrant ranching economy, an economy developed using surface systems to irrigate pasturelands is a shadow of its former self. Many small ranchers have already gone out of business and large farmers are also under intense pressure. Their systems depend on groundwater to irrigate highly productive potato, barley and other crops. Regulating extraction from their wells or forcing water rights to groundwater to fit—within the 'first-in-time-first-in-right' water rights system Colorado law requires for groundwater that is 'tributary' to surface systems would put most of them out of business. Similar pressures face the traditional acequia systems of the Hispanic communities.

The changes being wrought in the Valley's socio-economic and cultural systems are transformational. Urban areas are growing and rural settlers are shifting from traditional agriculturists to far smaller landowners, often-urban escapees, with non-agricultural livelihoods and fundamentally different sets of values from the long-established ones. The new residents tend to advocate environmental protection and the maintenance of in-stream flows for recreational as well as environmental reasons. As agriculture declines, so do the communities associated with it. As the NRC noted in relation to water use in New Mexico, 'Lifestyle, community organisation, and personal relationships are all intimately related to traditional water uses and allocation arrangements. The state system, however, values water essentially as a commodity; it does not see water as an element of community cohesion, history, and collective aspirations' (NRC, 1992).

The development of water resources in the San Luis Valley led to the creation of certain economic and cultural systems which are now being transformed by their own growth and by contradictions among the physical resource system, patterns of usage and the institutional frameworks intended to govern both. Such transformations are occurring in a context where scientific uncertainties regarding the hydrologic system abound and where the institutions originally created to manage water resources now have little resonance for the new sets of values affected by patterns of water allocation.

Groundwater in India

Over the past five decades, massive development of groundwater in India has fundamentally changed socio-economic and cultural conditions in myriad ways. These changes have been transformational: there is no possibility of returning to earlier conditions. Furthermore, their impact will result in further transformational changes.

Official data indicates that the number of energised wells in India has increased from a few thousand to over twenty million since 1950, (World Bank, 1998). As Table 1 documents, the structure of groundwater use in South Asia is fundamentally different from that in other parts of the world with, perhaps, some 60 per cent of the population depending on it. Over 50 per cent of India's irrigated area now depends on groundwater and, since the areas irrigated with groundwater one more producted than those irrigated with surface sources, an even higher level of its total agricultural production is dependent on groundwater.

As the percentage of the population dependent on groundwater suggests, the development of the resource has fundamentally transformed India in several ways. Groundwater development was the lead input required for the promulgation of the so-called 'green revolution' package of improved seeds, fertilisers and other agricultural technologies during the 1960s and 1970s. Without assured irrigation, farmers could not afford the risks associated with investment in agricultural intensification. From the perspective of agriculture access to groundwater is the single most important factor reducing exposure to risk. Farmers who use groundwater aren't dependent on surface water factors beyond their control—like irrigation rotation, the availability of water in dam, reservoirs personal relationships with neighbours or members of the irrigation bureaucracy—for their ability to obtain water when and in the amounts they require.

TABLE 1
STRUCTURE OF GROUNDWATER

Country	Annual groundwater use (km^3)	Number of groundwater structures (millions)	Extraction per structures (m^3/yr)	Per cent of population dependent on Groundwater
India	150-215	19-26	7900	55-60
Pakistan (Punjab)	45-54.5	0.5	90,000	60-65
China	75-106	3.5	21,500	22-25
Iran	29	0.5	58,000	12-18
Mexico	29	0.07	414,285	5-6
USA	100	0.2	500,000	<1-2

Source: Roy and Shah, 2003. The higher annual use numbers in the first data column are more recent estimates (personal communication, T. Shah).

As a result of its greater flexibility, groundwater development has been a major factor catalysing fundamental changes in agricultural and associate economic systems. It has allowed the development of settlements and intensive agricultural system in areas, such as Rajasthan and Gujarat, where available surface supplies would not have supported them. Groundwater development has also been a major contributor towards creating a wide network of support services (such as those for pumps and well drilling) and demand for agricultural labour (Kahnert and Levine, 1989; Dhawan, 1993; Seckler and Amarasinghe, 1999). In the process, it has played a major role in enabling many communities to move out of poverty by fundamentally changing the asset base they can draw on (Moench, 2003). This has had ripple effects. In many areas farmers and, more significantly, youthful populations, are diversifying into non-agricultural sections. In fact, the rural economy as a whole is undergoing a process of what might be called 'peri-urbanisation' (Moench, 2003). As Start citing Bryceson (2000) comments, 'straddling both rural and urban economic domains, rural people increasingly depend on urban labour markets, urban remittances, urban trade and urban social networks (Start, 2001). Rural household economies have became increasingly diverse, as Deb *et al.*, (2002) found in a survey of Aurepalle Village in Andhra Pradesh: 'In 1975, households were recorded in the survey as drawing on at most three sources of income. The majority of the farmers had one (37 per cent) or two (55 per cent) sources. By 2001, the number of income sources increased to five and no households except those in the non-farm category had only once source of income. The majority of the farmers (59 per cent) had between two and four sources of income and 16 per cent of the households had five sources' (Deb *et al.*, 2002). Much of this diversification is probably based on wealth accumulated during the preceding decades of agricultural intensification.

Diversification is driven by a variety of factors. On the one hand, the array of livelihood opportunities available to rural populations has expanded dramatically with the extension of road networks, communications systems and towns to historically rural areas. With wages and status in the non-farm economy exceeding those for farm labour, individuals and communities have strong positive incentives to diversify out of agriculture. On the other hand, where groundwater overdraft or other agricultural problems limit the viability of agricultural livelihoods, families face heavy pressure to diversify in order to survive. Both push and pull factors operate in most regions and are driving extensive diversification.

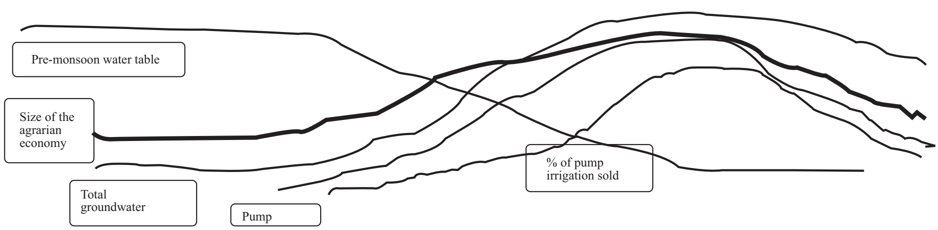
It is important to recognise that the shift toward a more diversified economy goes beyond economics: it has a direct impact on cultural characteristics as well. Prior to the advent of groundwater development Northern Gujarat was dominated by nomadic pastoralist cultures. Groundwater development both enabled and forced permanent settlement. Farmers don't like animals wandering across fields of young or ripening crops. Shifting from a single tenuous rain-fed crop grown during the monsoon to intensive agriculture that fully occupies land for much of the calendar year eliminates many of the seasonal resources nomadic communities depend on. As with traditional communities in the San Luis Valley discussed above, the shift altered the foundations on which communities were built. Nomadic cultures aren't just economic structures, they are ways of life with associated values and world views. In locations such as Gujarat, the cultural values and worldviews of nomadic communities have been all but fully replaced by those of place-based agricultural communities. The next shift will be equally transformational as values and worldviews associated with peri-urban societies are unlikely to be the same as those of the intensive agricultural communities they replace.

Tushaar Shah and others at IWMI have documented changes in the nature of agriculture associated with different levels of groundwater development. These changes are outlined in the diagram below.

It is important to recognise how profound these transformational changes are? Groundwater development hasn't just changed the agricultural economy, it has changed voting patterns, the nature of political issues, cultural structures, labour and migration patterns. These are fundamental social changes. In areas like Rajasthan, where the groundwater resource base no longer supports the new systems that have emerged, equally fundamental transformations can be expected as the economy moves beyond groundwater dependence. Such changes will not be easy. The linkages between water problems and fundamental global public goods such as poverty alleviation, health, education, vulnerability and social stability need to be recognised. It is also important to recognise that the case of groundwater is a subset of many other water-related linkages to poverty. Flooding, waterlogging, salinisation and a host of other water-related problems have a tremendous impact on agricultural livelihoods. Diversification is a common response in most situations, as are linkages with global public goods.

FIGURE 1
STAGES OF GROUNDWATER DEVELOPMENT

Stages:→	Stage I Popularisation of Green Revolution and Tubewell Technologies	Stage II The Rise of the Groundwater-based Agrarian Economy	Stage III Early Symptoms of Groundwater Over-draft	Stage IV Decline of Groundwater availability with impacts on local economy and quality of life.



Example Regions: → Characteristics →	North Bengal and West Bengal • Subsistence agriculture • Protective Irrigation • Traditional crops· Concentrated rural poverty • Traditional water lifting devices using human and animal power	• Eastern Uttar Pradesh • Western Goadavari • Central Gujarat • Pump ownership skewed • Access to pump irrigation prized • Rise of primitive pump irrigation 'exchange' institutions • Decline of traditional water lifting technologies • Rapid growth in agrarian income and employment	• Haryana·Western Uttar Pradesh • Combatore and Madurai, Tamilnadu • Diversification of agrarian economy; • Long-term decline in water tables; • The groundwater-based 'bubble economy' continues booming; • Tensions between economy and ecology begin to surface as pumping costs increase and water markets become oppressive; • Private and social costs of groundwater use finally part ways.	• North Gujarat • Coastal Tamilnadu • Coastal Saurashtra • South West Bengal • The 'bubble' bursts; agricultural growth decelerates and then declines; • Out migration and poverty increase • In some cases, villages are abandoned. • Water quality problems assume serious proportions; • The well-off and the 'smart' began moving out long before the crisis deepened; the poor are the last to leave and the hardest hit.
Public Policies and other external Interventions:	• Targeted subsidy for pumps· Public tubewell programs • Electricity subsidies and flat tariff	• Subsidies and institutional credit for wells and pumps continue • Donors augment resources for pump capital • NGOs promote small farmer irrigation as a livelihood program	• Subsidies, credit, donor and NGO support continue; • licensing, siting norms and zoning system are created but weakly enforced; • Groundwater irrigators emerge as powerful vote-bank.	• Subsidies, credit and donor support go; • NGOs and donors emphasise conservation; • zoning restrictions begin to be enforced; • water imports begin for domestic needs; • Public and NGO sponsored ameliorative action starts.

Source: Tushaar Shah in Bruke and Moench (2000)

CONNECTIONS: POVERTY, VULNERABILITY, SOCIAL STABILITY AND ENVIRONMENTAL SUSTAINABILITY

The transformational nature of the changes in interlinked hydrological, water use, socio-economic and cultural systems have been documented. Why should global society care? From the perspective of the authors, global society should care about such issues because they touch the very foundation of core humanitarian concerns and global public goods such as poverty alleviation, health, education and vulnerability, and social stability. These issues are, of course, complex both in their own right and in their interrelations. The goal in this paper is to identify only some of the key connections that highlight the fundamental role water plays.

Poverty

The connections between water, particularly groundwater, and poverty alleviation within agricultural economic systems have been discussed in detail elsewhere (Shah *et al.*, 2000; International Fund for Agricultural Development, 2001; Moench, 2003). The core argument is that access to groundwater provides the critical element of security that small farmers need to invest in agricultural intensification. They can thus generate far higher returns on their investment than would have been possible without assured irrigation. In addition, by greatly reducing the risk of loss from drought or fluctuations in water availability (a two-week gap in irrigation water supplies can reduce the yields of many crops by more than half) the reliability of groundwater enables small landowners to accumulate assets and gradually move out of poverty. Groundwater access can, in essence, create the foundation of an asset pyramid. Furthermore, the poverty alleviation benefits associated with groundwater development have impacts that extend beyond individual landowners. Agricultural intensification is, in its initial stages, often an engine for the creation of rural jobs and associated agricultural supply industries. In addition, the assets generated often enable farm households and regional economies to diversify. As a result, the role of groundwater development in poverty alleviation can be viewed as particularly important where large populations depend on agriculture and diversified economic alternatives to agriculture are unavailable or inaccessible. The reverse is equally true. Groundwater depletion in contexts where economies are not diversified and few livelihood options exist outside of agriculture will result in increases in poverty. Furthermore, processes of this type often affect different portions of the population in different ways. Some groups, for example, have skills and other assets that enable diversification while others lack effective access to opportunities within economies that are diversified.

What is the critical characteristic that gives groundwater a more critical role in poverty alleviation than either surface irrigation systems or natural precipitation has? Substantial research indicates that its importance is directly related to reliability and risk reduction. Economic analyses from Western US and the Negev Desert highlight the critical economic value associated with the reliability of and the insurance value inherent in irrigation using groundwater (Tsur, 1990; 1993). Groundwater has particular relevance in developing countries.

As Kabeer (2002) states, 'severe and chronic deprivation in developing countries is compounded by general uncertainty with respect to livelihood and life which threatens an even wider section of the population than might be counted as poor: 'short-term, often acute fluctuations in living standards are often superimposed upon longer-term, persistent deprivation associated with generally low standards of living'(Kabeer, 2002) citing (Burgess and Stern, 1991; Dreze and Sen, 1991). Kabeer (2002) highlights the fact that poverty 'has an agro-climatic dimension in that it is more severe in areas which are prone to floods or drought and are difficult to irrigate'. Finally Kabeer goes on to note that 'while downward fluctuations in income flows may take not-so-poor people below the poverty line, the effects of such fluctuations on the lives of those below the poverty line are likely to be devastating since it threatens their very capacity to survive: 'hunger humbles the proud but it makes the already poor destitute' (Kabeer, 2002: quoting Vasavi, 1999).

The key point here is the critical importance of uncertainty, fluctuations and extreme events in relation to poverty. Transformative changes and increased fluctuations in hydrologic systems (whether floods, droughts or simply reduced predictability in the timing and amount of precipitation) and the economic livelihood systems that have developed based on their use will, inevitably, have major implications for poverty. Uncertainty and risk both increase with the processes of transformative change. Individuals, families and communities that already have extensive assets—whether physical or social—are far more likely to be able to cope with or adapt to the uncertainties inherent in such changes. Those without capital are likely to become increasingly vulnerable as the rate of change increases or the nature of change becomes increasingly unpredictable.

It is important to recognise that the poor (or those who have always been poor) are not the only vulnerable ones. Transformative change may, in many cases, alter the dimensions of vulnerability. Groundwater overdraft in India, for example, may render middle-sized farmers among the most vulnerable as they were among the greatest beneficiaries of groundwater development. Access to a secure water source enabled them to increase their income and their standard of living substantially. In many cases, however, the increase in income may have been insufficient for them to diversify or develop skills outside the farm economy. While small farmers and the landless have substantial direct experience with the wage labour market and wealthy farmers often use accumulated resources to move beyond farming, many middle-less farmers lack these experiences and skills. Their income is undiversified, and their resources modest; thus, they find themselves locked into a rigid, water-dependent, agricultural system. Fieldwork by VIKSAT in Gujarat indicates that such farmers often lose their life savings while drilling new unproductive wells.[10] As a result, they may be more affected by transformative change than either the landless or small farmer who has already adapted to labour markets or the large farmer who has the resources to diversify and build skills. The dimensions of vulnerability have changed.

HEALTH, EDUCATION AND VULNERABILITY

The links between emerging water problems and issues related to health, education and vulnerability are many. Direct links such as exposure to pathogens or toxic chemicals are widely known and have been the focus of international attention for decades. Key examples such as growing arsenic-related health problems in the Ganges Basin have already been discussed and exploring them in more depth here would contribute little new insight. Instead, we will focus on the implications of itransformational change processes for society's ability to achieve its global goals of improving health standards and education and reducing vulnerability.

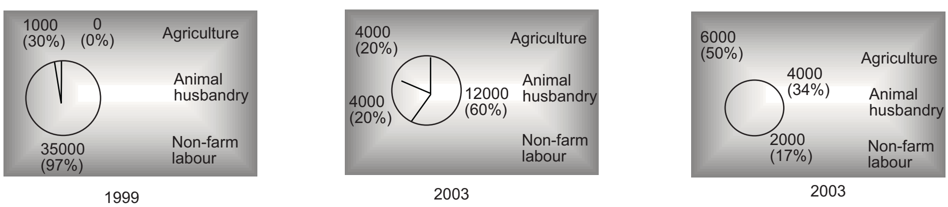
Groundwater development in Bangladesh was initiated as a response to widespread health problems and the high mortality rates associated with diseases such as cholera that are spread by pathogens in surface water supplies. While it is tempting to criticise organisations supported this initiative for inadequate testing, hindsight often makes the identification of problems easy. Furthermore, since arsenic mobilisation is related to levels of groundwater development, there is a fair chance that the problem would not have been identified in advance even if more extensive water quality testing had been conducted. As noted before, identification of the questions that should be asked is inherently complex whenever processes of dynamic change are involved. There are uncertainties even in the avoidance of health impacts that are directly related to known water quality parameters. Surprise a characteristic inherent to the transformative change of water use systems.

The relationship between health and transformative change processes extends well beyond direct impacts, such as those illustrated by the arsenic case. As previously noted, economic diversification is a common response to a wide variety of water-related problems such as groundwater overdraft, drought, flooding, waterlogging and salinisation. Such diversification is often double-edged. For communities which have the financial or social capital needed to maintain or improve livelihoods through diversification, this process may lead to reduce vulnerability and lead to associated improvements in health and education. The reverse is equally true.

Recent field data from our projects in India and Nepal indicate that flooding, drought and groundwater overdraft have a profound impact on the health and educational status of vulnerable populations. The example of diversification in Northern Gujarat, where a four-year drought has occurred in areas where groundwater levels have been falling for decades, is a case in point. As elsewhere, the diversification of livelihood strategies is the most common response. For families with substantial education and other social capital, there has been little impact on livelihoods. Among the vulnerable, however, diversification has been accompanied by substantial declines in income and has had to major social impacts. The experience of Vijesinh's family is typical (see Figure 2). In 1998 agriculture accounted for almost all of the family's Rs 36,000 annual income; by 2003 fifty per cent of their income came from non-farm labour and an additional 20 per cent came from animal husbandry. Diversification was, however, accompanied by a decline of over fifty per cent in their income to just Rs 12,000 in 2002.

FIGURE 2

THE IMPACT OF DROUGHT AND GROUNDWATER OVERDRAFT IN GUJARAT



Changes in relative shares of various sources of livelihood of Vijesinh's family through the drought

Source: Field surveys conducted by VIKSAT as part of the Adaptive Strategies Project[11]

Transformational change in livelihoods has major implications for health, education and livelihoods. Detailed fieldwork in the Satlasna area of Gujarat by VIKSAT, a local NGO documents the decline in income accompanying diversification of livelihood sources. Some of VIKSAT's insights closely parallel insights from historical studies of drought, which found that consumption of food and luxuries decline. In Satlasna, for example, drought-affected families consume almost no vegetables, milk, ghee or oil. Impacts with potential relevance for health and socio-economic development extend well beyond diet. In drought-free times girls married when they were around 18 years old. Due to the drought, the age of marriage for girls has declined to between 13 and 15 years in order to save money on child support. There is also an increase in school dropout rates as both boys and girls are put to work in construction sites. Finally, many women in the high-caste Darbar community have begun to work as wage labourers outside their own farms. Both these changes would be considered socially unacceptable in non-drought times. In addition, many men now leave their own villages and work in distant cities or rural areas for a few weeks to many months.

The implications of these changes on health and vulnerability are crucial. Reductions in the intake of nutrition-rich foods have long-term impacts on the health status of individuals, particularly children and pregnant women. Child marriage, a common survival strategy for the poor in South Asia, is associated with both neglect of women's health and increases in their vulnerability (UNICEF, 2001). The decline in education levels reduces future livelihood options and increases vulnerability for the lifespan of the individuals involved (UNICEF, 2001). The ripple effects can extend well beyond this. Field data from Nepal as well as studies in drought affected areas of Rajasthan and Gujarat indicate that, for the most vulnerable populations, declines in agricultural livelihoods are a significant factor forcing diversification into the sex trade. This has clear implications for the spread of STDs including AIDS, a major global health concern. The multiple dimensions of differential vulnerability for women and children to natural disasters such as drought are extensively documented in the global literature. Clearly, numerous fundamental global public goods related to health, vulnerability and the education of future generations are affected by the fundamental transformations now taking place in economic systems founded on water.

Social Stability

The role water often plays in livelihoods, poverty and vulnerability lies at the root of its association with questions of conflict and social stability. As do other authors, we view 'wars over water' as highly unlikely. Following an extensive review, a team led by Arron Wolf concluded that 'As near as we can find, there has never been a single war fought over water' (Wolf, 1998). Even when water is directly involved in conflicts it is often more a tool than an object of conflict itself. Gleick,[12] for example, documents numerous instances in which water supplies and infrastructure were disrupted or water was used as a weapon in conflicts which were otherwise unrelated to water. Instead of provoking conflict at macro-levels, water is more often a unit for cooperation than for large-scale conflict. Dialogue over water has, for example, continued throughout much of the Israeli-Palestinian conflict and has served as a point for collaborative research and the building of trust (Lonergan and Brooks, 1994; Brooks, 2001).

The fact that wars over water appear unlikely and (even if they do occur) represent the exception rather than the rule does not reduce the implications of transformative change in water resource systems for conflict and social stability. In agricultural economies, water is fundamental to livelihoods and to the distribution of wealth. Transformative changes in water availability and use systems can, as a result, generate substantial conflict and social instability at many levels, from local to regional. This pattern and the numerous links between water scarcity and social instability, including violent conflict, have been documented by numerous authors (Homer-Dixon, 1994; Wolf, 1998; Allan, 1999; Homer-Dixon, 1999; Moench, 2002). As Homer-Dixon concluded almost a decade ago regarding conflicts related to environmental scarcities, such conflict 'tends to be persistent, diffuse, and sub-national' (Homer-Dixon, 1994).

What is important to recognise is that the roots and probability of conflict or social instability in the context of transformative change are highly situational. As Tony Allen has so succinctly stated, 'water determinism is no more determining than other environmental factors: it does not determin' (Allan, 1999). He goes on to emphasise, that economic outcomes are not determined by water availability *per se.* Both Israel and Palestine, for example, have been able to generate sustainable livelihoods despite extreme water scarcity. 'When it becomes impossible to mobilise new water to sustain livelihoods in activities that are very demanding such as agriculture new approaches requiring the use of water in activities that use little water to produce high value goods and services prove to be economically sustainable (Allan, 1999).

The trick, it seems, to avoiding conflict is diversification and transformative change in economic systems away from water dependency. The problem is that such changes are not always possible or, as already discussed in this paper, they involve wrenching dislocations. IFAD points out that globally agriculture, the 'the least-cost workplace,' remains the foundation for most rural livelihoods (International Fund for Agricultural Development 2001). In large nations such as India where economies are deep and diversified, many niches exist for populations displaced from agriculture. This is far less true in small countries where economic diversification at the national level is low. In such situations, which are common in some countries of the Middle East, declining water availability is likely to be a major reason for the presence of a large unemployed population and increasing pressure for global migration. Furthermore, even where niches do exist, many of those needing or seeking to diversify lack the skills, knowledge or access required to develop productive livelihoods in the wider economy.

Evidence suggests that the creation of large unemployed or partially employed populations represents a major source of social instability that can generate conflict at local and higher levels. Homer-Dixon documents the manner in which environmental problems encourage destructive forms of competition from the entrenchment of local elites to the encouragement of corruption and the decline of civil institutions (Homer-Dixon, 1994). Similar observations are also clear from the results of collaborative research in India and Nepal (Moench, Caspari *et al.*, 1999). Key actors in Nepal believe that the failure of the state to 'deliver' basic water and other livelihood needs is a significant factor behind the Maoist insurgency.[13] On a less violent level, the groundwater overdraft in Gujarat has led to political demands on scientific organisations to falsify data and has contributed to political machinations over the flows of funding to rural communities (Moench, 1994). Similarly in Tamil Nadu, competition over increasingly depleted groundwater resources has led to social tensions within families, between communities and between water sectors (Janakarajan, 1994; Janakarajan, 1999). In some cases these tensions have been violent and in all cases they contribute to wider concerns, about governance such as distrust between governments and local populations, communal politics and the decline of community institutions.

Overall, transformative changes in water systems and the livelihoods they support can contribute substantively to social instability and to the creation of contexts in which disruptive forms of conflict are likely. Multiple pathways are present, causes are highly situational and, to reiterate Tony Allen's point, deterministic relationships do not exist. This said, it is an inescapable conclusion that the complex transformative changes now occurring have major implications for the larger global good inherent in stable societies and stable governance.

Environmental Sustainability

The implications of emerging transformative changes in hydrologic systems such as groundwater overdraft for environmental sustainability are relatively clear and have already been discussed extensively in this paper. The depletion of aquifers, declines in in-stream flows, reduction of wetland areas and adverse impacts on biodiversity are well known. What is important to emphasise is that such impacts go beyond the immediately obvious and already well-documented effects.

The case of Coimbatore District in Tamil Nadu is illustrative. In many locations, the depletion of groundwater resources has resulted in a reduction in the amount of land under intensive cultivation. In some areas, farmers have returned to relatively low-productivity rain-fed agriculture. In others, however, farmers are selling the topsoil to factories which make bricks. This is the case in the village of Kodangipalayam, where researchers from Tamil Nadu Agricultural University are undertaking surveys to determine the impact of groundwater overdraft.[14] This pattern is common as the demand for housing—and therefore for bricks—is increasing while the value of agricultural land is decreasing. This change fundamentally transforms the nature of the land.

Changes with similar implications for long-term environmental sustainability are common in many areas. They often involve changes in land use or water access that ripple through ecosystems or, as in the Tamil Nadu case, affect the core productivity of the land.

Conclusion

The transformative changes in hydrologic and water use systems now occurring in many parts of the world are of direct significance for global society. Although the immediate impacts of such changes are almost always highly localised, they have major implications for fundamental humanitarian, health, good governance, social stability and environmental sustainability values that are of direct concern at the global level. As a result, the identification of emerging water problem and the implementation of effective solutions to them are of direct relevance for global society. Such problems cannot be dismissed as problems of local concern alone.

TRANSFORMATIVE CHANGE: CHALLENGES TO CONVENTIONAL WATER MANAGEMENT APPROACHES

Despite the fundamental importance of emerging water problems and the widespread attempts to address them, success has been at best partial. We argue that this failure stems from the fact that current water management paradigms poorly reflect the characteristics of human organisation under conditions of change and uncertainty. In general, paradigms were designed by technical specialists with little training in the fundamental factors governing the political processes through which human society responds to problems and change. As a result, while the logic underlying most paradigms is clear and highly logical, they rarely function as envisioned. To understand why, it is worth exploring water management practice (i.e. what is actually happening on the ground) and on-going public debates over water management.

Water Management Practice

Most water management practice around the world focuses very narrowly on the achievement of narrowly specified objectives such as the delivery of water to specific points for irrigation, domestic, environmental or other uses, drainage and treatment of waste water and flood control. In general, the organisations created for these ends tend to be single purpose. Irrigation departments, municipal water supply utilities and even local user groups—all are common features of the organisational landscapes of many countries. Furthermore, most management organisations focus on immediate problems rather than on a wider (and generally much more nebulous) sets of objectives. As problems are addressed, attention shifts to new areas; thus, responses to problems tend to be incremental rather than comprehensive (Moench, 1999). A recent book compiling twenty-eight water management success stories in California is a case in point (Wong, Owens-Viani *et al.*, 1999). Only two stories discuss 'integrated' or 'comprehensive' approaches to water management; all the others involve locally tailored sets of interventions designed to achieve specific, local objectives. This seems to be a general pattern. As Gilbert White (2002) points out in his analysis of the water management history of the US during the 1900s: 'there is strong social resistance to incorporating all related social aims in humans' use of the environment into one coherent programme. It has been practicable to organise separate programmes for irrigating dry lands, making streams navigable, controlling some floods, promoting forest growth, preserving fish populations, countering severe soil erosion, and reducing water pollution. But it is very difficult to combine all of those aims in a single programme or set of objectives.' The situation in American is replicated in most parts of the world. In India, numerous organisations have been created for different aspects of water management. These range from large governmental irrigation and water supply departments down to local village committees established to manage irrigation, drinking water systems, water harvesting projects or watersheds. In virtually all cases, the immediate focal point of activities is targeted and tangible—the construction or operation of a specific piece of technology or the protection of a clearly defined, area. Furthermore, the need for and benefits from management tend to be very immediate.

Water management activities are highly focused regardless of whether the organisations involved are government departments, NGOs, private companies operating within the market or community-based organisations. Let us take the case of India, where volumes have been written about all of the institutions, which function within the water sector and the variety of competing roles they play. In the implementation context, however, what does each actually do?

- **The private sector:** These actors focus almost exclusively on water supply. Examples include the following:
  - *irrigation technology supply companies* (such as Jain Irrigation);
  - *actors within urban domestic water markets* (tanker water suppliers, companies such as *Bisleri* which sell bottled water, and, in some cases, cooperative groups running as mini-utilities);
  - *irrigation supply organisations* such as the private pump companies in Gujarat and other parts of India about which much has been written (Shah, 1993; Janakarajan, 1994; Moench, 1994; Palmer-Jones, 1994; Shah, 1996; Janakarajan and Moench, 2002); and
  - *organisations supplying industrial and other users* the prime example of which is the tanker markets in Tamil Nadu that have been documented extensively (Janakarajan, 1999; Janakarajan and Moench, 2002) but which are well- known to operate in many other areas as well.
- **Government departments and programmes:** With the exception of flood control and hydropower, these actors focus almost exclusively on water supply and water harvesting. Examples include:
  - *Wastelands development and watershed programmes:* The primary focus is on treatment through revegetation and on the construction of structures (checkdams, bunds, etc.) in order to recharge or store water regardless of the ministry within which such programmes fall;
  - *Irrigation departments:* The almost exclusive focus of field activity is the construction, operation and maintenance of irrigation systems along, with the collection of the basic data required to meet this objective;

- *National drinking water mission, state public health and engineering departments, municipal utilities:* The primary focus is on the construction of wells and piped systems to supply good quality water to urban and rural residents for domestic uses.
- *Central groundwater board and state groundwater organisations (SGOs):* The primary focus of activity is the collection of data to guide financing for new wells and, in the case of some SGOs, the construction of wells for drinking water and other water supply purposes.

■ **Non-government organisations:** Although there is much discussion about demand management, virtually all field-level implementation activities focus on water supply and water harvesting. Even where efficient water use technologies have been promoted, their uptake, with rare exceptions, not based on the desire to save water but on the desire to increase yields, reduce labour requirements and irrigate additional area. The major areas of focus follow:

- *Watershed treatment:* This include revegetation, the construction of checkdams, contour bunding, and other activities;
- *Water harvesting:* Large programmes for harvesting rainwater through checkdams, gully plugs, bunds, and other techniques for, incorporating harvesting mechanisms in building design (urban and rural); and
- *The formation of water user associations:* These local groups operate and maintain irrigation and drinking water systems.

■ **Communities:** Virtually all initiatives that have been started by communities themselves focus on one of four objectives:

- Construction and operation of wells for drinking or irrigation supply;
- Construction and operation of traditional drinking water and irrigation systems such as village wells or the khul systems of the Himalayan region.
- Construction of water harvesting structures; and
- Lobbying GOs and NGOs to undertake the above activities.

The only real exception to the supply-focused nature of organisational activities is in the of national and regional NGOs, whose primary function has been research and advocacy for better water management practices. Even among them, though, it can be argued that they have been most successful in implementing highly targeted, single-function activities. The two initiatives that have had the greatest direct impact that we are aware of are:

1. Advocacy by the Centre for Science and Environment for the revitalisation of traditional water-harvesting techniques (Agarwal and Narain, 1997); and

2. Opposition to the Arun large-dam project in Nepal combined with the promotion of practical, small-scale hydroelectric projects to replace it (Gyawali, 2001).

While opposition to other water supply projects has been intense as in, for example, the history of the Narmada and Tehri dams, early opposition proved relatively ineffective and both dams were ultimately, built. From our perspective, this was probably due to the inability of their opponents to provide clear, equally focused alternatives that would have generated at least some of the benefits the big dams were purported to. More importantly, however, our analysis suggests that their failure relates back to fundamental elements of human organisation.

Water Management and Human Organisations

The fact that most water organisations adopt a relatively narrowly focus on specific tasks is paralleled in most walks of life. Business literature, for example, contains numerous recommendations for organisations to focus on their core strengths, core functions and core products. Business success occurs when organisations produce products that people demand—a concept quite distinct from need. In addition, businesses need to be focused in order to develop the competence and capability essential for success. 'Strategies that are too far from the firm's competencies and capabilities are inherently risky' (Javidan, 1998).

The tendency for organisations to focus narrowly on specific tasks may be rooted deeply in human psychology. In a general discussion of the business environment, Hawkin *et al.,* (1999) make this point: 'The University of Chicago psychologist Mihaly Csikszentmihalyi has found that people all over the world feel best when their activity involves a clear objective, intense concentration, no distractions, immediate feedback on their progress, and a sense of challenge.' The need to focus, to work toward clearly defined objectives and to produce tangible results may represent a fundamental constraint on the viability of broadly-focused organisations seeking to manage groundwater or any other resource.

The tendency of human society to produce highly-focused organisations may, in addition, be related to factors that go beyond this need. First, as the number of functions an organisation attempts to undertake increases, the complex second-order interactions it must take into account are likely to increase exponentially. Combining drinking and irrigation water functions within a single organisation, for example, requires an organisation to internally analyse and understand the interactions between the demands each function places on the available resources rather than focusing on each function separately and only addressing interactions when problems occur. This adds to the cost of transactions, both those within the organisation and those with different constituencies it functions in relation to. The internal operational complexity of a multi-function organisation is likely to be far higher than when separate organisations (or separate organisational components) focus independently on domestic and irrigation water supply functions and only interact when specific constraints affect their operations. As we argue elsewhere, logic suggests this is an important factor influencing why most debates in the water resource sector have emerged in the context of very specific constraints rather than through the integrated analysis of water resource and use systems (Moench, 1999). Second, data and analytical limitations are likely to increase disproportionately more as the functional focus or scale of an organisation increases. Limitations in data are almost always a central concern in water management debates. This may well be an inherent rather than a situational problem. The behaviour generated when systems interact is often chaotic and unpredictable. As a result, simply collecting better data won't ease the challenges for organisations that attempt to undertake multiple functions. Finally, third, multiple, functions imply multiple interacting scales of operation. Insights from hierarchy theory, one conceptual framework for analysing scale issues (Allen and Starr, 1982; O'Neill, Angelis *et al.*, 1986; O'Neil, 1988; Gibson, Ostrom *et al*.,. 1998; Gibson, Ostrom *et al.*, 2000) suggest that this may be an unachievable goal. As Gibson *et al.*, (1998) state: 'Despite the goal of finding inter-scale models, many understanding scales of operation scientists…realise that their predictions are scale and level dependent and that a single mechanism rarely explains patterns found at different levels' (Gibson *et al.*, 2000). They continue with an observation relevant to geography: 'widespread agreement exists that explanatory variables for a given phenomenon change as the scale of analysis changes.' (Gibson *et al.*, 1998).

This series of potentially fundamental reasons suggest why humans rarely attempt or succeed in the creation of organisations for comprehensive integrated water management. Instead, we tend to create organisations that focus on 'one piece of the puzzle.' As humans, we seem to take one slice of a system or one specific function and focus on that. Only where slices interact with other slices and constraints arise do we move beyond single, narrowly-focused organisational forms. This propensity has major implications for the strategies that we, as very human humans, should attempt in order to address what is a widely acknowledged need that we authors fully support—comprehensive integrated management of the water resource base. Many global public goods hinge on success in this are. Our main question is how to get there from here?

GOVERNANCE

The issue of paradigms

Integrated water resource management has been described both as a 'process' (Global Water Partnership Technical Advisory Committee, (2000) and as an 'approach' (World

Bank, 1993).[15] IWRM is to be implemented by organisations (governments, NGOs and other actors) with a high degree of participation from local stakeholders and taking into account a wide variety of social, economic, environmental, equity and other considerations. The goals of IWRM are laudable, but its approach is, for the reasons outlined above, structurally flawed.

Distinctions need to be made between an 'approach' (i.e. a process that can be directly implemented by one or any given set of organisations) and a 'system' in which checks and balances serve as the sorting mechanism that governs what ultimately occurs. This sorting process is, in turn, highly dependent on whether or not key functions (execution, dispute resolution, representative conceptualisation, contestation, legislation, information flow, and resource allocation) occur within societies. IWRM, basin planning, conventional concepts of groundwater management and virtually all-existing water management paradigms have yet to address the question of governance head on.

What Does Governance meant?

In the water sector, most debates over governance have focused on organisational issues and the need for structural reforms to address problems of inefficiency, corruption, accountability to users, service quality and so on. The debates have occurred within wider global trends toward decentralisation within government (Johnson, 2003). These debates are, according to Johnson, founded on two sets of arguments, which are, from our perspective, complementary. As he states:

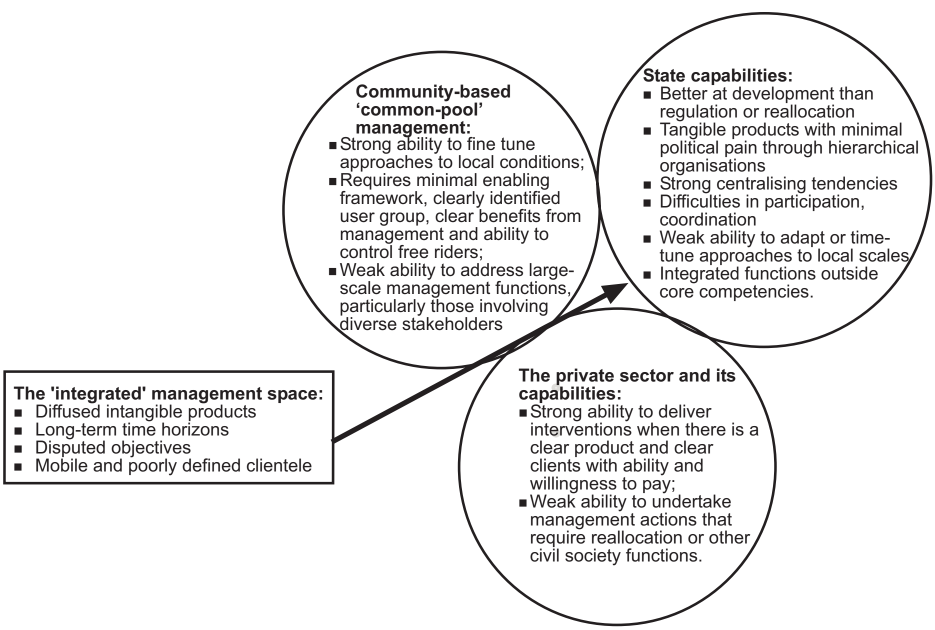
> 'Assertions in favour of decentralisation are often founded upon a wider critique of central state planning, which holds that large and centrally-administered bureaucracies represent an inefficient and potentially destructive means of allocating resources (and generating wealth) within society (Lal, 2000; World Bank, 2000; Economist, 2001). Three assertions are used to substantiate this claim. One argues that central state agencies lack the 'time and place knowledge' (Heyek, cited in Ostrom, 1993) to implement policies and programmes that reflect people's 'real' needs and preferences. Decentralisation is thought to create the conditions for a more pluralistic political arrangement, in which competing groups can voice and institutionalise their interests in local democratic forums (Rondinelli, McCullough *et al.*, 1989; Crook and Manor, 1998).
>
> A second of Johnson's arguments, which is that the operations of governments (based on the principle of command and control) are qualitatively different from those of markets (based on competition and exchange), which are in turn different from the operations voluntary organisations (based on some measure

> of altruistic motivation) (see Robinson et al., 2000). Viewed in this way, states lack the flexibility and reach to provide certain types of goods and services, particularly ones with large requirements of information. Decentralisation, it is argued, creates institutions that are more amenable to local needs and preferences (Ostrom, 1993).' (Johnson, 2003).

The second of the above assertions is further substantiated by the wide conceptual body of research that has come to be known as 'cultural theory' (Thompson *et al.*, 1990; Douglas, 1992; Rayner, 1994; Douglas and Ney, 1998; Hendry, 1999; Gyawali, 2001).

Many debates over decentralisation revolve around reforms within existing political and institutional structures. In India, for example, they involve the creation the creation of new *panchayat* raj institutions, essentially new tiers of government within an existing political and administrative organisational framework (Johnson, 2003). Although goal has been to improve governance by creating pathways of upward and downward accountability within existing organisational frameworks, we believe a wider lens is essential. In our perspective, good governance is an outcome rather than an approach or process, which occurs within specified organisational frameworks and it depends on whether or not key functions are occurring within society rather than on whether or not specific approaches

FIGURE 3
THE INTEGRATED MANAGEMENT DILEMMA



or processes are being followed. It is important to specify clearly what we meant. Our analysis suggests that a number of interdependent core functions are central to good governance. They include:

- **Representative conceptualisation:** The diverse goals of individuals and organisations within society need to coalesce into 'directions.' This is function is often served by a good politician, who articulates both the key issues society faces and the potential options for solving them. In democratic societies, voting is central to achieving this broad base of social support, but good politicians often depend for their survival on their ability to assess social directions and conceptualise goals even where formal processes of representation are absent. We believe that it is important that conceptual approaches resonate within society—that they represent majority views and achieve widespread ownership—but that this may be different from the presence or absence of specific representative processes such as voting.
- **Decision making:** Translating conceptualisation into action depends on decision making function. In national governments this is generally achieved through the legislative process. Where water management is concerned, the equivalent might be the current imperfect processes of participatory planning and the stakeholder involvement.
- **Financial and other resource allocation:** Decisions cannot be translated into action unless society has mechanisms for allocating financial, technical and other essential resources to do so.
- **Execution:** Delivery is among the ultimate tests of good governance. Are constraints addressed? Do water systems function? Do governance systems enable the formation of organisations that actually work?
- **Contestation:** Good decision making depends on informed contestation. Do voices exist within society that are capable of identifying and challenging 'bad ideas?' In academic parlance, does a mechanism for peer review exist?
- **Information flow and transparency:** Informed contestation cannot occur in the absence of good information. This is why freedom of the press is so central to democratic societies. It is also why the tendency of governments, corporations and other organisations to restrict access to basic data is so corrosive in the water resource context.
- **Dispute resolution:** Unless effective mechanisms for dispute resolution exist, contestation leads to deadlock. Contestation is essential to good governance; effective dispute resolution is its equally essential counterpart.

Most debates over water resources management have not attempted to separate and address how functions essential for effective water governance can be met. This is, from our perspective, the core challenge of today. National constitutions often focus on at least a sub-set of the above functions but strategic approaches to addressing emerging issues in the water sector have not moved to this level. The issue isn't just one of participation and decentralisation. As Johnson documents through his review of literature and in the case of India's *panchayati* raj institutions the history of the ability of decentralisation to achieve more effective and representative governance is distinctly mixed (Johnson, 2003). Its failure may be related to the focus within most governance debates on the formal structures of government and representation rather than on a deeper analysis of whether or not core functions are being fulfilled within society. The distinction is important. Most attempts to improve governance focus, for example, on specific democratic procedures for representation, but procedure and outcome may be related, this may not always be the case.

RETURNING TO THE QUESTION OF WATER MANAGEMENT IN THE CONTEXT OF TRANSFORMATIONAL CHANGE

What does all this mean for water management in practice? To clarify that, it is worth briefly revisiting the core points we have made.

First, we have argued that emerging water problems are embedded in and part of a process of transformative changes in the nature of water systems and the interlinked systems from which water use emerges.

Second, we have argued that such problems must be addressed because they affect basic humanitarian values and fundamental global goods.

Third, we have argued that conventional water management paradigms are inadequate because they poorly reflect how humans organise and the core societal functions from which good governance stems. In addition, existing approaches are unable to address some of the inherent challenges central to management in the context of dynamic, poorly understood systems operating at multiple scales.

In addition to the above three core arguments, we have observed that organisations tend to function best when they have relatively narrow and clearly defined functional mandates. Drawing on the literature, we have also observed that there appear to be certain qualitative differences between different forms of organisation (i.e. between hierarchical, individualistic and shared identity-groupings). These qualitative differences generate different perspectives and strategies for those operating within each organisational mode to follow. Balancing the insights and tensions produced by these modes of organisation is central to effective and equitable management.

The above observations and arguments lead to the central hypothesis of this paper: broadly effective approaches to water management depend on systems in which all of the core functions central to governance are able to function. The issue isn't finding the single best organisational model for structuring governance but of ensuring that an functions actually occur. As Johnson points out, substantial cultural and other differences between contexts greatly affect the degree to which formal mechanisms or structures of governance parallel practice (Johnson, 2003). In some cultural contexts, informal mechanisms may contribute to functional requirements much more than formal structures do.

To sum up we argue that the identification of effective solutions to emerging water problems requires a much greater understanding of the interconnected nature of knowledge, governance and the inherently unpredictable dynamics of interlinked human and physical resource systems. Such research is important both for the immediately practical insights into potential responses to water problems provides and as a catalytic element within the inherently political process through which society identifies problems and appropriate responses in the context of ongoing transformative change. The final section of this paper explores the core argument about the importance and role of research further.

THE ROLE OF RESEARCH

The understanding of the fundamental importance of research as a catalytic element essential for society to identify and respond effectively to emerging water problems stems from many aspects of the arguments in preceding sections, but can be encapsulated in four key aspects:

1. The transformative nature of ongoing changes;
2. The impact of water-related change processes on key humanitarian values and global goods;
3. The qualitative difference between forms of organisation and the values they profess within society; and
4. The societal functions central to effective governance.

Change, Values and Knowledge Systems

The first and second of these aspects are relatively straightforward. Clearly, research is essential if society is to identify immediate practical responses to problems when core systems are changing in fundamental ways. Because systems are transforming, history alone is a poor predictor of future conditions and of the impact which management interventions (whether technical, economic, social or institutional) will have in relation to management objectives. As a result, research is essential to continuously identify emerging management needs and to monitor the impacts interventions are having. Research is particularly important because of the impact water-related change processes have on core humanitarian values and global goods. Unlike marketable products, humanitarian values and global goods are not ‘self-advocating.’ Thus, if these values are to be identified and protected as conditions change research is essential.

The importance of research is still larger than promoting waives. Society’s insights on water and the way we construct our understanding of water-related issues is based not just on information but on systems of knowledge. When knowledge systems remain static, so do the insights they generate. The paradigm shift from sector-driven approaches to water development to IWRM concepts that has taken place over the last five decades was the result of a shift in knowledge systems. It can, in many ways, be seen as growing out of the gradual development of systems theories in diverse fields (from forestry to physics) that have been in gestation at least since Darwin. These theories have changed the way society attempts to organise the types of information we collect and analyse and also how we attempt to respond to problems as they arise. Although we have argued that the conceptual foundations of IWRM are inadequate, it is important to recognise the huge advance they represent over preceding approaches to water management. Before IWRM, water experts, engineers and the public in general was taught little if anything beyond the narrow tools necessary to deliver water to meet specific, narrowly-targeted functions. The change in knowledge systems has the very least, served to embed fundamental recognition that complex networks of values and impacts are associated with any intervention which affects water systems. The extent of this knowledge system shift is evident in the fact that many individuals, from small farmers to national decision-makers, are aware, for example, that environmental trade-offs are associated with water development. At the same time, while knowledge systems have evolved, the numerous gaps identified in this paper (and the many, at best partially grounded, assertions we have made in the process) indicate the fundamental importance of continued evolution in knowledge systems. Basic research into the identification of new issues, new processes, new methods of understanding is central to this process.

Globally, attention to basic research on water related issue is declining in favour of targeted, applied research. This is a false economy. While targeted, applied research is essential, without basic research the knowledge systems through which we organise our understanding of issues and potential approaches are likely to become rigid and unable to capture the implications of fundamental transformative changes as they occur. New insights are essential for the training of new generations of experts, decision-makers and other individuals capable of responding to the conditions they will face during their lives. The lag time between insight and its incorporation into society is clearly evident in water education. Even now, decades after IWRM concepts were first introduced, most engineering education in South Asia remains exclusively technical and produces experts with little understanding of the systemic implications of their work.

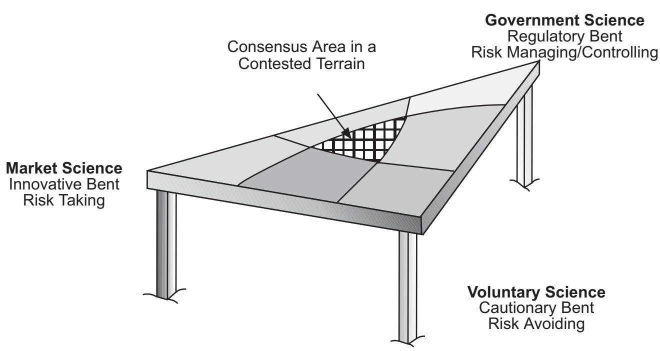
RESEARCH AND QUALITATIVE DIFFERENCES BETWEEN SPHERES OF SOCIAL ORGANISATION

Moving beyond the question of knowledge systems and existing knowledge gaps, it is important to recognise that 'not all research is created equal,' or rather that certain spheres of understanding critical to the evolution of effective responses to water problems and their implications for humanitarian values and global goods is unlikely to be generated without specific targeted investment at a societal level. Our argument here rests on observations regarding the qualitative differences between different spheres of social organisation.

Spheres of Social Organisation

In his analysis of water related decision making in Nepal, Gyawali (2001) argues that different forms of social organisation have inherent biases in the types of information they collect, the analyses they conduct and the information they share. This is illustrated in his diagram of the 'three legged stool of Nepali science' (see Figure 4). The core insights from this argument are as follows:

FIGURE 4
THREE LEGED SCIENCE



1. Private sector organisations functioning within a market environment will invest in research that contributes toward their operations. Their research will produce high-quality information on techniques and consumer demands related to their market niche. Only part of this information and insight will be shared. Advertising will be used to disseminate key information that improves their position within a market (research documents that our brand 'y' is much better than their brand 'x'). In most cases, the rest will remain undisclosed.
2. Hierarchically organised elements of the state and professional organisations will produce research that supports their mandate and professionally derived worldview. In this case, research is often conducted in a consulting mode with the goal of supporting the

specific programmes, activities and worldview a given organisation espouses. So-called 'best practice' documents are typical products of this mode of research. While it may contain key insights, best practice research typically codifies as core knowledge the perspectives and approaches of the organisation financing it. Again, institutional filters operate. There are disincentives to conducting research that might challenge established positions and activities. This mechanism operates within all hierarchically structured elements of society. Even within the 'free domain of academia' professional advancement within a field often depends on the production of knowledge that contributes to established approaches rather than challenging them. The range of insights generated and the degree to which they improve understanding at a societal level is heavily influenced by institutional filters.

3. Group identity-defined organisations tend to produce research insights that highlight that identify. Egalitarian groups, groups that define themselves on the basis of shared humanitarian values or perspectives on global goods, are the source of most research on and information about threats to such values. This type of group often lacks the internal self-financing that supports the much more detailed forms of data collection and analysis present in either hierarchically-structured or market forms of organisation. As a result, the research is often less detailed and less grounded in extensive actual data than that produced by the other two forums. Institutional filters operate here as well; such organisations face strong incentives to produce information that strengthens the affiliation of members in the group. (Witness what others call the 'alarmist' nature of much environmental analysis.)

Overall, qualitative differences between forms of social organisation will result in the production and dissemination of qualitatively different types of insights. This has important implications for the final argument we make in this paper: research is central to effective governance in water and other fields.

Research and Governance

Earlier in this paper I argued that 'good governance is an outcome rather than an approach or process occurring within specified organisational frameworks. It depends on whether or not key functions are occurring within society rather whether or not specific approaches or processes are being followed.' The critical role of research in governance rests on the importance of key functions rather than specific frameworks or processes.

As the saying goes, 'information is power.' Our understanding of governance highlights the roles contestation, conflict resolution and information flow play as part of society's systems for the identification and resolution of constraints. While our analysis says nothing about the specific mechanisms through which each of these functions must occur, it does suggests that good governance outcomes depend on whether or not the functions occur effectively.

Let us start with a simple, tangible example. National decision makers depend on information as the basis for their decisions on policy and action. If the information which society produces contains key gaps or it institutional filters prevent it from flowing to decision makers, the courses of action they select will be made in a highly-biased context. This is, in essence, the argument made by Drez and Sen for the relative failure of China and the success of India in responding to famine (Dreze and Sen, 1991; Dreze *et al.*, 1995). If decision-makers depend for information solely on governmental sources, institutional filters may well hide key issues. Market-based organisations may well produce key information but in the absence of specific interventions, it is unlikely to flow to governmental decision-makers. Furthermore, in many situations research and information generation by egalitarian organisations does not exist. As a result, decision makers are unlikely to have access to insights regarding key humanitarian issues or public goods. In any situation where you have publicly contested decision making, having publicly validated research entered into the policy process is critical.

The role of research as a catalyst for good governance goes far beyond the targeted insights required by established governmental decision-makers. If good governance is an outcome of specific functions within society, then the role of research depends on its relationship to those functions. Both contestation and conflict resolution, two functions central to governance, depend on research as a critical input for their effectiveness at multiple levels within society.

Information and knowledge are, to use a term coined by Baker and Romm, (1990) the 'negotiating text' on which contestation and conflict resolution depend. Whether within organisations or between broad groupings within society, debates over approaches, impacts, strategies and other immediately tangible aspects of water management are heavily influenced by the information context. When fundamental information gaps and the capacity to generate new insights are limited, neither the contestation nor the dispute resolution functions can occur successfully. In this situation, debates are likely to be conducted on the basis of ideology and polemics rather than actual insights. Research, particularly basic and applied research, 'fills the gaps' between the types of information produced by the inherently stronger legs of society (the market and hierarchical government organisations) and is an essential catalyst for good governance. Research is a agent of catalytic change. Unless basic research occurs, core humanitarian values and public goods are unlikely to be successfully represented in governance outcomes. We need to recognise the importance of neutral territories for research and the relationship between the generation of 'pure knowledge' and of 'instrumentalist knowledge'.

Before closing, two final points are important to make. First, there is an interaction, a synergy, between spheres of knowledge, data and research that are context dependent.

Our arguments point to the catalytic role of research and to the qualitatively different contexts within society where research is likely to be conducted and new insights generated. It does not, however, point to any specific organisations within society that should play a lead role in research. There is a great danger that our argument for the catalytic role of research within governance would be equated with a need to increase funding to traditional research organisations such as universities. While it could be argued that such funding is important, we do not advocate it. Because the role of research is context dependent, the organisations with the greatest comparative advantage (both technically and in terms of their location within society) for undertaking that research will also be context dependent. Our second point, is that on, going transformational change processes affect the structure, location and nature of the research enterprise. Those seeking to serve as agents of change must question existing systems and locations of knowledge production and dissemination in order to identify key gaps and underrepresented points. In many cases the location of knowledge production is likely to lie outside of established research organisations, most of which were established in earlier times to meet specific functions. As the terrain changes, so must the locus and role of research.

NOTES

1 National Audubon, 658 P. 2d at 718 (quoting J. Inst. 2.1.1)

2 Personal communication, CGWB officials attending the IWMI strategic review meeting held on 3 October 2003, New Delhi.

3 Personal Communication: ENPHO and DWSS.

4 Personal communication, John Whitney, USGS.

5 Personal communication, John Whitney, USGS.

6 Personal communication, John Whitney, USGS.

9 Beaton (1989) Greesewood is *Sarcobatus vermiculatus*, Rabbitbrush is *Chrysothamnus nauseosus.*

10 Personal communication, Srinivas Mudrakartha, Director the VIKSAT

11 Field Documentation of Coping and Adaptive Responses to Drought in Gujarat A progress Report, VIKSAT, presented at the project coordination meeting, September 25-27, 2003, Kathmandu.

12 http://www.worldwater.org/conflict.htm. Accessed 12/2001

13 Presentation by Dipak Gyawali (former Minister of Water Resources, Government of Nepal) and Ajaya Dixit (founder, Nepal Water Conservation Foundation), August 2003, Boulder Colorado.

14 Personal communication, K. Palanasami, Director, Water Technology Centre, TNAU.

15 'IWRM is a process that promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems, Global Water Partnership Technical Advisory Committee (2000). Integrated Water Management. Stockholm,

Global Water Partnership**.** Similarly, while not using the term IWRM, the World Bank states: "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 decentralised management and delivery structures, greater reliance on pricing, and fuller participation by stakeholders" (World Bank, 1993).

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WELLS AND ILLFARE: CONDITIONS AND CHARACTERISTICS OF GROUNDWATER IRRIGATION IN TAMIL NADU

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CORE ARGUMENTS

This chapter argues the degradation of Tamil Nadu's groundwater resource base through over-extraction and pollution which is increasing rural poverty, social inequity and conflict.

Groundwater is a crucial productive resource throughout India particularly in Tamil Nadu. For rural agricultural populations it has almost replaced land as a determinant of social and economic status. Increasing access to groundwater has diverted attention from the maintenance of tank irrigation systems and other surface sources and in the process, has shifted the determinants of water access away from communities and into the hands of individuals. While access to groundwater has never been fully equitable due to the natural variations in resource conditions, landownership, wealth and other factors, inequity is growing. Patterns of inequity are socially embedded and exacerbated by factors such as inheritance patterns. In many cases, the ownership of an individual well is divided among many people. This can be a source of conflict and often results in differential access between dominant owners and those who are less capable of exercising their partial ownership rights. Competition and conflict are increasing in the face of pollution and substantial declines in groundwater levels. Declining groundwater levels, in turn have lead to the competitive deepening of wells and, in many areas, to large financial losses as existing wells become dry or new, unproductive wells are drilled. Shallow wells have gone dry in many areas and farmers now drill multiple bores alongside or within existing wells. Decrease in water level are also leading to a decline in the quality of surface sources, such as the traditional spring channels, which are constructed to divert subsurface stream flow.

Declines in water level and pollution affects the availability and reliability of water supplies for irrigation. Farmers have responded to the scarcity by adopting efficient water use technologies. Nonetheless, water scarcity is reducing yields and having a direct impact on agricultural incomes. Indirect impacts are also significant. Informal water markets, for example, initially emerged as farmers with access to surplus supplies sold water to

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neighbouring farmers who either lacked financial resources to dig their own wells or had insufficient supplies in the wells they owned. Now water markets are declining as farmers reserve all available water for their own use. Furthermore, even where water markets still exist, their operation is often highly inequitable since they function as part of the interlocked land and labour markets in which buyers are dependent on the goodwill of sellers. As water becomes increasingly scarce, the degree of dependency intensifies, placing purchasers in an even weaker bargaining position.

What do decling groundwater levels imply for policy? The evidence of an increase in poverty due to the degradation of the nation's groundwater resource base implies that the Government of India's policies which support further groundwater development in areas suffering from overdraft must be reversed. Policies such as the supply of highly subsidised power are particularly problematic. In addition to encouraging indiscriminate pumping, such policies tend to benefit the wealthy sections of the rural population. Policies that support more equitable access to—and sustainable use of—groundwater resources are essential. Furthermore, in areas where inequity is high and current groundwater-use patterns are unsustainable, policies that support the efforts of marginalised populations in shifting from agricultural and to livelihood activities may be required. The inequities inherent in the power relations within rural communities imply that simple legal or other types of reforms, which aim to address groundwater overdraft and pollution directly, are likely to be insufficient.

ORGANISATION OF THE PAPER

The introduction presents an overview of the growth of groundwater irrigation in India and highlights some of the problems which have emerged in other regions. The focus then shifts to a detailed case study of the situation in Tamil Nadu where conditions illustrate the challenges for the two-thirds of India underlain by hard rock aquifers. The first section in the case study focuses on the characteristics and use of groundwater irrigation in the Vaigai, Noyyal and Palar basins. The core issues of declines in groundwater levels and the competitive deepening of wells are discussed. A discussion of well irrigation its costs and its relationship with surface irrigation, follows and is complemented with an along with analysis of how well irrigation has exacerbated social differentiation within village societies. The final section presents conclusions with respect to both Tamil Nadu and the country as a whole and explores policy options.

INTRODUCTION

We believe the convention is to capitalise it's a key event like the stuck market crash of 1929. In the decades since independence in 1947, official statistics indicate that both the number of wells and the total area have growing and are projected to continue growing at an exponential rate until the maximum irrigation potential is reached around the year 2007 (Moench, 1992; Moench, 1992; World Bank, 1998). This increase in groundwater irrigation has been a major factor contributing to the increases in yields and agricultural production recorded throughout India. Yields from areas irrigated by groundwater are greater than those from areas irrigated from surface sources by a factor of one-third to one-half (Dhawan, 1995). Variability in the quantity of food production has also declined, in large part due to the reliability of groundwater sources (World Bank, 1998).

From approximately 50 million tonnes in the early 1950s, India's cereal production increased steadily to 200 million tonnes in 2000. Likewise, per capita availability of food grains has also gone up steadily from 141 kilograms in 1951 to 200 kilograms in 2000. Rice and other cereals are now exported. Nevertheless, production has not resulted in increased food availability for all sectors of society. While there is a strong association between groundwater development and poverty reduction, inequities remain. In any case, progress is threatened by emerging overdraft and other groundwater problems (Moench, 2001; Moench, 2002). While India has been able to create and maintain a large buffer stock of food grains, both India and the world are concerned related to that

FIGURE 1
GROUNDWATER IRRIGATION POTENTIAL

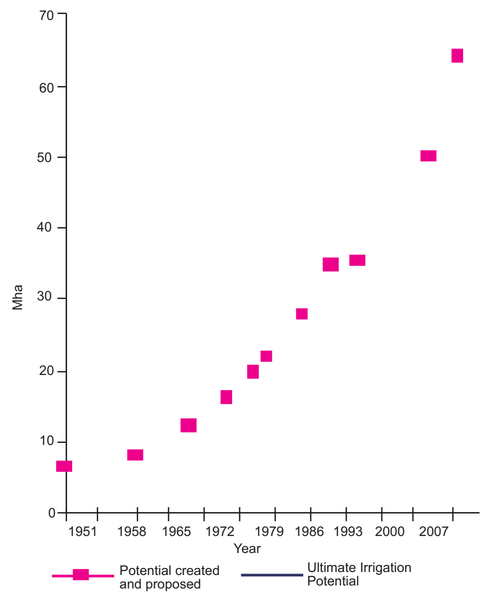
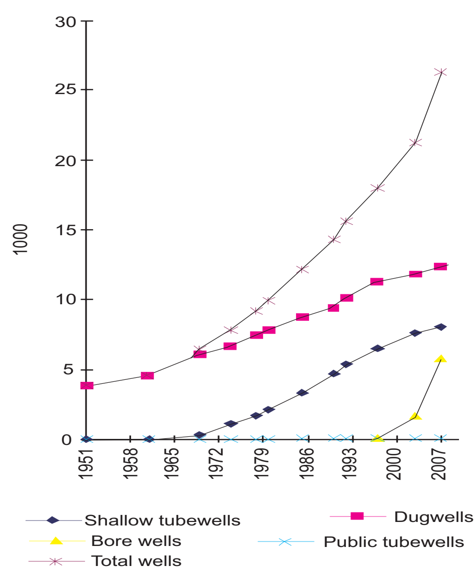


FIGURE 2
GROWTH OF WELL NUMBERS IN INDIA

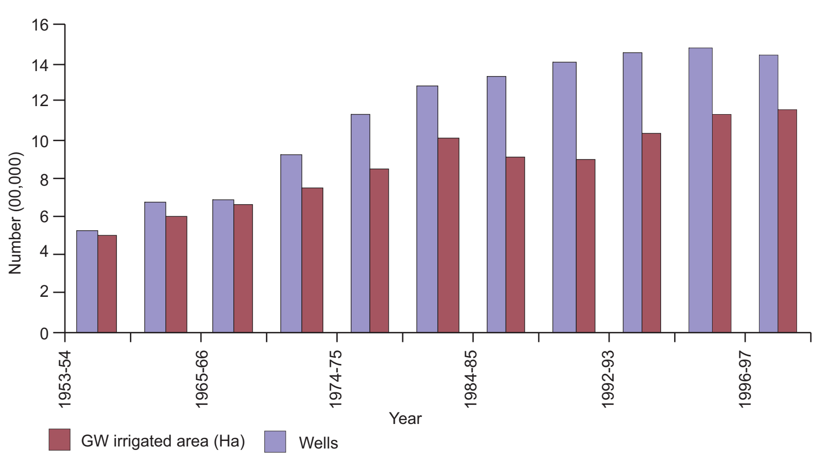


rates of increase of both and yields irrigated area. According to Rosegrant and Ringler (1999), at the global level, 'the growth rate in irrigated area declined from 2.16 per cent per year during 1967-82 to 1.46 per cent in 1982-93. The decline was slower in developing countries, from 2.04 per cent to 1.71 per cent annually during the same periods.' Yield are also growing more slowly and projections indicate that growth will continue to slow over the coming decades (Rosegrant and Ringler 1999; FAO, 2000). In fact, in some areas, such as in Sri Lanka and in the rice-wheat system of India, Nepal, Pakistan and Bangladesh, yields have been stagnant for a number of years (Amarasinghe *et al.*, 1999; Ladha *et al.*, 2000). The slowdown in growth may be related to emerging groundwater problems, particularly overdraft and pollution. We do not, however, believe that the relation is a simple one: the impact of groundwater depletion and degradation on yields and agricultural production—and more importantly, its impact on rural livelihoods—is complicated by of differential access to groundwater resources, unsustainable development and power relations at the village level. As one author argues elsewhere, while in recent decades groundwater played a crucial role in creating stable social conditions, now that resource base is threatened, so is social stability (Moench, 2002).

The issues raised in Tamil Nadu typified those now emerging in many hard rock areas of India. The increasing number of wells is not, as Figure 3 demonstrate, equivalent to an increase in the area irrigated by groundwater.

The numbers of wells in Tamil Nadu grew exponentially from the 1950s to the 1980s but the rate of growth is now slowing and even declining. Furthermore, since the early 1980s although the number of wells has increased, the total area irrigated by groundwater has not

FIGURE 3
WELL IRRIGATION IN TAMIL NADU



increased and those contractions have emerged despite the fact that there is an extensive system of subsidies encouraging the continued expansion of groundwater development.

The most important of these subsidies has been the provision of free power to agricultural pumpsets, a scheme which cost the Exchequer approximately Rs 20 billion in 1999. Other schemes have included the provision of low interest loans for deepening existing or constructing new wells and for purchasing pumps and other equipment. Because the power subsidy encouraged high levels of groundwater pumping, it is widely implicated as a contributing factor in the emerging groundwater overdraft problems (Malik, 1993; Moench, 1993; World Bank, 1998). Well-development subsidies have also had a significant impact. Although well spacing is regulated, a study undertaken in the Vaigai Basin of Tamil Nadu revealed that for every sample well selected for the survey there are at least three wells located within the prohibited distance (Janakarajan, 1997a). Furthermore, subsidy schemes have encouraged groundwater development to the detriment of traditional irrigation sources such as tanks and spring channels.[1] Although these sources have played a key role for several centuries not only in providing irrigation water, but also in recharging groundwater and, thereby, in preserving local environmental systems, they have not been maintained. Many tanks and spring channel sources have dried up, have become clogged with silt or have been encroached upon for construction or cultivation. Outside the Vaigia Basin, in areas of such as the Palar Basin, channels are now in violation of pollution abatement laws, being used to drain industrial effluent. Overall, while substantial attention has been devoted to promoting groundwater irrigation, inadequate or no attention is being paid to creating effective avenues for sustaining the resource base or to mitigating the impacts of emerging depletion and pollution problems on rural society.

Groundwater is a crucial productive resource. Infact, our research in Tamil Nadu indicates that access to it has almost replaced land in determining an individual's socioeconomic and political status. In the past, when surface water was the only source of irrigation, the single most important productive resource was land, and access to it determined one's power and position in village society. The rapid growth of groundwater irrigation, the change in cropping patterns from cultivating drought-tolerant—but relatively low-yield—varieties to higher-yielding but water-sensitive varieties, and the declining status of traditional surface sources have transformed groundwater into the most important productive resource. In this context, it is the ownership of wells, along with land that determines an individual's status. In Tamil Nadu, marginal and small farmers own 60 per cent of the wells (Janakarajan, 1997a). Mere ownership of wells, however, means nothing unless they are productive and can be kept productive. Since that is often not the case, owning the majority of wells has not given small and marginal farmers greater access to groundwater. The decline in water levels has created a situation in which only those who are able to afford to repeatedly engage in competitive well deepening can have access to water. The growing inequity in access to groundwater has increased social differentiation, which in turn has result in deprivation, poverty and the consolidation of inequitable power relations within local communities. These topics are the focus of our detailed analysis of field data collected in Tamil Nadu.

GROUNDWATER OWNERSHIP AND ACCESS IN TAMIL NADU

Access to groundwater depends upon a wide variety of factors, one of the most important of which is the question of well ownership and its connections with the social relations and power structures in a village context. The rights involved in groundwater access are fundamentally different from those involved in traditional, community or state-managed surface irrigation systems. Under British Common Law, the basic civil law doctrine governing property ownership in most of India, groundwater rights are appurtenant to land ownership (Singh, 1990; Singh, 1991). If you own land, you can drill or dig a well on it and capture as much groundwater as you are able to for use on the overlying land. When land is sold, groundwater access rights are passed on with the land and cannot legally be separated from it. The legal definitions of rights, however, are often quite different from the practical rules in use that determine the effective access any individual has or does not have to groundwater. In Tamil Nadu, some of the most important factors affecting access to groundwater include whether wells are owned by one individual or many and the size of landholding. Ownership is also affected by well density, the ratio of the area irrigated by wells to the area irrigated by surface sources, cropping patterns and yields.

Ownership of wells—sole and joint—across farmer size categories

Sole and joint ownership of wells

In Tamil Nadu, agricultural land is generally divided among heirs at an individual landowner's death. This has increasingly become the case with wells, too. Because landholdings are relatively small, water is a critical resource and wells are key productive assets, the ownership of wells is often split among heirs the result has been a shift from sole to joint ownership of wells. Since well ownership, has become a central point of conflict within communities and even within families it must be considered in any analyses of emerging groundwater problems and potential solutions. Joint ownership is increasing the gap between the 'haves' and 'have-nots.' Sometimes the results are extreme: after inheriting theirs shares in a well, individuals often lower their pumpsets (several pumpsets can be installed a single well if its diameter is large) and thereby exclude other shareholders from access to water. Such micro-level conflict complicates decision making and appears to be undermining the possibility of achieving a consensus on the sustainable use of the resource base.

Incidence of joint well ownership

Inheritance laws and the synonym of land and groundwater ownership have resulted in the sub-division and fragmentation of both wells and land. Although there are good records of sole ownership, there is virtually no macro database documenting the nature and extent of joint well ownership in Tamil Nadu or, for that matter, in the rest of India either. However, village-level studies conducted in various river basins in Tamil Nadu by Janakarajan point to how widespread joint ownership is and highlight the dilemmas and uncertainties associated with the management of jointly owned wells.

A survey of 1,100 wells in 27 villages in the Vaigai River Basin (Southern Tamil Nadu) revealed that about one-third of the wells are jointly owned (Janakarajan, 1997a). Even higher levels of joint ownership (47 per cent of the sample) were found in another survey of eleven villages in the Palar River Basin (Janakarajan, 1999). Research conducted in the Noyyal and Palar River Basins for a project related to local water management also shows a high incidence of joint well ownership (See Tables 1 and 2). Of the 7,120 sample wells in 51 villages investigated during a meso-level survey in the Palar Basin, 43.6 per cent are jointly owned. The extent of joint ownership is not, however, uniform: it varies between 17.2 per cent and 59.1 per cent. The degree of variation is even higher in the Noyyal Basin: of the 14,358 wells in 41 villages surveyed, between 31.3 per cent and 87 per cent are jointly owned, with 53 per cent average. The joint ownership of wells is a complicated issue, especially as the number of shareholders in any one well reached 30 in the Palar and Noyyal basins (See Table 1). There is some indication that jointly owned wells are more likely to be in disuse than wells owned by a single person. Throughout the Palar Basin, the jointly owned wells that are not in use is 30.4 per cent, while only 24.7 per cent of individually owned wells are defunct.

Extent of shared ownership of wells across different landholding size

Not only is does data from eight villages in the Palar Basin indicate that shared well ownership is common, it also suggests that the number of shares is strongly associated with the amount of land owned (Table 2). Data in the Table 2 highlights the skewed distribution of well ownership and the strong correlation between well and land ownership. Key points to note include the following:

- The average number of wells owned per household increases proportionately as the size of landholding increases. This implies that access to more land is positively associated correlated with access to more groundwater.
- Size of landholding and incidence of joint well ownership, in contrast, are negatively correlated. The larger the landowner the more likely s/he is to his/her own well outright rather than have to share. The relationship could indicate either large landowners that

TABLE 1
WELL OWNERSHIP PATTERNS IN THE PALAR AND NOYYAL BASINS, 1998-99

Cluster	No. of villages	No. of wells	No. of individually owned wells	No. of joint owned wells	Per cent of individually owned wells	Per cent of joint owned wells	Largest no. of shareholders in a single
Palar River Basin							
1	2	499	302	197	60.6	39.4	9
2	21	2803	1779	1024	63.5	36.5	29
3	5	476	270	206	56.7	43.3	10
4	8	1666	681	985	40.9	59.1	8
5	13	1006	427	579	42.4	57.6	8
6	2	670	555	115	82.8	17.2	5
All clusters	51	7120	4014	3106	56.4	43.6	29
Noyyal River Basin							
1	4	1819	1250	569	68.7	31.3	10
2	5	1225	781	444	63.8	36.2	9
3	2	438	57	381	13	87	15
4	2	510	190	320	37.3	62.7	15
5	7	4610	2112	2498	45.8	54.2	9
6	4	1670	325	1345	19.5	80.5	5
7	6	1841	854	987	46.4	53.6	30
8	6	634	335	299	52.8	47.2	11
9	5	1611	829	782	51.5	48.5	20
All villages	41	14358	6733	7625	46.9	53.1	30

Palar River Basin clusters	
1	Upper reach of the basin, no tannery effluent
2	Upper reach of the basin where tanneries are concentrated
3	Upper reach of the basin where tanneries are concentrated (second cluster)
4	Middle of the basin where tanneries and industries are concentrated
5	Middle of the basin where tanneries are concentrated
6	Middle of the basin where no tanneries are located
Noyyal River Basin clusters	
1	Villages along the Tiruppur - Avinashi road
2	Villages along the Tiruppur - Perumanallur road
3	Villages along the Tiruppur -Uthukuli road
4	Villages along the Tiruppur - Kangayam road
5	Villages along the Tiruppur - Dharapuram road
6	Villages along the Tiruppur - Palladam road
7	Villages along the Tiruppur - Mangalam road
8	Villages along the Tiruppur - Orathapalayam road
9	Villages around the Chennimalai textile units

Source: Meso-level survey, 1997-98

TABLE 2
SHARED OWNERSHIP OF WELLS IN THE PALAR BASIN

Land holding (acres)	No. of HHs reporting	Number of households by landholding category and their per cent ownership in shared wells						
		Share in Wells						
		<0.1	0.1-0.2	0.21-0.30	0.31 -0.50	0.51-0.75	0.76 **-0.99**	**1 or more**
Up to 1.0	89	15	25	15	23	0	0	14
1.01-2.0	124	1	16	17	58	1	0	39
2.01-4.0	92	7	3	7	35	2	0	53
4.01-6.0	40	0	2	7	7	1	0	35
6.01-10.0	37	0	0	5	10	1	1	29
10.01- 15.0	16	0	0	0	3	0	0	19
>15.01	8	0	0	1	0	1	0	12

Note: Some households (HH) own shares in several wells, as a result the numbers reported as owning a given percentage share in a well don't add up to the number of households reporting.

Source: Main survey, 1998-2000

are wealthy enough to construct their own wells or that they purchase all the shares to one well from other large landowners who own more than one well.

- Unlike large landowners, small landowners frequently own relatively small shares in the wells they rely on. For instance, all of the sampled farmers who owns less than 20 per cent of the shares in a well had less than six acres of land. This suggests that small landowners are likely to be more vulnerable than large landowners to losing access to groundwater.

In principle, shared ownership of wells should enable sections of society, which are unable to afford to dig their own wells to access groundwater. The operation of shared wells is, however, often complicated by caste and other social factors. While the details of the management of jointly owned wells for each case in our survey villages was not documented, interviews do suggest that conflict over sharing water from jointly owned wells is widespread and that practical difficulties surrounding pumping and management are the greatest cause of that conflict.

Joint wells are commonly operated by installing a single pumpset and running the motor for a fixed number of hours for each shareholder in rotation. Operational costs are divided among shareholders in proportion to the number of shares they own the lack of cooperation over sharing operating costs and the limited supply of water and power available are common problems. The most common problem in the operation of jointly owned wells, however, is financial constraints. In contrast, traditional tank irrigation systems have disintegrated primarily due to the lack of incentive to manage the system (Janakarajan, 1993). If shareholders don't cover their share of operational costs, they are prevented from using the pumpset. When the erratic power supply disrupts schedules for sharing the available pumping time. Village *panchayats* (councils) are often involved in resolving disputes, but settlements tend to be short-lived and erupt again during the next period of scarcity.

An alternative to sharing a single pump in a joint well is for each shareholder to install his her own pumpset. This is possible because most wells are large enough in diameter that multiple pumpsets can be installed. This approach, however, often results into competition over the supply of water available. Stored water is rapidly drained and competition is inflamed when one shareholder competitively installs a higher-powered motor in order to extract water faster than the other shareholders. Disputes are especially common when people of different caste share wells and are often resolved only after one shareholder buys the others out. In some instances, poor farmers selling their land as well as their shares in a well.

In addition to disputes over pumping, disputes over the need to deepen a well are also frequent. In some of the cases documented, shareholders with different landholdings disagreed on how the potential benefits from deepening their well should be distributed, and one or more shareholder subsequently refused to contribute to the cost of boring deeper. The village *panchayat* often solves this kind of dispute by physically dividing the well into as many shares as there are shareholders and leaving it up to the individuals to dig and deepen their own portions. Such physically fragmented wells were common in all the surveyed villages. Although this approach is common, it encourages competitive deepening, which amounts to the construction of sub-wells within a well. In such cases, shareholders who lack the resources to deepen their own portion lose access to groundwater and the well is effectively controlled by those who can dig their portion deepest. We also documented many instances in which wells had to been abandoned due to the proliferation of too many shareholders and the emergence of too many disputes.

We recorded the history of each joint well we encountered in the Palar Basin. We discovered that most wells were initially owned by individuals and only subsequently divided into shares, primarily because of the nature of inheritance laws. When land is divided among heirs, wells are also divided. Because of this, most shareholders in jointly owned wells are related. Over time, however, shares are often sold to non-family members and the number of kinship ties among owner decease.

While sharing water from a jointly owned well is often problematic, there are some positive aspects. The fact that at least one-third of the surveyed wells are jointly owned indicates the arrangement is sustainable. Indeed, all villages have (informally) institutionalised rules governing the sharing of water from jointly owned wells. The joint ownership system promotes groundwater use and particularly benefits those who cannot afford to dig a well of their own. Many joint wells, however, fail for two interrelated reasons: declining groundwater levels and lack of funds to dig deeper wells. In attempting to bore deep and secure access to water, many joint well owners become so heavily indebted they are eventually forced to sell their well shares along with their parcels of land. In effect, the system, while it does promote equity in access to groundwater, also reinforces inequality in village societies.

Ownership of wells across categories of landholding size

Because constructing a well for irrigation requires a substantial investment, it is often portrayed as being affordable only for resource-rich farmers. Our data does not support this position. Survey data from 27 villages in the Vaigai Basin indicate that nearly three-fourths of all wells are owned by farmers who possess less than five acres, a relatively small area of land (Janakarajan, 1997a). A similar survey of eight villages in the Palar Basin indicates that the 65 per cent of farmers whose landholding size is less than four acres own 54 per cent of the wells, although they own only 29 per cent of the total land held by the farmers surveyed. In this category of landholding size the average area irrigated by each well is 1.46 acres. In contrast, the three per cent of farmers who each own more than 15 acres of land own eight per cent of the wells and 19 per cent of the total land. The average area irrigated by each well in this category of landholding size is 26 acres. More detailed data on landholding size and well ownership is given below in Table 3 and Figures 4 and 5. These data indicate that, while the wealthy do tend to own more wells, the distribution of well ownership is far less skewed than that of land ownership. Average well ownership per unit of land, in fact, declines proportionately as the size of landholding increases. The data do not, however, indicate the type or productivity of the wells owned by different classes of farmers. Since the average area irrigated per well is far larger in the larger landholding classes, these wells may be more productive and actual access to groundwater may be more skewed than suggested by simple comparisons between well and land ownership alone.

Although the above data indicate that well ownership is far less skewed than land ownership, a number of factors suggest that less wealthy landowners do not derive as much benefit as it appears. First, as the data in Table 3 on the area irrigated by each well indicate, wells owned by large farmers are likely to be much more productive and capable of irrigating large areas than wells owned by small farmers. Second, as water levels decline,

TABLE 3

OWNERSHIP OF WELLS ACROSS CATEGORIES OF LANDHOLDING SIZE IN THE PALAR BASIN

Landholding size (in acres)	Number of well owners	Total number of wells owned	Total land owned in size class	Average area irrigated by each well
< 1.00	26	29	16.7	0.64
1.01-2.00	64	86	101.7	1.59
2.01-4.00	67	100	193.9	2.89
4.01-6.00	28	43	140.8	5.03
6.01-10.00	35	75	257.7	7.36
10.01-15.00	14	35	173.8	12.42
15.01-25.00	5	13	97.0	19.40
> 25.00	3	17	111.1	37.04
Total	242	398	1092.7	4.52

Source: Main survey, 1998-2000

FIGURE 4
LAND AND WELL OWNERSHIP IN THE PALAR BASIN

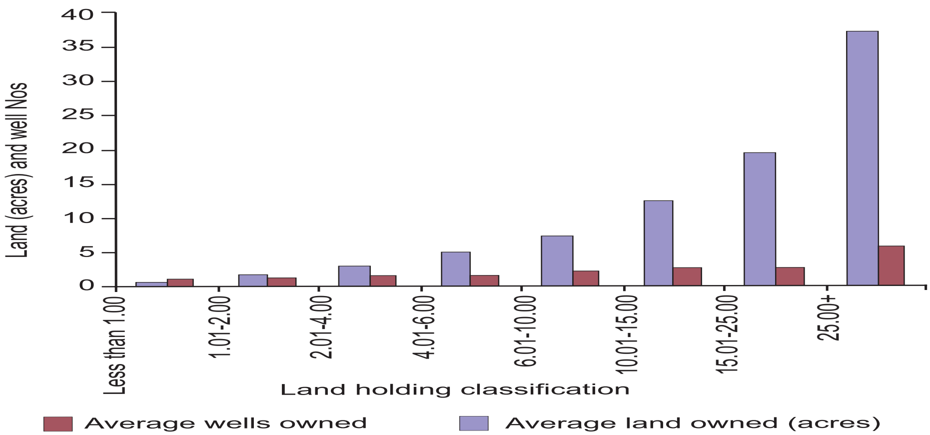
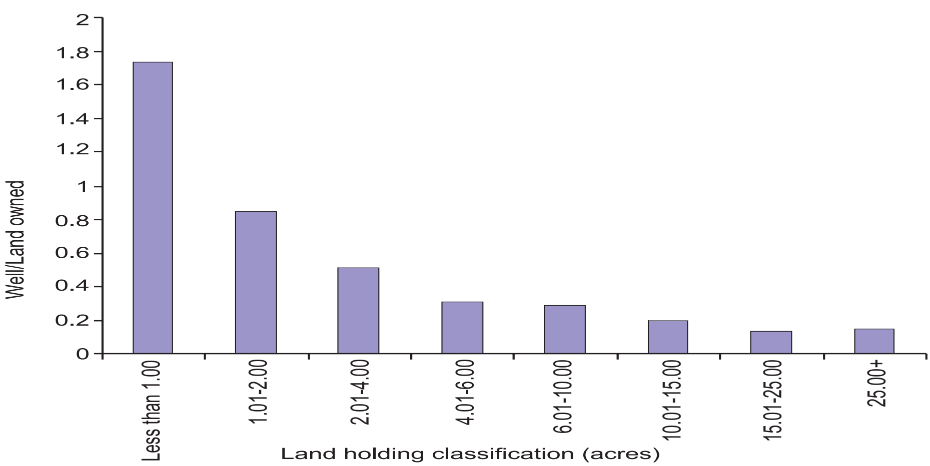


FIGURE 5
AVERAGE NUMBER OF WELLS PER CATEGORY OF LANDHOLDING SIZE IN THE PALAR BASIN



large farmers are able to devote more resources to increasing the depth of their wells than small farmers. In addition, access to a larger area of land provides a greater number of potential well sites. Because hard rock geology is highly variable, access to locations for new wells is often critical to success. A third difference is that many large farmers established wells earlier than small farmers did and were thus able to tap the resource before the competitive deepening of wells became a major issue. As a result, although small farmers appear to own a larger numbers of wells, many are growing increasingly vulnerable as the groundwater table continues to decline. In order to remain in the race of competitive well deepening, they have to keep reinvesting in their wells, even without assurances that they will strike substantial quantities of groundwater. While some are successful, the large majority of small farmers fail and fall into a debt trap.

Linkage between surface and groundwater

The extensive development of groundwater resources also affects surface stream, spring and irrigation systems in the Palar Basin. The Palar Basin is known for its rich riverbed aquifer, which contributes substantially to spring channels and, although extraction is, in fact, illegal, to the digging of thousands of wells along the riverbed. The illegal pumping of groundwater has dried up surface water bodies and has resulted in reduced flows downstream. The fact that over 100 mld (million litres/day) of groundwater is pumped from the Palar riverbed for drinking and industrial use has a direct impact on spring channels, which were originally constructed to tap river sub-flows and traditionally provided irrigation for at least one full crop. In the past, at least one spring channel provided water to each village along the river; of the thousands of spring channels recorded as having existed, most have dried up or been encroached upon. Out of the 51 surveyed villages in the Palar Basin, spring channels have almost completely dried up in 35, function only poorly in six, and are still fairly effective in only three. In the other seven villages, the channels have been taken over by tanneries for discharging industrial effluent. Since these channels pass through the villages, they pollute groundwater considerably and render it unusable.

In addition to the impact on the riverbed aquifer, the illegal pumping of groundwater in areas traditionally irrigated by large, ground level water tanks is also having a major impact. Since a significant number of wells are located in these areas, the tanks are losing their importance as a source of irrigation (Vaidyanathan and Janakarajan, 1989). The rapid spread of well irrigation, accompanied by large-scale rural electrification and the introduction of high-yielding variety (HYV) crops, has contributed to a rise in conflicting interests in the use of ground and surface water. Because HYV crops require more consistent, controlled and timely application of water, and available tank water is not adequate to grow three, short-duration HYV crops, wells have a major advantage over surface water sources. Indeed, studies indicate that there is a positive correlation between the rapid growth in well construction and the decline of traditional tank irrigation systems. Furthermore, Lindberg (1996) demonstrates how individual rationality conflicts with collective rationality eventually results in the erosion of common property resources. Individuals have strong incentives to disassociate themselves from the collective maintenance of tanks and to pump groundwater indiscriminately, a practice, which leads to a progressive decline in water table levels. The government's policy of supplying free electricity for agricultural use has further aggravated the problem of groundwater depletion.

In the 51 surveyed villages, well density ranged from a low of 0.30 per hectare to a high of 0.79 per hectare, with densities in wetlands, areas traditionally irrigated using surface sources, typically higher (0.33 to 0.79 wells per hectare) than those in dry lands (0.30 to 0.62 wells per hectare). The density of wells was much higher than expected even in villages where tanks were reported to still be used for irrigation. Farmers interviewed reported that the reliability of tank water was low and the associated risk and uncertainty high. As a result, many farmers have invested in wells to gain access to a more reliable source of water. In most villages, tanks, if they function at all, are used as percolation ponds. Indeed, access to private sources of water for irrigation from wells has made farmers averse to cooperate in collective tank and spring channel maintenance.

Traditional irrigation systems in six out of the 17 tank command areas (the total area of land irrigated by a single tank) surveyed in the Palar Anicut System were defunct. The density of wells in these six commands was quite high. In one of the tanks, the sluices were permanently closed to facilitate recharge into the wells located in the command. The traditional irrigation systems served by the operational tanks were reasonably unimpaired, and it was these same command areas in which well density was very low (Vaidyanathan and Janakarajan, 1989; Janakarajan, 1993). A similar result was obtained in a large-scale study undertaken at Tamil Nadu Agricultural University (Palanisamy *et al.*, 1996). The close association between high well density and the disintegration of tank irrigation systems has also been found in other villages in Tamil Nadu (Harriss, 1982; Janakarajan, 1986; Chinnappa and Nanjamma, 1977; Janakarajan, 1997b). The results of all studies are not, uniform: a rather study of tanks in the Periyar-Vaigai System shows that an increase in the number of wells in tank command areas does not lead to a decline in the use of the tank system, although it did point out that the effectiveness of tank systems does vary with well density (Vaidyanathan and Sivasubramaniyan, 1998).

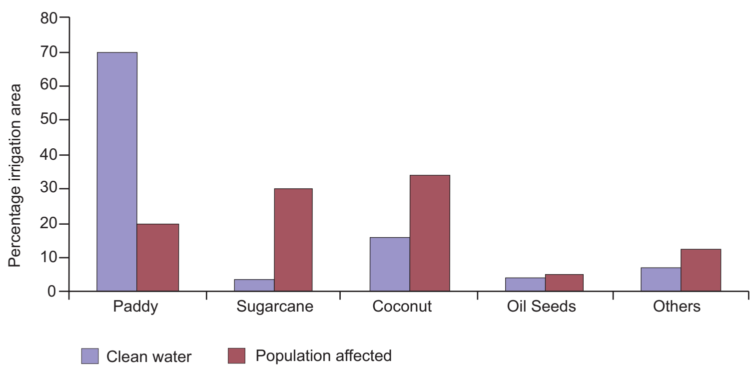
It can be argued that pumping recharged groundwater is a more efficient way of using available water supplies than withdrawing that same water from surface sources is. In fact, in several villages, the wealthy farmers who own multiple wells find it convenient and useful to close down tank sluices so that the impounded water constant recharges their wells. But in many cases, with absolutely no maintenance of inlets and no regular maintenance of channels, tanks and springs become heavily silted and store very little water. The degration of tank systems hurts farmers who do not own wells and who are entirely dependent on tank water.

POLLUTION, CROPPING PATTERNS AND YIELD

The Palar and Noyyal River basins are under severe stress, not only from groundwater over-extraction but also from pollution. It is important to analyse irrigated areas, cropping patterns and crop yields in this context.

The net irrigated area, per well in villages in the Palar and Noyyal basins where the groundwater has been polluted is 2.72 acres, which is only 65 per cent of the average net irrigated area of 4.16 acres per well found in areas where the groundwater is uncontaminated. Differences in cropping patterns are even more striking. In the surveyed villages of Palar Basin, the total cultivated area on land irrigated by the wells we sampled is 903 acres, of which 505 acres (56 per cent) is devoted to paddy. Over 90 per cent (456 out of 505 acres) of this paddy is grown in villages where the groundwater is unaffected by pollution. This is equivalent to 2.9 acres of irrigated paddy per well-sampled in pollution-free villages, whereas only 0.50 acres of irrigated paddy are cultivated per well-sampled in polluted villages. Polluted villages cultivate larger areas of sugarcane and coconut, species which are more tolerant of polluted water than rice is (Figure 6). Distinctions in cropping patterns are not as great in the Noyyal Basin because paddy is not a major crop there.

FIGURE 6
CROPPING PATTERNS IN THE PALAR BASIN



In both the Palar and Noyyal basins the impact of groundwater overuse and pollution on water scarcity is great. For about 33 per cent and 28 per cent of the wells sampled in the basins respectively, has no irrigated area, implying that the wells are no longer utilised. The difference between villages affected and those unaffected by the impacts of groundwater overuse and pollution is substantial. In the Palar basin, 26 per cent (41 out of 159) of the wells sampled in unaffected villages are no longer functional, while in villages that are affected, 41 per cent (39 out of 94) of the wells sampled are defunct. In the Noyyal Basin, 25 per cent (28 out of 112) of the sample wells in unaffected villages are no longer used, while in the affected villages, 34 per cent (23 out of 68) of sample wells are dyes functional.

The difference in well-irrigated areas between affected and unaffected villages has a large impact on crop yields. About one-third of the farmers interviewed in both river basins reported zero crop yield, 43 per cent in affected villages compared to only 28 per cent in unaffected villages. The fact that farmers in villages unaffected by pollution also report some percentage of zero yields is significant. Where groundwater has not been polluted, zero yields are caused by over extraction and wells drying up. In villages that are affected by pollution, zero yield is primarily due to severe water contamination. The economic impact of pollution is evident in a comparison of the values of crop production in different villages. For instance, 50 per cent (79 out of 159) of the wells sampled in unaffected villages in the Palar Basin and 54 per cent (60 out of 112) of the wells sampled in unaffected villages in the Noyyal Basin reported that crop yields per acre exceeded Rs 5,000. In contrast, in villages affected by pollution only 17 per cent (16 out of 94) of the wells sampled in the Palar Basin and 16 per cent (11 out of 68) of the wells sampled in the Noyyal Basin reported values exceeding Rs 5,000. These impacts are of particular concern for small farmers who can neither deepen their wells nor relocate them to less polluted areas. As Box 1 illustrates, however, the impact of pollution even on wealthy farmers is often substantial.

BOX 1:

NOYYAL BASIN, ORATHAPALAYAM VILLAGE

The owner of the well (Code: OPM) also owns another four wells and has 18 acres of land. All the wells are interconnected with pipelines. His original objective was to pump water from every well and channel the wells together for irrigation. This was done because the water yield from his wells was low. The wells range from 50 to 70 feet deep, and the total amount spent in digging them and installing the pumps, pump sheds, pipelines and other equipment came to Rs13 lakhs (approximately $27,000 at Rs 48/$1). The farmer engaged in agriculture profitably until the late 1980s. Then in 1990, a dam was constructed across the Noyyal River in this village to irrigate 11,000 acres of land, and the destiny of this well owner was changed. The dam collects all the effluent discharged by 750 dyeing and bleaching plants located in and around Tiruppur town. Because of very high and other chemicals and salts in the effluent water, the water stored in this dam has never been used for irrigation. Unfortunately, all the wells belonging to this farmer were adjacent to the dam and also became polluted. The farmer is currently growing coconut trees, which tolerate some salinity. His annual income has declined from about Rs 3 lakhs ($6,250) to less than Rs 50,000 ($1,042). He has accumulated Rs 4 lakhs ($8,333) of debt. The situation of many small well owners is much worse: they have given up their cultivations in this village and have sought employment in the Tiruppur knit-wear and dyeing and bleaching industries.

SECTION 4: DECLINE IN THE WATER TABLE, COMPETITIVE DEEPENING, AND THEIR SOCIO-ECONOMIC IMPLICATIONS

In many parts of India, the rapid expansion of groundwater irrigation, and, in some cases, pumping rates that exceed recharge rates have resulted in groundwater mining (See, for instance, Bhatia, 1992; Rao, 1993; Moench, 1992; Vaidyanathan, 1996; and Janakarajan, 1997a). The resultant decline in groundwater levels is widely viewed as a major cause of the competitive deepening of wells and the emergence of conflicting interests among well owners. There, is however, little data, which documents the extent of water level declines in specific locations. The most recent formal statement on the status of groundwater resources in India by the Central Ground Water Board was published in 1995 and is primarily based on data from 1989-1990 which contains no information on actual water level changes (Central Ground Water Board, 1995). In most states, the amount of groundwater monitoring data is not enough to accurately document water level changes at the local level even if the data were made readily available (Moench, 1994; World Bank, 1998).

Since the data collected through monitoring is scant (or just 'since data is scant') water level changes in the study areas in both Palar and Noyyal basins was estimated by comparing the original and the current depths of the wells sampled. The result indicates that water level declines both within and outside canal and tank command areas are significant. The data, which is based on a survey conducted between 1998 and 2000 of 237 wells in eight villages in the Palar Basin and of 171 wells in four villages in the Noyyal Basin are presented in Figure 7 and 8. The data came from wells located in both dry and wet lands and shows that wells in both basins have been deepened over time. The increase in depth is even more pronounced if bores drilled within the wells are included. In the Palar Basin, almost 60 per cent of wells were initially under 30 feet deep, while less than 30 per cent are now that shallow, bore depth included. Originally, no wells were deeper than 100 feet; now, over 14 per cent are deeper. The difference more is dramatic in the Noyyal Basin, where originally almost 60 per cent of wells were less than 40 feet deep while now only 17 per cent still are and where more than 30 per cent exceed 100 feet in depth.

Earlier studies also indicate that the depth to which wells need to be dug has increased over time, a newcomer has to dig deeper than old times had to (Janakarajan 1997a). Of the sampled wells in the Palar Basin, the average depth dug before 1960 was 30.2 feet. It rose to 35.8 feet for wells dug between 1961 and 1970, went up to 41 feet for wells dug between 1971 and 1985, and averaged 69 feet for wells dug up to 1997. Similarly, in the Noyyal Basin, the average depth of wells dug before 1960 was 42.6 feet, while the average depth of wells dug since 1985 is 66 feet. If one includes borewells (which are more common in the Noyyal than in the Palar Basin), the average depth has increased from 100 feet between 1960 and 1970, when the first bores were dug. Fifteen years later

FIGURE 7
CHANGES IN WELL DEPTH IN THE PALAR BASIN

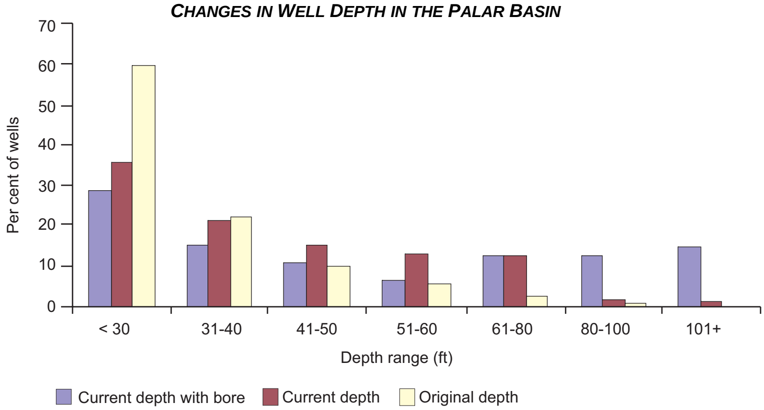
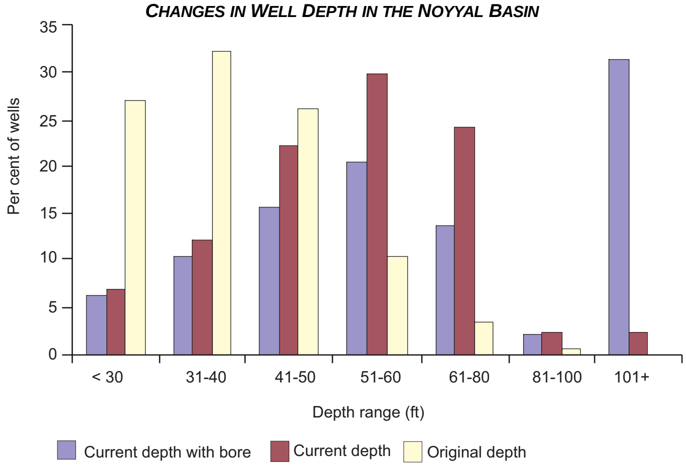


FIGURE 8
CHANGES IN WELL DEPTH IN THE NOYYAL BASIN



since 1985 the depth is increased to 260 feet. For the Noyyal Basin, this suggests that the annual rate of water level decline is approximately 10 feet.

The increase in well depth has been accompanied by changes in water extraction technologies. In the Palar Basin, of the 253 wells surveyed, 191 were originally used with *kavalai* (bullock-bailing lifts), though only one and that no longer in use, was still reported to exist. Similarly in the Noyyal Basin, 121 out of 181 wells sampled were originally used with *kavalai,* but only one is operational to day. The disappearance of this technology is

BOX 2:
PALAR BASIN. KATHIAVADI VILLAGE

The well (Code: KYD 40) was dug in 1938 to a depth of 15 feet. Between 1950 and 1985, it was deepened six times to a depth of 39 feet. In mid-1960, an electric pump replaced the manual lift. There are three adjacent wells located within a radius of 150 feet whose depths were initially around 30 feet. A drought in the late 1980s caused all the well owners to deepen their wells. By 1992, the depth of this well was 50 feet and it had both vertical and horizontal bores dug within it. This caused two of the adjacent wells to dry up and reduced yields in the third. Their owners now lack the financial resources to further deepen their wells. In contrast, the owner of the this well is irrigating about five acres of his land and is selling water to others so that they can irrigate another two acres during each season. This is a clear case of competitive deepening where one well owner has been able to maintain or increase his prosperity while others are forced to purchase water.

BOX 3:
NOYYAL BASIN : SA PALAYAM VILLAGE

The well (CodeM SAP 2) owner initially had an open well which he used until 1980. It was 70 feet deep with six vertical and six lateral bores. The well stopped yielding water during a drought in the 1980s despite an investment of over Rs 3 lakhs. It was permanently abandoned in 1990 when neighbours installed 250 feet deep bore wells. At that point the owner also decided to dig deep bores. Over ten years he installed ten bores on different parts of his land to depths of between 300 and 700 feet. Of these, only two, the deepest one and one other, currently supply water and more than 25 bore wells around his well have dried up. The farmer spent Rs 5 lakhs on all the bores and can now cultivate eight acres of coconut and tobacco from his 20-acre landholding. A rich farmer who also owns a tobacco processing company, he has no debts. His income is, however, derived primarily from the tobacco company (which employs 100 women), not from farming. During the interview, he was proud to point out that neighbouring farmers had had to sell their land because of their bores drying up.

probably a function of two factors: water level declines, which render manual lift devices, useless and the spread of mechanical pumps, substantial which have to be used in borewells. It is also interesting to note that the number of wells with no water-lifting device has gone up considerably over time, from 3 to 71 in the Palar Basin and none to 19 in the Noyyal Basin. These are wells that were deepened but subsequently abandoned either due to the lack of water or to its bad quality.

As discussed in Boxes 1-3, declining water levels have led to fierce competition among well owners. The vast majority of farmers have deepened their wells several times. In addition, because many farmers install lateral as well as vertical bores, water availability in adjacent wells is often severely affected. While disputes over water and well deepening are common, no disputes over lateral bore installations, even when they penetrated adjacent farmlands were reported in our survey. Despite the degree of competition and conflict over well deepening, farmers do not seek justice through the court of law because groundwater property rights are known to be poorly and ambiguously defined. The persistence of unsettled disagreements bodes ill for future well users and adds tremendously to the costs incurred by current users (Janakarajan, 1997b). It is significant to note that competitive deepening is virtually absent in villages affected by pollution since farmers have no incentive to use groundwater for irrigation.

THE IMPACT OF WATER LEVEL DECLINES ON WELL TECHNOLOGY

Declining water levels and competition have major implications for the types of well technology that can be used, and technology usage has in turn had a variety of impacts. First, the design and type of well has changed because conventional, large-diameter round or square wells cannot be used when water levels fall. New technologies for both wells and pumping have spread in recent decades. The majority of wells in the Palar River Basin are now fitted with both vertical and lateral bores and most farmers in the Noyyal River Basin install deep bores right from the surface. Hydraulic drilling companies have proliferated in the Noyyal region and generate large profits from the business opportunities there. Borewell drilling has substantially exacerbated the competitiveness and over pumping of groundwater. A second, development related to water level declines is the huge increase energy demands as well deepening necessitate the use of high power motors and compressors. Until thirty years ago, bullock bailing was the main method of water extraction but today that practice is almost extinct. It was followed, until the mid-1980s, by pumping with low capacity (3.5-HP) pumpsets. Now 10-HP motors are common, particularly in the Noyyal Basin, and in many cases farmers use more than one motor in the same well. The government's policy of free power supply encourages high demand for energy. Third, declining water levels have encouraged greater efficiency of water use. Until the late 1980s, open channels were used the transport water from wells to fields. Now farmers often use underground pipelines and hoses. Fourth, the high cost of constructing well and buying equipment disproportionately hurts small farmers, who own about 60 per cent of the wells in the country. While large farmers have the resources to survive unsuccessful investments in well digging and well deepening or to weather persistent droughts (as occurred in the 1980s), for a small farmer the losses in investments are often insurmountable.

It is worthwhile to looking at the impact of competition on changing technologies in more detail. The case of the Noyyal Basin illustrates the ongoing changes clearly.

TABLE 4

PUMP TYPES AND NUMBERS IN SURVEYED VILLAGES OF TAMIL NADU

Well, Pump and Cistern Characteristics	**Number of wells in each village***			
Kar	**Ora**	**Sou**	**Uga**	Deep
borewell from which water is pumped with a motor as well as a compressor in order to store water for later use—to be pumped again for irrigation (pumped twice)	8	2	16	15
Deep borewell from which water is pumped with a motor as well as a compressor in order to store water for later use—to be pumped again for sale to industries (pumped twice)	0	0	0	3
Deep multiple bores (up to 3) simultaneously operated with one high power motor (10 HP) as well as a compressor to store water for later use—to be pumped again for irrigation (pumped twice)	5	0	3	8
Deep multiple bores (>3) simultaneously operated with 2 high power motors (up to 10 HP each) as well as two compressors in order to store water for later use—to be pumped again for irrigation (pumped twice)	1	0	0	0
Shallow well pumped for direct irrigation with up to 5 HP motor (pumped once)	6	5	6	7
Shallow well which is pumped with a motor up to 5 HP for sale to industries as well as irrigation (pumped once)	0	0	0	2
Deep well which is pumped with up to 7.5 HP motor for direct irrigation (pumped once)	5	7	18	10
Deep dug well with multiple vertical bores installed pumped with a high power motor directly for irrigation (pumped once)	5	0	2	4
Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (up to 10 HP) and with a compressor to store water in a concrete tank (capacity 100,000 litres) both to sell for urban industrial use as well as to pump for own agricultural use (pumped twice)	2	0	0	1
Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (up to 10 HP) and with a compressor to store water in a concrete tank (capacity 100,000 litres) for later use in own industries (pumped twice)	3	0	0	0
Multiple deep bores (up to 4) from which water is pumped simultaneously with a single high power motor (up to 10 HP) and one compressor to store water in a concrete tank (capacity 100,000 litres) for own agricultural use by allowing water to flow with gravity (pumped once)	1	0	0	1
Shallow wells not in use	12	6	9	8
Total of all typologies	48	20	54	59

*Villages: Kar: Karaipudur; Ora: Orathapalayam; Sou: South Avinashipalayam; Uga: Ugayanur.

Source: Main survey, 1998-00

Unlike in the Palar Basin, groundwater in the Noyyal Basin is extracted from deep bores. In some locations borewell depths approach 1,200 feet. Due to the hard rock local geology, yields from such wells are very low, making continuous pumping difficult or even impossible. Wells need time to recharge through gradual seepage from fractures in the bedrock before they can be pumped again. To circumvent this slowness, farmers use compressor technology, which allows them to run pumps even when there is very little water. Approximately 95 per cent of the borewells in this basin are fitted with compressors. Even with a compressor, however, it takes six to seven hours to pump the amount of water that can, in ordinary circumstances, be pumped in one hour. Since the yield is low, the flow is insufficient for use directly for irrigation or sale. Instead water is pumped and stored in cisterns—either adjacent dry dug wells or concrete tanks with capacities of up to 100,000 litres until there enough water is pumped to use for irrigation or sale. With compressor use the consumption of electricity soars to double or triple the amounts an ordinary pump uses due to (a) the use of compressors to run pump motors, (b) running motors for long periods of time to pump small amounts of water, and (c) the need to pump the same water twice (water is pumped up from the bore first and then pumped a second time from the storage tank).

Because of the low yields in deep borewells and the use compressor technology, the pumping and storage of water has had a major import on for both energy use and the overall cost of obtaining groundwater. Based on sample survey data collected in four villages in Noyyal Basin, we have developed a typology that illustrates the diverse techniques and equipment required (Table 4). As this table demonstrates, farmers often need to invest in high-capacity pumps and substantial storage structures. Low yields also force farmers to drill multiple bores within dug wells. Finally, in many cases (37 per cent of the sample wells) the same water is pumped twice, once directly from the well and once again for irrigation or sale.

COSTS AND INVESTMENTS IN WELLS

The variety of pumping and well technologies now in use has a profound effort on the cost of accessing groundwater. The cost of a well in the Palar Basin for example, is much lower than it is in the Noyyal because water tables are higher in the Palar Basin and expensive compressor and storage facilities are not required. The average cost of pumping equipment in the Palar Basin is Rs 14,600 ($304) per well (including motors, pumps and other accessories). In the Noyyal Basin, equipment costs an average of Rs 31,000 ($646). In addition, at least five or six trial bores must be dug, for every successful borewell, and even a successful borewell may stop yielding water after some time. Indeed, according to the available statistics for Tamil Nadu (Government of Tamil

Nadu, 'Season and Crop Report, 1997-98'), about ten per cent of all the wells in the state are no longer in use. Many wells were abandoned only after investing over Rs 100,000 ($2,083) (Janakarajan, 1997a). The total investment in wells eventually places a heavy burden on the community as a whole as well as on individual farmers. The cost is not restricted to the community either as the electricity that is free for use with agricultural pumpsets in Tamil Nadu is subsidised by taxpayers all over India? Because pay nothing for electricity usage, they do not hesitate to pump water even if delivery is low.

Basic information on the investments farmers have made to first attain and then maintain access to groundwater was collected as part of our survey in the Palar and Noyyal basins. While reading the results below, it is important to note several key limitations of the data. In most instances, since the amounts quoted by well owners are below costs, the current values are likely to be higher than the data suggests. In addition, significant difficulty was faced while gathering this information as farmers had forgotten costs and

TABLE 5

COSTS (IN RS) OF WELL IRRIGATION IN WET AND DRY LAND AREAS IN THE PALAR BASIN

Village	No. of wells sampled	Cost per well when constructed	Average current cost per well	Original average cost per hectare of NIA*	Current average cost per hectare of NIA
Kathiavadi	13	2,615	91,000	1,935	67,000
Poondi	15	8,733	79,000	6,488	58,000
Gudimallur	7	857	86,000	534	54,000
Periavarigam	5	8,800	58,000	9,205	61,000
Solur	5	1,800	51,000	5,556	159,000
Damal	38	13,289	75,000	4,297	24,000
RN Pettai	8	4,875	65,000	7,800	104,000
NM Pattu	8	6,250	87,000	2,317	32,000
Average		8,242	72,286	4,767	69,875
Costs of well irrigation in dry land areas					
Kathiavadi	27	11,074	116,000	8,413	88,000
Poondi	7	16,857	84,000	19,250	96,000
Gudimallur	12	5,583	79,000	9,293	131,000
Periavarigam	25	5,400	93,000	6,139	105,000
Solur	16	7,063	93,000	7,766	103,000
Damal	11	16,000	81,000	6,780	35,000
RN Pettai	34	10,471	76,000	19,734	143,000
NM Pattu	18	10,444	68,000	8,835	58,000
Average		10,362	86,250	10,776	94,875

Note: Solur, Periavarigam, Gudimallur and Poondi are villages affected by tannery effluent pollution and the groundwater is heavily contaminated; Kathiavadi is partially affected; Damal, NM Pattu and RN Pettai are unaffected by pollution.
* NIA = Net Irrigated Area

Source: Main survey, 1998-2000

TABLE 6
COSTS (IN RS) OF WELL IRRIGATION IN THE NOYYAL BASIN

Village	No. of wells sampled	Cost per well when constructed	Average current cost	Original average cost per hectare of NIA*	Current average cost per hectare of NIA
SA Palayam	54	9,907	230,333	7,778	180,837
Ugayanur	59	22,797	199,559	20,345	178,097
O Palayam	20	9,000	202,450	6,020	135,418
K Pudur	48	21,000	252,521	21,279	255,879
Average		15,676	221,216	13,856	187,558

Note: O.Palayam and K Pudur are affected by effluents from dyeing and bleaching industries and the groundwater is heavily contaminated; SA Palayam and Ugayanur are unaffected by pollution.
* NIA = Net Irrigated Area

Source: Main survey, 1998-2000

wells had been sold, as inheritance was transferred. We have not included some of the more dubious data in our analysis.

Our data indicate that the costs incurred by individual farmers while constructing and equipping wells are high and often disproportionate to income levels. In addition, costs differ by land type: wetlands and lands within the command of a surface irrigation system register some groundwater recharge from surface water percolation, whereas water table declines are high in dry areas. In the Palar basin, the amount spent at current prices per well was Rs 72,000 in wetlands and Rs 86,000 in dry lands (on average for the eight villages surveyed). Wells in wetlands tend to supply much larger command areas and require fewer supplementary equipment investments than do wells on drier lands. As a result, although the total well costs differ by less than 20 per cent, the net cost per hectare of land is much higher for dry lands than for wetland—Rs 95,500 versus Rs 70,000, a difference of 36 per cent. In the Noyyal River Basin, the average current cost per well—Rs 221,000—is higher still as is the cost per hectare of irrigated land Rs 188,000.

The above tables highlight two key points. First, the costs incurred, both per well and per hectare are high. According to the Ninth Five-Year Plan (1997-2002), the cost incurred by government departments to create one hectare of major and medium irrigation potential land is Rs 40,166 at current prices (Government of India, undated). In our survey of the Palar Basin, individual farmers spent Rs 70,000 and Rs 95,000 to irrigate one hectare area by wells in wet and dry lands, respectively. In the Noyyal Basin, the costs per hectare are far higher—Rs 190,000 on average or approximately 4.7 times what the government spends to create one hectare of irrigation potential land under major and medium projects. Newcomers to irrigation need to spend a huge amount to develop one hectare of land, and, in addition, they have to bear the risk of failure due to water level declines, drought and difficulties in locating a productive zone. Both the cost and risk vary greatly from village to village. Local groundwater conditions and the presence or absence of pollution have a large impact on the costs of wells and irrigation and the likelihood of failure. Well irrigation is a gamble not all those who invest in wells succeed. In fact many lose the race of competitive deepening or are forced to abandon wells due to pollution. Many well owners either are forced to sell their land or become entrapped in a cycle of debt as they keep constructing new wells. The result is new dimension of inequality emerges: those who are able to keep up with competitive deepening become potential water sellers; others are forced to buy water (Janakarajan, 1997b; Vaidyanathan, 1996).

WATER MARKETS—CONFLICTS AND CONTRADICTIONS

As the cost of wells has increased, the sale of groundwater in rural areas has become a common phenomenon. Like joint well ownership, the emergence of water markets in rural areas is a spontaneous response to scarcity and facilitates the sharing of a scarce resource. The magnitude of water markets and the terms and conditions under which they operate vary greatly depending upon the local availability of groundwater, water quality, soil conditions and a variety of other factors. While a full review of water markets is beyond the scope of this paper, a number of points are important to note.

First, the price paid for water is often dictated by the supplier. If it is bought from the state, the price individuals are willing to pay is insignificant in comparison with the price demanded by private sellers. As the Committee on Pricing of Irrigation Water reports, 'At present, the actual gross receipts per hectare of area irrigated by major and medium projects is barely two per cent of the estimated gross output per hectare of irrigated area…'(Planning Commission, Government of India, 1992). On the other hand, farmers pay up to one-third of their gross produce, or up to Rs 40 per hour for water supplied by a private well owner (Janakarajan, 1992 and 1997a).

Second, private sellers, particularly those in Tamil Nadu and Haryana, pay very little or nothing to the state for power. As the Table 7 indicates, electricity tariffs in Tamil Nadu were first subsidised for small farmers only but were in the early 1980s to a horsepower basis. Since 1989/90, power for agricultural use has been supplied for free, and power consumption in the agricultural sector has, as a result, been increasing. As the data indicates, although the number of pumps has been steadily going up, the primary reason power consumption has increased is the amount of energy used per pump, which jumped up drastically in the year electricity was first supplied freely (Figure 9). The greater per pump usage may be due to the long-term decline in the water table or to the low delivery of water from the wells, both factors which encourage farmers to run pumps for longer hours. It also indicates that, if operation costs nothing farmers will run their pumps even under poor conditions. A related concern is that owners secure the benefits of power subsidies in disproportionate degrees: the 38 well owners surveyed in the Noyyal Basin, an estimated 23 farmers who pump water only once receive a power subsidy of Rs 7,110, while the 15 prosperous well owners who pump the same water twice (once from the well and a second time from the storage facility) receive approximately Rs 53,478 in subsidies. Thus power subsidies are heavily biased in favour of the wealthy.

Third, there is a high degree of polarisation between water sellers and buyers. In a separate study of the Vaigai Basin (Janakarajan, 1997a), it was found that a little more than three-fourths of water buyers are poor farmers who have less one-hectare of land. A distinct study in the Palar Basin indicated that the extent of inequality in the distribution of land among cultivators (excluding the landless) is extraordinarily high, as reflected in a Gini coefficient of concentration of 0.88. Differences in Gini coefficients calculated separately for water buyers and water sellers, however, are relatively small (0.34 and 0.40 respectively). This suggests that the between-group component of inequality (i.e. between sellers and buyers) is far greater than the within-group component (Janakarajan, 1992). Furthermore, the vast majority of water buyers belong to socially disadvantaged castes. The scheduled castes, the most deprived in the Indian social hierarchy, make up 27.3 per cent of water buyers (Janakarajan, 1997a). In sum, the people involved in water commerce are sharply polarised socially as well as economically and have unequal capacities for bargaining.

The disparity between water sellers and buyers often leads to minor disputes. Take, for example, the common, informal rule that a buyer should purchase water only from the closest well owner or, if all involved agree, from the next nearest well owner. This rule is intended to avoid conflicts since increasing distances would require transporting water through the irrigation channels of other farmers. At the same time, it places adjacent well owners in a monopolistic position and puts buyers at their mercy. When buyers perhaps

FIGURE 9
AGRICULTURAL POWER USE IN TAMIL NADU

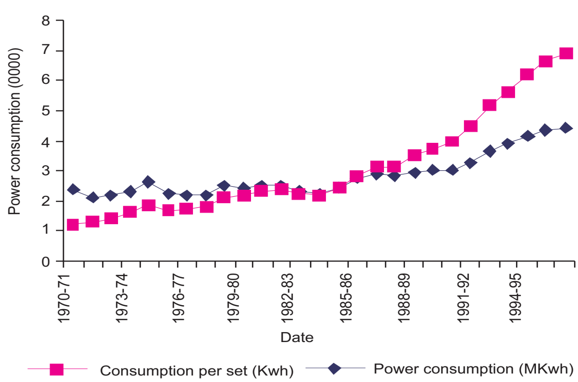


TABLE 7
ELECTRICITY TARIFFS AND CONSUMPTION OF ELECTRICITY PER PUMPSET IN TAMIL NADU, 1970/71 TO 1996/97

Year	Total energy consumed for all pumps (million kWh)	Number of pumps	Energy consumed /pump (units)	Tariff charged for agricultural pumps (per unit of electricity)
1970/71	1,241	529,932	2,342	8 paise
1971/72	1,269	594,169	2,136	9 paise
1972/73	1,430	649,241	2,203	11 paise
1973/74	1,576	681,205	2,314	11 paise
1974/75	1,847	706,914	2,613	11 paise
1975/76	1,675	742,745	2,255	16 paise
1976/77	1,697	773,702	2,193	16 paise
1977/78	1,786	809,606	2,206	Big farmers: 16 paise Small farmers: 14 paise
1978/79	2,104	840,557	2,503	Big farmers: 14 paise Small farmers: 12 paise
1979/80	2,186	887,227	2,464	Big farmers: 14 paise Small farmers: 12 paise
1980/81	2,299	919,162	2,501	Big farmers: 14 paise Small farmers: 12 paise
1981/82	2,354	945,520	2,490	Big farmers: 15 paise Small farmers: 12 paise
1982/83	2,230	965,017	2,311	Big farmers: 15 paise Small farmers: 12 paise
1983/84	2,200	982,606	2,239	Big farmers: 15 paise Small farmers: 12 paise
1984/85	2,415	982,606	2,458	Big farmers: Rs 75/ HP/ yr Small farmers: Rs 50/ HP/ yr
1985/86	2,840	1,033,533	2,748	Big farmers: Rs 75/ HP/ yr Small farmers: Rs 50/ HP/ yr
1986/87	3,114	1,074,184	2,899	Big farmers: Rs 75/ HP/ yr Small farmers :Rs 50/ HP/ yr
1987/88	3,136	1,116,177	2,810	Big farmers: Rs 75/ HP/ yr Small farmers: Rs 50/ HP/ yr
1988/89	3,524	1,184,450	2,975	Big farmers: Rs 75/ HP/ yr Small farmers: Rs 50/ HP/ yr
1989/90	3,740	1,235,941	3,026	Big farmers: Rs 75/ HP/ yr Small farmers: Rs 50/ HP/ yr
1990/91	3,974	1,318,671	3,014	Rs 50 / HP/ yr for £ 10 HP; Rs 75 /HP/ yr for >10 HP
1991/92	4,451	1,359,748	3,273	From 1991 on, free for all farmers
1992/93	5,160	1,403,673	3,676	
1993/94	5,618	1,445,951	3,885	
1994/95	6,228	1,488,469	4,184	
1995/96	6,626	1,528,807	4,334	
1996/97	6,910	1,567,317	4,409	

Source: Compiled from various issues of the Tamil Nadu Electricity Board – A Glance.

seeking better terms violate the rule conflicts ensue (Janakarajan, 1992). In any case purchasing water from distant wells is difficult because the buyer needs to have equipment to transport the water (such as a hose) and has no guarantee that distant sellers will supply water regularly (Janakarajan, 1997a). Second, unequal trading relationships in water markets often results in the exploitation of the weaker agent. Buyers are often required to provide free or underpaid labour services to the seller. Refusal is impossible because well owners can retaliate by stopping the supply of water in the middle of a season (Janakarajan, 1992). In several cases in the Vaigai Basin, payments for water were made through labour and crop sharing. While this can have advantages for cash-poor water buyers and in the case of crop sharing, spreads risks, it is also open to abuse. Water markets also become interlocked with other labour, credit and product markets (Janakarajan, 1992 and 1997a). In addition, there are instances in which water buyers were forced to lease their parcels of land in favour of the water seller and under terms dictated by the latter. This is reverse tenancy, in which the lessee the wealthy water-selling farmer is more powerful than the landowner, the poor, water-buying farmer. In addition, in some villages, water sellers collude to fix the price of water, a situation which generates great resentment among buyers (Folke, 1996; Janakarajan, 1992). Overall, though, instances of open conflict between water buyers and sellers are infrequent.

Agricultural water markets may now be declining. In the Noyyal River Basin, selling water for agriculture was never significant, though selling water to industries is common. In the Palar Basin, local agricultural water markets flourished until approximately a decade ago, since when, there appears to have been a significant drop in the extent of water sales (Table 8). Farmers attribute this to progressive declines in the groundwater table, which make it difficult for them to irrigate their own crops and leave no surplus to sell to others. In other words, selling water has generally been a supplementary activity; the primary goal of well ownership is to supply one's own needs not to sell water. Table 8 gives information on water sales in the Palar River Basin. Roughly ten per cent of the wells sampled in three of the eight study villages reported some water sales; water was supplied to about 35 acres of land in one crop season. The remaining five villages are affected by pollution from tanneries

TABLE 8

WATER SALES IN THE THREE OF EIGHT STUDY VILLAGES IN THE PALAR BASIN THAT REPORTED ANY SALES AT ALL

Village	Total number of wells sampled	Number of wells reporting water sales	Gross area for which water was sold in 1998-99 (acres)
Damal	49	7	20.50
Kathiavadi	41	1	2.50
Ramanaicken Pettai	43	5	11.70
Total	133	13	34.70

Source: Main survey, 1998-00

and would have had no success in selling their water even if they had tried.

The decline in activity in the agricultural water markets does not necessarily imply a decline activity in the overall water market. Though some industry owners do own their own deep borewells, in the Noyyal River Basin there is a major trade in water between rich farmers and urban industries (mainly dyeing and bleaching), a logical effect of the higher return from water sales to those with a greater ability to pay. In two of the study villages, SA Palayam and Ugayanur, an estimated 80 million litres of water is transported daily from 21 deep bores of up to 427 metres depth. Such sales can generate significant revenue: the rate for a 12,000 litre tanker varies between Rs 75 and Rs 400, depending on the season. Most of the wells were originally dug for agricultural use but have now been converted to commercial use for water sales; rich farmers who own the wells also use them to irrigate part of their land. The effect of water sales on surrounding users appears to be disastrous yields from neighbouring wells have declined substantially, forcing farming households to dramatically reduce cultivation and seek jobs in urban industries.

Overall, the evidence from Tamil Nadu indicates that local water markets are not a solution for addressing growing water scarcity and, at least in the context of free power supply, have a limited impact on reducing demand. At present, water markets seem to exacerbate existing inequalities.

A RETURN TO THE LARGER PERSPECTIVE

This detailed case study of groundwater use in Tamil Nadu relates closely to the core issues which face groundwater development and management at a national level in India and Nepal.

That groundwater can play a critical role as a buffer against drought needs no elaboration. It is also now well established that crop yields in areas irrigated by groundwater are generally higher than those in areas irrigated by surface sources and that access to groundwater plays a critical role in agricultural development. In addition, strong arguments can be made that access to groundwater can play a major role in poverty alleviation and that it has done so in countries such as India (Moench, 2001). Because access to groundwater reduces agricultural risk, it can enable farmers (whether poor or wealthy) to begin the gradual process of agricultural intensification and accumulation that allows them to move out of poverty. The problem with groundwater, as this paper documents, is that access to it is not uniformly distributed. Even in areas where groundwater is close to the surface and major investments are not required to access it, the capacity to exploit groundwater tends to parallel the existing resource differentials within society. Innovative farmers, farmers with exposure to new ideas and sufficient land to test them on (i.e. wealthy farmers) tend to be the initial adopters. As a result, the initial benefits from groundwater development tend to disproportionately favour those who are already economically well situated. This disparity grows as declining water level, pollution or other factors increase the cost of accessing groundwater. By them, the first farmers to have accessed groundwater have often accumulated sufficient resources to be able to diversify their operations and to afford the new equipment needed deepen existing or drill new wells as required. Latecomers to groundwater and those whose overall resource base (land, education and access to capital) is limited face major difficulties securing and maintaining access to groundwater. As a result, economic disparities within communities and competition over scarce resources increase, thereby increasing the potential for conflict. The situation is aggravated by the fact that access to groundwater is dependent primarily on individual capabilities. Unlike tank maintenance, use of groundwater doesn't depend on community action. Furthermore, once an individual has access to groundwater, any incentive they may have had to contribute to community water supply systems is, for all practical purposes, eliminated. As a result, community systems erode and existing 'safety nets' for the poor, such as tanks, spring channels and large surface irrigation projects, disappear. In this context, groundwater, or the struggle to maintain access to it, can contribute to poverty and exacerbate socio-economic disparities.

The situation in Tamil Nadu is complicated by the hard rock substrate. Because wells are dug into hard rock, where water storage is low and well yields are unpredictable (depending on whether or not wells hit productive fracture zones), the dynamics of groundwater access differ from those in areas underlain by alluvial aquifers. Several factors contribute to this difference:

1. **High, location-dependent risk**: The risk of investing in unproductive wells is far greater in hard rock areas than it is in alluvial areas. In most alluvial areas, regional water levels are the primary factor determining the ability to access groundwater—one just needs to drill a well to sufficient depths. In hard rock areas, fracture patterns can be highly variable. As a result, success in tapping a productive zone depends on the ability to drill multiple trial bores and on having a large landholding with multiple locations where wells can be dug.
2. **Low storage**: The low water storage potential in hard rock areas puts latecomers at a significant disadvantage. Water levels decline rapidly and those who construct the first wells in a storage area are far more likely to obtain water at a more reasonable cost than those who attempt to tap the resource later.
3. **Low yields**: Because well yields tend to be low in hard rock areas, little surplus is available beyond quantities needed to irrigate the immediate areas.

Low well yields, low storage and the high risk nature of hard rock aquifers have important implications for the nature of water markets. Many of the studies on water markets in India have been conducted in the deep alluvial aquifers of Gujarat. There, although water levels are falling, the capacity to pump water from any given well tends to be relatively high and uniform within a given area. As a result, small, medium and even large farmers are often able to reliably pump significantly more water than they can use for irrigation on their own lands. There is often, a strong incentive to sell the excess supply. Since power is charged at a flat annual rate based on pump horsepower (outside of Tamil Nadu) there is no marginal cost and the sale of any excess supply at any rate reduces average costs. In many locations like Gujarat, which rest on alluvial acquires the bargaining position of buyers and sellers is relatively equal. These dynamics can faster water sales at rates below the full cost of well development (Shah, 1993; Moench, 1995; Moench, 1996). The situation in hard rock areas where well yields are low and often vary greatly across seasons is fundamentally different; here, surpluses are far smaller and much more variable. A hard rock area creates a than they are from alluvial acquirers seller's market in which the bargaining position of water buyers is weak. The weakness of water buyers is probably a major factor underlying the interlocking of other agricultural markets with the water market.

Where does this leave us with respect to global and local debates over the role of groundwater markets? This role is discussed in detail in *Water Markets, Commodity Chains and the Value of Water (*Moench and Janakarajan, 2003). It is, however, important to emphasise here observation from fieldwork that water markets in Tamil Nadu and in the rest of India are self-initiating institutions. They weren't created though government interventions and their characteristics are difficult to influence through government policies. They exist as informal institutions outside the formal legal or regulatory frameworks of the government. In addition, their characteristics vary greatly depending on their location and or any case changes as conditions changes. As a result, while it is important to understand the impact of groundwater markets on the access of local populations, to a key resource there probably isn't much that can be done to influence their dynamics under the existing circumstances.

The above comment on groundwater markets raises the question of how civil society is going to respond to the escalating and competing demands on a shrinking groundwater resource base. Tushaar Shah illustrates the issue at a national scale in a diagram (See Figure 1 Moench's artilce this volume) he prepared for the book *Groundwater and Society* (Burke and Moench, 2000). This diagram illustrates the transitional nature of groundwater development and use across India. Initially, groundwater development catalyses change and the development of an intensive agricultural economy. Then, as development levels reach or exceed sustainable levels, the economy that has grown based on intensive groundwater irrigation must change. In some areas, intensive agriculture based on groundwater use may be sustainable. In other areas, limitations on the physical availability of water will force a transition. How this transition occurs is, perhaps, the greatest question facing groundwater management. Will it be possible for populations to make a planned (or at least a smooth) transition to other forms of economic activity and limit groundwater extraction to sustainable levels or will the transition be driven by the types of coercive dynamics currently seen in the case of Tamil Nadu? In the Noyyal Basin, small well owning farmers in Orathapalayam and Karaipudur have been so badly affected by water pollution that they are being forced out of agriculture and are seeking jobs in urban areas. A similar dynamic is occurring in Ugayanur and SA Palayam villages, where farmers have been driven out of agriculture due to their inability to keep up in the race of competitive well deepening. In SA Palayam, 16 out of the 54 wells we sampled have gone dry and are no longer in use. Their owners have failed to exploit water and are heavily in debt the over 60 per cent of well owners in Tamil Nadu who are small and marginal farmers with landholdings of less than five acres. Their very economic survival of threatened by pollution and groundwater overdraft. How rural populations of this type can shift towards more sustainable livelihoods is a critical question throughout much of India.

Two final issues we feel compelled to address are power subsidies and pollution. As documented above, most of the existing power subsidies are captured by the wealthy. In addition, the provision of free power encourages highly inefficient water use practices and thereby increases the groundwater overdraft. This is a clear case where policy reform is required. Reform must, however, also address the issue of an economic transition. At present, small farmers cannot even afford a tariff of just Rs 0.50 per unit of electricity consumption. Forced to close down their wells due to economic impracticability small farmers well be driven from agriculture and their land (Janakarajan, forthcoming). Continuing subsidies that primarily benefit the wealthy and encourage unsustainable patterns of groundwater use is counterproductive but likely displacement of small farmers caused by policy reforms such as new tariff structure must also be recognised and addressed.

Pollution is also a critical issue, which cannot be addressed through policy reform alone. In fact, the existing pollution laws in Tamil Nadu, as in the rest of India, do enable sufficient action to be taken. The problem is that they generally are not enforced. As we argued in our book *Rethinking the Mosaic* (Moench *et al.,* 1999), social auditors, the independent voices that raise uncomfortable truths in society are essential for putting pressure on governments and others to act.

NOTES

1 Spring channels are traditional structures for diverting the sub-flow in the gravely beds of streams.

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WATER MARKETS, COMMODITY CHAINS AND THE VALUE OF WATER

MARCUS MOENCH* AND S. JANAKARAJAN#

CORE ARGUMENT

The objective of this paper is to situate debates over the functioning and role of water markets within the concepts of management and adaptation. We will argue that existing water markets in South Asia are fundamentally different from the formalised, legal, rights-based water markets of the Western United States. South Asian 'informal' water markets are, for one, neither inherently equitable nor inherently inequitable. Nor do they capture *in situ* values (like environmental values and sustainability) associated with water resources. They do, however, play a valuable role in increasing access to water by increasing the reliability of its supplies in rural areas. While clearly imperfect, water markets, at least those in urban and peri-urban areas, are also an effective mechanism for shifting water from lower to higher value domestic uses as well as for forcing consumers to pay relatively high rates. In addition, water markets create strong incentives for using water efficiently and for conserving it. Furthermore, unlike most urban water supply systems, in which wealthy consumers capture subsidies with access to both storage and piped systems, water supplied through urban markets is unsubsidised. If existing urban water supply systems can be reformed so that they deliver sufficient supplies to meet the basic needs of all sections of society, then existing water markets may be an effective mechanism for meeting the demands of the wealthy for more water services.

Overall, the existing water markets in South Asia represent a partial but highly adaptive set of institutional arrangements for meeting the water needs of urban and rural residents. They have developed has occurred without the establishment of a quantitative or other formalised water rights system that goes beyond the basic rights of capture. Approaches to addressing regional water needs and problems that recognise the role played by existing water markets may be able to identify key points of leverage for meeting urban water needs without instituting fundamental institutional reforms or executing large-scale inter-basin transfers.

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WATER MARKETS AND THE VALUE OF WATER

International focus on the role of markets as a mechanism for allocating water and communicating its value to users has increased over the last two decades. In many water management circles, water markets are seen as an important, if not an essential, tool for reallocating water away from the demands of agriculture, the largest user, to meet growing urban and industrial demand. More fundamentally, markets are increasingly seen as an important mechanism for communicating the economic value of water and, thus, for encouraging conservation and efficient use both within and among applications.

Debates over water markets are often clouded by confusion over what is really being discussed. The primary model for water markets is the one developed in the Western United States. This model involves a well established, though far from perfect, set of quantitative water rights systems and substantial government involvement in regulating transfers to avoid negative externalities and adverse impacts on third parties. Although transfers between individual end users are possible, much of the activity in this model involves the transfer of substantial quantities of water between institutional users such as agricultural water districts and municipal water supply authorities. The indigenous local water markets found throughout South Asia and in many other parts of the world are fundamentally different. Although often discussed using the same terminology, local water markets in South Asia are based on informal rights of capture (if you can physically pump or divert water, you can sell it), not on quantitatively defined rights systems. These markets generally involve very local and volumetrically small transfers of water between individual users (between adjacent farmers, from farmer to industrialist, or from farmer to tanker owner) rather than between institutional users. Finally, because these markets are 'extra-legal,' governmental regulation of their functioning is minimal to non-existent (Moench, 1994).

Attempts are being made to replicate the American model in locations such as Chile, Mexico and South Africa, where legislation to reform water rights and, in some locations, to register wells has been passed. The success of this approach is widely debated. As Carl Bauer (1998) discusses in his well-researched and documented book on the Chilean water market, 'Chile's experience with free market water policies has been uneven.' According to him, the new water code has worked relatively well within the agricultural sector. Separating water from land ownership, for example, has fostered flexibility and encouraged the consolidation of water user associations as entities distinct from the state. With other aspects, however, major problems have emerged. Equity is one concern since 'peasants generally [lose] out in the transition to the new Water Code' and there have been 'serious problems' with 'inter-sectoral relations at the regional or river basin scale,' where the new legal framework has 'done a poor job of coordinating different water uses and resolving conflicts between them' (*Ibid*). On a more fundamental level, Bauer argues against the often-touted proposition that 'markets—as opposed to governments—are neutral, objective, and apolitical.' Instead he points out that:

> To exist and operate over time, markets depend not only on economic factors of supply and demand, but also on many extra-economic factors and prior definitions: such as political decisions, legal rules, cultural attitudes and geographic and environmental conditions. These factors and definitions are affected by relations of social and political power and by the distribution of wealth. Markets can be no more neutral than their surrounding social contexts and underlying institutional arrangements.

Finally, Bauer makes an observation of great relevance to the South Asian situation: water rights and market-based approaches are critically dependent on the capacity of the judicial system. Because water transfers often affect issues of basic livelihood and economic development and because water rights are extremely difficult to define fully, conflicts are an inherent part of any reallocation process. As a result, Bauer concludes:

> The capacity to resolve conflicts effectively and with legitimacy is especially critical in a neo-liberal legal and economic model, a model built around broad private rights and liberties and a minimal state. This capacity depends on the judicial system which must control state regulation and balance different private rights. The courts must be fairly independent from other branches of government, and willing and able to rule on disputes with substantive policy implications.

Bauer's analysis highlights the importance of understanding basic market assumptions before entering any debate over the positive and negative aspects of water markets. As Frederick (1996) indicates:

> Two conditions must be satisfied for the development of efficient markets. There must be well-defined and transferable property rights in the resource being transferred, and the buyers and sellers must bear the full benefits and costs of the transfer. Both conditions are now commonly violated for water resources. The fugitive nature of the resource makes it difficult to establish clear property rights, and the interdependence among users might cause externalities or third-party impacts when the use or location of water is changed.

The above issues are, perhaps, particularly problematic in the case of groundwater resources. With groundwater, benefits perceived by users are generally limited to extractive values. *In situ* values—the maintenance of aquifer levels, the insurance value of water held in stock, and environmental values such as groundwater contributions to stream base flows—tend to be public goods. As a result, the value of these goods is generally not reflected in groundwater use patterns or prices (National Research Council Committee on Valuing Groundwater, 1997). In addition to the extractive—*in situ* distinction, defining groundwater rights in a manner both transparent and reflect we of third-party considerations is particularly difficult due to technical limitations in our ability to quantify water balances and aquifer characteristics. Groundwater is an 'invisible resource,' and key aquifer characteristics, including the amount of water available on a sustainable basis, are often technically impossible to determine within the parameters of available data (Moench 1995; Burke and Moench, 2000).

Due to the above types of market failures, the effectiveness and equity of water markets as a mechanism for efficient, equitable and environmentally sustainable water allocation is widely debated, even in a Western US type locality. Activity in water markets in the Western US has generally been light: it involves limited volumes of water and a relatively small number of transactions (National Research Council, 1992). There have been major debates about the impacts of water markets on the ability to protect in-stream flows; on third parties, including other rights holders and areas of origin; and on vulnerable sections of society, including minorities, Native Americans and the poor (Nunn and Ingram, 1988; Moench, 1991; National Research Council, 1992; Moench, 1995). Conceptual concerns over the use of market frameworks in natural resource management have been expressed ever since such approaches were first proposed. In the early 1970s, for example, Schwab (1972) wrote 'Profit-motivated behaviour in a free market framework cannot be expected to exhibit much concern for conservation. It will tend to sacrifice the uncertain future for the more predictable present. To protect society against the risk of future shortages and crises, there will have to be active government involvement…' . Finally, there are ethical concerns about the basic premise from which water markets start: that there should be individual, private ownership of what has historically been a common heritage and a public resource (Moench, 1995).

In many cases, debates over water markets have become polarised along ideological lines. Those who believe in neo-liberal economic perspectives advocate them on principle, with little recognition of the complexities Bauer highlights in his analysis of Chile (1998). Many others criticise markets without providing any insight into alternative mechanisms that could, as markets do, provide flexibility in allocation and incentives for efficient use. Markets can be seen as filling a vacuum left by states which are unwilling or unable to provide basic resources to their citizens. They can also be seen as a framework for allocation that decentralises decision-making to the level of individuals and reduces the intrusion of bureaucracy into everyday life.

The above debates, though given due consideration, will not be resolved in this chapter. We believe it is important to acknowledge the value of the near universal agreement that changing economic and demographic patterns and the desire to grant environmental needs more recognition will necessitate the development of balanced and flexible mechanisms for water allocation in the coming decades. The most critical issues are more practical than ideological. They include the following questions:

1. Do water markets as they currently exist 'on the ground' in developing countries provide some of the flexibility and incentives for water conservation that are essential for meeting our needs in the coming decades?
2. Are relationships across water transactions equitable or are they embedded in social relationships that create conditions for forced sales or other forms of inequity?
3. Are major third-party impacts evident in the functioning of water markets?
4. What should the role of governments and international institutions be in relation to existing, imperfect water markets? In particular, how much reliance should be placed on attempts to create the types of private rights systems and government regulatory frameworks that represent the essential foundation for formalised markets of the type found in the Western US?

To provide some insight into the above questions, this paper will first focus on the key questions of flexibility, incentives for conservation, profit and equity relationships across transactions, and third party impacts in the functioning of water markets in Ahmedabad, Gujarat; Chennai, Tamil Nadu; and Kathmandu, Nepal. It well then, discuss the larger question of state roles, along with their implications for global debates over management approaches based on market mechanisms.

THE STRUCTURE OF WATER MARKETS IN INDIA AND NEPAL

Water markets in India and Nepal can be broadly classified into three types:

- **Rural-Rural**: These water markets generally involve transactions within the agricultural sector rather than transactions between sectors. In most cases, well owners sell water to adjacent farmers either for cash or for a share of their crop. This type of water market has been extensively investigated in a number of locations but much of the literature draws heavily on experiences in Gujarat (see for example, Bhatia, 1992; Shah, 1993; Janakarajan, 1994; Moench, 1994; Palmer-Jones, 1994; Moench and Kumar, 1995; Palanisami, 1996; Shah, 1996; Dubash, 1999; Moench, 2000). The research is characterised by two ongoing debates: first, whether water markets function in an equitable manner or have become sources of power and accumulation; and, second, whether or not they contribute to the efficient use and sustainability of the resource base. The debate over water markets is closely linked to debates over power pricing. In many Indian states the electricity for groundwater pumping is, provided at a flat annual rate based on pump horsepower or is free of charge (i.e. subsidised by the state). Given this situation, the existence of water markets provides a strong incentive to extract as much water as possible in order to maximise short-term returns and minimise fixed costs.

- **Rural-Urban**: This type of market is becoming increasingly common in rural areas adjacent to large urban areas or medium sized towns. The transfers here typically involve the sale of water by well owners (generally farmers) either directly to industries or to tanker companies which then deliver supplies to end users (smaller industries, commercial establishments and households). The promotion and formalisation of rural markets has been advocated as a potential mechanism for meeting the needs of urban areas such as Chennai, which avoids both costly long-distance transfer projects and the political difficulty of making administrative reallocation of supplies from existing agricultural users (Briscoe, 1996). Although less studied than rural-rural markets, rural-urban water markets are very common and represent a major source of supply for many users. They have also become increasingly differentiated, with people purchasing everything from bulk supplies of low-quality water for specific uses like irrigation to high-quality bottled water for drinking. The impact of such transfers on agricultural users is probably the most controversial issue with respect to these markets (Janakarajan, 1999).
- **Urban-Urban**: These markets are similar to rural-urban markets with the significant exception that they don't involve transfers of water from agriculture to urban applications. In addition, at least in some situations, urban water markets are supplied by water from municipal utilities. In Chennai, for example, the municipal authority supplies water to large (1-5 m^3) plastic tanks situated around the city. The water from these tanks is then sold in small quantities by water vendors stationed at the tanks to end users, generally families or small restaurants, for domestic use.

The urban demand for water which markets meet is a direct consequence of inadequate municipal supply systems. In many cities, a large portion of the population lacks in-house connections and even if users have direct connections, the supply delivered by municipal systems is insufficient for meeting their demands. Even during the best of times municipal supply systems often provide water for only a few hours a day while during periods of drought supplies are often very erratic. This represents a major problem even for households, which are connected to the system and able to afford substantial storage facilities (cisterns and rooftop tanks). For households dependent on public tap stands, collecting water can require major investments of time and effort. In addition to limited supplies, quality is another major concern driving the development of high-end markets for bottled drinking water. The poor quality of municipal systems is increasingly recognised as a problem. Overall, for both quantity and quality, rural-urban and urban-urban water markets are, at least for the wealthy, a way of bypassing the limitations of the public supply system.

A major part of this paper will focus in detail on the structure of rural-urban and urban-urban water markets in Kathmandu, Chennai and Ahmedabad. We focus on these types of water markets because far more information on rural-rural water markets and their dynamics has already been published. Before delving into the urban context, it is important to highlight some of the conclusions of studies of water markets in rural areas.

Key conclusions from studies of rural-rural water markets

In virtually all situations, the presence of a local water market increases the flexibility of water allocation within villages and enables people without wells to obtain access to water. This is of great importance for farmers because yields and income depend heavily on access to water at the time crops require it. Beyond these similarities, however, the wide array of studies on local water markets in India—most of which relate to groundwater—highlight the context-dependent nature of their functioning and characteristics.

Take the case of equity. In some situations, water markets operating on the basis of flat rates enable small farmers to gain access to water supplies at less than the full cost of groundwater pumping and infrastructure requirements (Shah, 1993). In other situations, water markets function as part of, and are embedded within, land and labour markets or are heavily influenced by the social, ecological and geographic context (Janakarajan 1994; Dubash, 1999). Dubash (2000), for example, found that prices within villages are often uniform and that equality in terms of exchange is emphasised by both buyers and sellers but that such price structures often stop at village borders and that adjacent villages frequently follow different systems. He attributes this pattern to differences in the spatial characteristics of aquifers and wells as well as to social differences such as land ownership patterns. As a result, while water markets can contribute to equitable access for small farmers, they can also have the reverse effect by forcing marginal farmers deeper into relationships of dependency. He emphasises that the equity implications of local water markets which function in an extra-legal manner and are regulated primarily by village institutions and geography are highly dependent on context. Dubash (2000) concludes with a caution:

> 'against policy manipulation based on a generalised understanding of how exchange systems for groundwater operate, and particularly one based on neoclassical models of oligopolistic or competitive markets. Policy interventions aimed at concerns of equity and sustainability must be based on a sufficiently realistic understanding of the structural conditions of groundwater access and the path dependent emergence of village level institutions that regulate groundwater use and access.'

Where the efficiency of water use is concerned, the impact of water markets remains unclear. Power and water prices are often an insignificant factor in the overall economics of crop production. In the Western US, for example, energy prices help determine farmers' willingness to invest in water conservation but play a minor role in crop choice and therefore in decisions about overall water use (Moench, 1991). As a result, water and energy prices *per se* will create only marginal incentives for efficiency unless they increase significantly beyond present levels. Much of the debate in South Asia is linked to questions about power tariffs, which, in most Indian states, consist of a flat annual charge based on pump horsepower. One comparative study of diesel and electric wells conducted in the early 1990s found that farmers who paid high unit costs for diesel used water more carefully and reduced the area under-low-value, water-intensive crops than farmers who used electric pumps with a flat rate tariff (Moench, 1993; Moench and Kumar, 1994; Moench, 1995), but that reductions were relatively marginal despite the very substantial price difference. While organisations such as the World Bank argue strongly for the full-cost pricing of power, political realities have kept reforms in power prices well below cost, which is perhaps Rs 3.5-4 per kWh in rural areas (World Bank, 1998). In Gujarat, for example, the new optional metered tariff for power in agriculture was, at the end of 2000, Rs 10/month plus Rs 0.5/unit.[1] In other states, such as Punjab and Tamil Nadu, there is currently no charge for power for agriculture, but a substantial increase in power prices would have a major impact the economics of crop production and, as a result, on the efficiency of water use. According to a proposal prepared by the International Water Management Institute and others, 'IRMA has estimated that the Mehsana farmers use 0.38 kWh of power to produce one cubic metre of groundwater; at Rs 2.50/kWh, groundwater pumped in North Gujarat will begin to cost over Rs one rupee per cubic metre; at this rate, most groundwater-irrigated agriculture would collapse. And so would the region's dairy economy; at one rupee per cubic metre the irrigation cost of alfalfa would rise to Rs 10,000/ha and would raise 3-fold the farm-gate cost of dairy production, which is the mainstay of the region's rural economy.'[2] Since back-of-the-envelope calculations suggest that farmers in North Gujarat were paying over one rupee per cubic metre a decade ago, this extreme projection may be unfounded.[3] In addition, due to political limitations on prices charged for power, water prices are unlikely to be forced much higher. Nonetheless, the most general conclusion appears to be that the prices established in water markets do provide some incentives for efficiency, but that prices are not high enough at present to cause farmers to abandon low-efficiency practices (such as flood irrigation) or to necessitate major crop shifts. Flood irrigation remains widespread and there has been a significant expansion in the area under alfalfa cultivation to supply Gujarat's growing dairy industry. Most responses to falling water levels focus on harvesting new supplies, not on managing demand.[4] As a result, even in North Gujarat, where market prices for water are relatively high, efficiency of use has not greatly increased.

A final concern in rural-rural markets is sustainability. Under the flat rate tariff or free power supply structure for electricity in agriculture, water markets produce few incentives for increasing the sustainability of groundwater use. Due to the flat rate structure, farmers face declining average costs. As a result, they have an economic incentive to pump as much water as they can use and, when water markets exist, to sell as much as they can. In this situation, water markets encourage over-extraction rather than sustainable use. The impact of flat rates on actual pumping levels has never been quantified, but the direction of the incentives it creates is clear. Changing to a pro rata (consumption-based) system for power charges would reduce but not necessarily eliminate the incentive to over-extract groundwater.

In sum, existing studies of water markets highlight the fact that then impacts are context-dependent. While the emergence of water markets has clearly increased flexibility and the reliability of access to water for farmers, their implications for equity, efficiency and sustainability are less clear. Many of their impacts depend on local conditions or on external features such as the structure of power tariffs. Overall, rural-rural water markets and their implications for efficiency, equity and sustainability are, as Dubash (2000) indicates, heavily influenced by the social and institutional context in which they occur.

Urban and Rural-Urban Water Markets

The functioning of rural-urban and urban-urban water markets is of particular importance for two reasons. First, India is projected to be more than 50 per cent urban by 2020. While the absolute number of people living in rural areas will continue to grow, urban areas will grow much faster and will create huge demands on water resources. Second, as a result of this demographic shift, there will be increasing pressure to transfer water from the agricultural sector to urban dwellers. Since urban dwellers are generally more educated and politically active than their rural counterparts, political power in India is likely to shift even more heavily toward urban areas. This will make urban demands for water supplies even more potent. While agricultural interests may resist pressure to transfer water, demographic patterns suggest that such transfers will occur by one mechanism or another.

Markets may be that mechanism. They are advantageous in that they induce purchases to conserve and that they compensate those who give up water.

While large-scale, legally-structured markets for water supply to urban areas do not yet exist, small-scale, extra-legal markets are common. It is important to understanding the dynamics of these markets in order to generate insights into the larger role water markets could play and into the issues or concerns such a role might create in meeting projected urban demands. The next section first presents case studies carried out in Ahmedabad by Shashikant Chopde and Srinivas Mudrakartha of VIKSAT, in Chennai by S. Janakarajan of MIDS, and in Kathmandu by a team from NWCF-ISET. A detailed discussion of their functioning and the allocation and equity issues they raise follows:

Case Studies

Kathmandu[5]

Kathmandu, Nepal's largest city and its capital, is undergoing rapid development and expansion. This phase started with the opening of the country in 1951 and continued with the subsequent flood of modernity and population growth. In recent years, rural-urban migration has soared due to the economic opportunities in Kathmandu and the deteriorating political conditions in rural areas. Kathmandu Valley's population is now estimated to be approximately one million, but will undoubtedly experience a rapid increase over the coming years.[6]

Water supply in Kathmandu was historically delivered through traditional systems such as a widespread network of stone waterspouts called *dhunge dhara*. The oldest located at Hadigaun, was built in 554 A.D but is still in use. Waterspouts were built at least through the late 1800s and were part of a functional system for delivering water to consumers through a network of *raj kulo*, or drinking and irrigation water supply channels. The rapid development Kathmandu has witnessed in the last twenty years has lead to the failure of a number of *dhunge dharas*. Water supplies have been cut off constriction in some places, while in others supplies have been contaminated by the growing population. That nearly all *dhunge dhara* show high levels of fecal coliform contamination, especially during the monsoon season, is probably attributable to the absence of a city sewer system. Because the water of *dhunge dhara* is considered religiously pure, most people consider it clean enough to drink straight from the spout, although some boil or filter it first. Although this traditional system is growing increasingly overwhelmed and polluted, it still supplies water for domestic use to a significant portion of Kathmandu's population. Many users also rely on local wells that have been dug or drilled into the upper aquifer underlying the city. These wells are generally viewed as polluted and their water is used only for bathing, washing and other non-drinking uses. Since Kathmandu is located on the sediments of a lake that once filled the valley, it is underlain by relatively productive aquifers. The upper, unconfined aquifer is becoming increasingly polluted but still serves as a primary source of water for many shallow wells.

Modern pumped water supply systems were introduced on a minor scale more than 100 years ago to provide water to royal and other high-status residences. This nucleus was subsequently expanded into a general municipal supply system, currently operated by the Nepal Water Supply Corporation (NWSC), which receives water from rivers flowing into the valley and from a network of wells which tap the lower, confined or semi-confined aquifers beneath the urban area. The ability of this system to meet the city's demand is limited. Most of the water flowing into the valley is already being used and the deeper, unpolluted aquifers under the urban area suffer from overdraft. Estimates suggest that the demand for water in the Kathmandu Valley exceeds 155 million litres/day, but according to newspaper reports, the municipal supply system can deliver only 120 million litres/day in the wet season and 60-70 million litres/day in the dry.[7] The estimated rate of loss is very high over 70 per cent. In addition much of this water flows back into the upper, unconfined aquifer, where pollution levels render it unsuitable for urban supply. Overall, water supply from the municipal system is characterised by growing uncertainty about and variation in the quantity delivered. During the dry season some households receive 0.5 to 2 hours of water a day while others get water once a week or not at all. To compensate for shortages and losses, the government has invested in the Melamchi Project, a major scheme to divert water from a stream outside the valley and deliver it to Kathmandu through a 26.5 km-long tunnel. A variety of initiatives to reduce losses have also been introduced, but none have had much effect. Regardless of these long-term plans, most residents in Kathmandu experience significant disruptions in the supply they receive from the modern system and frequently find themselves short of water. As a result, the poor continue to depend on *dhunge dhara* and on increasingly polluted local wells, while those who can afford to purchase water from what they hope are higher quality sources.

Kathmandu's private water market relies on tanker trucks that deliver water extracted from a limited number of wells within the urban periphery to end-users. It developed in response to the failings of the municipal supply system and in fact, fells gaps in that system by reliably delivering supplies to private residences and to hotels and other businesses in the Valley. *Dhunge dhara* and private wells in the meantime continue to play a vital role in serving the middle-to lower-income population of the city, whose access to improved services is poor. These latter two sources affect the shape of the private water market by acting as a low-cost alternative to the insufficient supply of municipal piped water and the expensive supply delivered by tankers. Which water source a household decides to use depends on its preferences for water quality and quantity in relation to its location, water availability, and financial status. In Kathmandu, unlike in many other urban areas of South Asia, the tanker-based water market is a relative luxury primarily serving the upper-middle and wealthy classes.

The cost of water delivered by private tankers varies depending on the water source, the location of the customer and the size of the truck. In general, a small tanker which delivers six cubic metre, costs NRs 900 (USD 1.99/m^3), while a large tanker delivering 12 m^3 costs NRs 1,200 (cost ranges USD 33/m^3). NWSC has a small tanker service that supplies treated municipal water at NRs 160/m^3, or USD 2.12/m^3. Despite the high cost, NWSC tankers offer a legitimacy that customers respect and are willing to pay for when they face shortages in the piped municipal supply. Tanker water is generally not used by the middle to low-income portions of the city's population for two reasons: cost and lack of storage capacity. To make use of tanker deliveries, purchasers be able to store 5-12 m^3 of water.

The tanker companies which operate in the Valley are largely small entrepreneurs with an average of two tanker trucks each. They function on demand, which is seasonally skewed: the busiest time of the year is the dry season, when the municipal supply is particularly low. A tanker truck typically makes from three to five deliveries per day in the dry season, whereas during the rest of the year some companies make as few as four deliveries a month. A rough calculation of the private market supply of water to Kathmandu during the dry season is six million litres/day.[8] This constitutes a substantial contribution to the official dry season supply for NWSC, 80 million litres/day minus 60 per cent losses. In fact, the private market makes supplies nearly 19 per cent of the total.[9]

Kathmandu's private water market is an unregulated system of water tanker companies that have found a niche amongst the insufficient municipal supply and the public waterspouts and wells in the city. The market functions outside the jurisdiction of the government and neither price nor water quality regulations govern it. Since it lacks official legitimacy and accountability, individual companies have been forced to create their own standards in order to build the trust of their customers. Needless to say, standards range widely and there is little means of verifying what they are for each of the 80 companies.

Tankers draw from a range of sources from springs at the Valley's edge to borewells in or adjacent to the city. According to one NWSC official, these source have a high iron and ammonium content, yet most of the water tanker companies sell goes untreated to the customer. Spring water is never treated, while well water sometimes goes through a rudimentary purification process. Customers who were asked seldom knew the source of the water they purchased. Tanker customers frequently complained that the water delivered was poor quality; they claimed it was discoloured or smelled bad, and a number of people reported having contracted serious skin irritations from tanker water. In the absence of market regulations, there is a need for instituting a governing body which will both foster trust among customers while at the same time support the interests of tanker companies.

To increase their legitimacy, a number of tanker companies formed the Tanker Association in 2000. Its goals are to ensure that their growing customer base gets good quality water and to unite their voice in the face of government restrictions. The Association was established following several disputes between tanker companies and the police over acquiring the driving permits needed to operate their large trucks in the city. According to a Tanker Association representative, member companies pay a monthly fee of NRs 300 and agree to abide by the Association's rules. Membership gives tanker owners the right and the duty to fill their trucks at sites controlled by the Association. To establish a standard quality of water, the Association requires all member companies to use a single water source, which it tests every three months. The source in current use is an unfiltered spring source in Chobar, which is considered by consumers and tanker owners to be the cleanest source in the Valley. The Association is interested in establishing a second water source, a borewell, because the supply at Chobar does not suffice during the dry season.

The supply system in the Valley can be viewed as a competing set of institutions and sub-systems. Virtually all the sources of water available entail certain costs to users. In the case of the traditional *dhunge dhara,* the costs are primarily measured in terms of time and labour. In a few instances, communities who use a *dhunge dhara* also require users to pay; the charge varies depending on how the water is used. Charging for *dhunge dhara* water is uncommon, but the cost is comparatively high. In some locations, users are charged NRs 3 for a 8-10 litre pot of water. This is equivalent to NRs 300/m^3, or US$3.98/ m^3. In another case, the professional washer community in Dhobi Ghat, which has an exceptionally good *dhunge dhara,* charges people outside the community to use of their water. A sign at the source states the charges; a moneybox is hung below it for contributions.[10]

The amount charged is also determined by the costs associated with renovating the water source in question—a *dhunge dhara*, for example—constructing a community well or maintaining a community source. Money to renovate or construct a *dhunge dharas* is usually collected on an ability-to-pay basis with contributions ranging from approximately NRs 500 to 5,000 per household. In addition to the direct financial costs, of a *dhunge dhara* are the cost associated with the time and energy spent waiting in line, collecting water and carrying it back for use within the household. Water collection is almost exclusively a woman's job, and one that is significantly more difficult during the dry season. Depending on where they live in the city, women can spend up to 45 minutes walking to the nearest *dhunge dhara* and often wait in line for six or more hours. To avoid the long lines, some women make the trip in the middle of the night to collect enough water for a family of four or more. The figures noted above depict extreme cases during the dry season, but it is very common for women to get up at four in the morning and to wait in line for two hours. If one assumes a wait of two hours to collect 15 litres and an implicit labour cost of NRs 15/hr,[11] the cost of water amounts to NRs 2,000/ m^3 or USD 26.53/m^3. A wait of six hours implies a cost of NRs 6,000/m^3, or USD 79.58/m^3.

Two main problems with the traditional supply system are that it doesn't provide complete coverage and its supply fluctuates. *Dhunge dhara* are located primarily in the low-lying, core areas of town, out of the reach of much of the urban population. The supply at each *dhunge dhara* varies according to its location and source and, as is the case for the municipal supply, the dry season flow of most *dhunge dhara* is considerably lower than it is during the rest of the year. The dry season, thus, is a time of poor supply within the city. Some areas, specifically Patan, have an extremely good supply year round, while others, such as Thamel, serve a large area with very low flow.

A survey of women's perceptions of water conducted as part of this research demonstrated that the issues associated with *dhunge dhara* are common to other water sources as well. All water sources except tanker water and locations with a sufficient supply of NWSC piped water and a substantial storage capacity, require a significant amount of time and energy, a cost generally born by adult women. The non-monetary costs associated with securing a supply of water vary from nighttime collection from the household NWSC tap to walking up to 45 minutes to the nearest *dhunge dhara* or waiting in line at a tap stand. Water costs are relatively high at all income levels, requiring households to regulate their water use and to conserve whatever water is available.

Table 1 provides a general profile of and the costs associated with different aspects of the Kathmandu water market. As can be seen, the market is relatively unstructured and fragmented. The costs and the characteristics of the services within it vary greatly.

The costs and other problems associated with all forms of water supply in Kathmandu have generated a wide range of coping mechanisms. These strategies are outlined according to income level in the table. In general, if households are unable to use a shallow well as an alternative source of water, they must choose either to the labour-intensive and time-consuming route of collecting water from *dhunge dhara* or depend on expensive tanker delivery. Strategies to avoid making this choice, such as asking a neighbour for water or stretching what is received from the municipal piped supply do exist. It is quite common for people to give away small quantities of either drinking water or low-quality well water if they have a sufficient supply. The responses of the people we interviewed suggested that there is a feeling of mutual respect between those who had given water and those who had received it. Those giving understood the necessity of the resource and were willing to share, while those receiving respected and did not take advantage of the giver's generosity. This dynamic emerges primarily between higher and lower income level households.

To sum up, the tanker water market in Kathmandu primarily serves high-end customers who have storage facilities of at least five cubic metre and can pay NRs 900-1,200 for a tanker of water. Approximately 80 small tanker companies serve residents and commercial establishments and meet as much as 18 per cent of the total demand for water during the dry season. This market has emerged to meet the demand for a convenient

TABLE 1
COST COMPARISON FOR WATER SOURCES AVAILABLE IN KATHMANDU, NEPAL

	Cost (NRs)				
Source	Monetary	Non-monetary	**User Profile**	**Quality**	**Water Use**
NWSC household pipeline	4/m³	Nighttime collection,storage system (cistern or vessels)	All incomes in houses, level of supply unconnected to income	Generally considered good quality, limited contamination	All household needs unless contaminated
Private	100 to 150/m³	5m³ storage capacity. Health costs potentially significant but unknown	High to high-middle income, with 5m³ storage capacity	Variable quality, unfiltered spring or borewell	All household needs
dhunge dhara	Free to 300/m³ cash. Implicit labour cost of up to 6,000/m³ when women have to wait 6 hours for 15-litre. More typical implicit cost: 2,000/m³	Labour intensive: walking, hauling, waiting in line. Health costs potentially significant but unknown	Middle to lower income	Variable quality	All household purposes
Private well	3,500 to 20,000 initial cost to dig	Manual or electric pump collection. Health costs potentially significant but unknown	High to low-middle income residents with property	Usually low quality, select areas high quality	Garden, cleaning, toilets. Seldom consumed
Community	Initial contribution 500-5,000	Collecting water manually or electrically with pump. Health costs potentially significant but unknown	Middle to low income	Variable quality	Washing, cleaning, toilets. Consumed in Patan

supply of water created by the gap left by the combined services of traditional, but often low-quality sources and the poor coverage of the modern, but poorly functioning, piped system. The demand is has arisen due in part to the shortage of supply from both systems and in part to the low quality of water from local wells. The net result is a mosaic in which the lower economic strata of society pay for water largely through women's labour and time and the health risks associated with drinking from polluted wells and *dhunge dhara* and higher-income households pay through the direct cost of tanker deliveries and the potential health risks associated with drinking water from unknown sources. Only a few

TABLE 2
COPING STRATEGIES EMPLOYED BY KATHMANDU RESIDENTS

	Sources Available					
Income	**NWSC**	**Tanker**	**Private well**	**Comm. well**	***Dhunge* dhara**	**Coping Strategy**
High	X	X	X			Prioritise water use, well water not for drinking, electric pump on pipeline, storage capacity of at least 5m^3
High-middle	X	X	X	rare	rare	Prioritise water use, well water not for drinking, *dhunge dhara* water collected by car, washing done at relative's house, electric pump on pipeline, storage capacity of 5m^3
Middle	X		X	X	X	Prioritise water use, well water not for drinking, storage capacity of 5m^3, hand pump on pipeline, use of *dhunge dhara* and community well
Low-middle	X		X	X	X	Prioritise water use, washing and bathing done at community well or *dhunge dhara*, depend on neighbours for drinking water
Low	rare			X	X	prioritise water use, depend on neighbours for water, use community well and *dhunge dhara* heavily

sectors of the city can rely on water provided by NWSC for all their needs, and these, generally wealthy, sectors pay the least, in both monetary and non-monetary terms.

Ahmedabad

Ahmedabad is underlain by a deep alluvial aquifer. Although water levels in this aquifer have been declining for decades (Gupta, 1985), physical access to it is not a major problem. The Ahmedabad Municipal Corporation (AMC) runs an extensive system for meeting the city's water needs. Water is supplied to consumers at the subsidised rate of Rs 1.23/m^3, a price well below the Rs 6.8/m^3 it costs the government to supply the service. Parts of the urban area are supplied from French wells in the Sabarmati River that access water released from the reservoir in the Darhoi River far upstream. Other parts of the urban area are supplied from a network of tubewells run by the AMC. In addition, many commercial establishments, private residences and housing societies own their own wells. Most middle- and upper-class residences also have cisterns for storing water. Given the relatively extensive network of sources, water scarcity is a significant concern only for those who live in lower-middle class and poor areas where private wells are few and storage is limited. In most cases, the AMC delivers water twice a day for several hours and is able to meet the demand for basic domestic needs, even during the dry season. As a result, the demand for additional water supplies are mostly due to a high-volume occasion such as a marriage or come from commercial establishments and hotels that either lack their own well or are situated in an area where the quality of the groundwater is poor. In these cases, municipal sources cannot meet the demand.

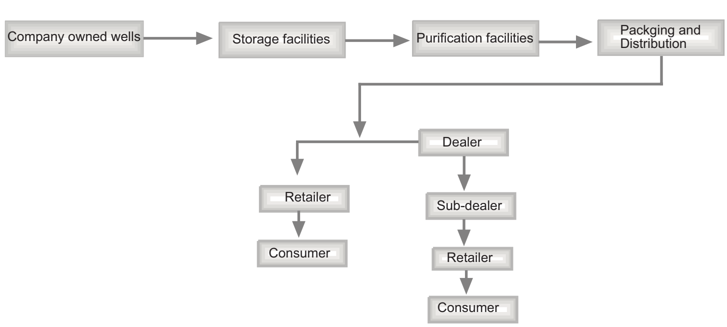
Although the volume of supply available from municipal sources is, in most cases, sufficient and the price charged to consumers is highly subsidised, quality is a major concern. A survey of water sources in Ahmedabad conducted by VIKSAT found that the concentration of fluoride is above the permissible limits of 1.5 parts per million (ppm) in 86.5 per cent of the area. Total Dissolved Solids (TDS) were also above the permissible limit of 2,000 ppm in most of the area. Ahmedabad residents have long been aware of the high level of TDS in their groundwater and recent attention to the health problems associated with high concentrations of fluoride in water has increased their concern over water quality. According to VIKSAT's survey, contamination has become the major factor propelling the development of water markets in the urban area.

The combination of short supply for large-volume users and low quality has driven the creation of a two-tiered water market in Ahmedabad: private companies with purification facilities sell partially demineralised water in pouches and bottles to users whose primary concern is quality; and private tanker companies deliver large volumes. At present there are nearly 500 tanker companies which supply water in Ahmedabad (Consortium of Resource Persons of the Consultative Group led by Katar Singh, 2000).

Mineral Water Suppliers

There are six main brands of mineral water for sale in Ahmedabad. Each has its own wells and storage, purification and primary distribution systems. They market water either directly to retailers and consumers through their own distribution system or indirectly through a network of dealers. The structure of a typical company is shown below:

FIGURE 1
STRUCTURE OF MINERAL WATER SUPPLIERS



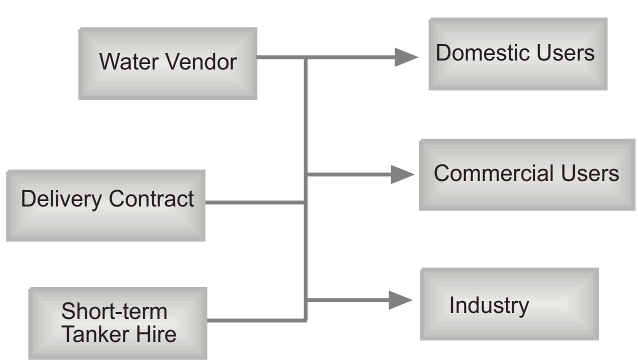
The higher quality companies maintain specific standards for the mineral concentrations in the water they deliver. Water is available in 200-ml and 250-ml pouches, and in 1-1.5-l, 2-l, 5-l and 20-l bottles. Prices are uniform: all retailers charge Rs 12 for a 1-l bottle, Rs 17 for a 1.5-l bottle and Rs 20 for a 2-l bottle. The end cost that consumers pay is Rs 1,200/m^3 (or USD 26.55/m^3) in the case of 1-l bottles. The profits generated for traders at each step in this chain range from a few to as high as 25 per cent.

Private water vendors

Most private water vendors own their own source of supply, typically a borewell drilled 150 to 200-m deep. They also typically operate their own delivery tankers. In some cases, however, well owners also contract private tanker owners to deliver their water to consumers. This is common during periods of high demand, such as during the marriage season, festivals and droughts. Since these times of high demand are intermittent, water vendors avoid major capital costs by relying on intermediate-term delivery contracts or by hiring tankers for short periods. Most suppliers have a set clientele, including households, commercial establishments (hotels, restaurants, etc.) and, in some cases, industries.

Based on the average figures of energy use and discharge (100m^3/hr), researchers in Anand estimated that the average energy consumption for groundwater pumping is 0.38 kWh/m^3.[12] At current Gujarati Electricity Board rates for commercial users in the medium block (420 paise/unit), the implicit cost of energy to pump water is Rs 1.59/m^3 (USD 0.04/m^3). If the pump is registered as agricultural, and if the pump is run for 2,000 hours a year the implicit cost of energy for the well owner to pump water at the well head is only Rs 0.33/m^3.[13] Water rates for bulk consumers—those purchasing tankers with capacities from 6,000 to 12,000 litre—commonly range from Rs 33/m^3 to Rs 37.5/m^3 (USD 0.73/m^3 to 0.83/

FIGURE 2
MARKET STRUCTURE FOR PRIVATE WATER VENDORS



m^3), excluding transportation. One supplier provides water for as little as Rs 30/m^3, including transportation. Smaller consumers often purchase water from *carbas* (small, manual push-tank) distributors. C*arbas* have a 45-litre capacity and cost Rs 300/month (Rs 222/m^3 or USD 4.91/m^3) for daily delivery. Most of the buyers of these small volumes of water are small restaurants and hotels. Low volume commercial users and those most concerned with quality (i.e. those purchasing bottled water) pay the highest prices.

The market structure within Ahmedabad is driven primarily by concerns over quality and shortages for large-volume users. In most situations, access to water *per se* is not the driving force. Instead, the high salinity of and fluoride concentrations in both well water and much of the municipal supply; produces a demand for cleaner water. This market structure is significantly different from that in Kathmandu in three respects: (1) much of it is driven by a demand for quality rather than by water shortages; (2) there appear to be far fewer water vendors; and (3) low-end users do not face the high implicit costs attached to waiting for hours at tapstands to receive deliveries.

Surveys conducted by VIKSAT in other urban areas of the Sabarmati Basin show distinct variations in the characteristics of the water market. The best-served area is Gandhinagar, the capital, where government sources supply 460 litre/capita/day (LCD) the highest rate in the basin, and 98 per cent of households are covered. The rates for water in Gandhinagar are also the lowest in the region—just Rs 0.33/m^3, although the actual cost of supply is Rs 24/m^3. Moreover, due to a variety of factors, only 85 per cent of the fee charged is actually collected. The total subsidy (including uncollected charges) amounts to 85.6 per cent of the cost of providing water. Since 77 per cent of houses have storage tanks and the water supplied by the government is relatively good quality and highly subsidised there is little demand for water from other sources. In less privileged urban areas of the Sabarmati basin, however, the demand for private sources of water is strong. The conditions in these other areas are summarised in the Table 3.

The table highlights the regional variations in water supply within Gujarat. The private tanker market is relatively well developed in areas where water is either scarce or of poor quality. Privately supplied water, which includes that transported by tankers, is far more expensive than government supplied water. In addition, government sources are heavily subsidised and only 85 per cent of the charges imposed are actually collected. Overall, the subsidy to consumers from government sources is over 85 per cent of the cost of supplying the water. Despite the high government subsidies, profit margins in the private sector are still very high. During the summer months, for example, the profit margin for the private market in the central alluvial region is 58 per cent, while that in the hard rock region is 125 per cent. Even in the relatively water-rich southern region, the profit margin is 91 per cent. In non-summer months, profit margins range from 27 to 70 per cent in different regions. While a large part of the profit margin reflects service charges

TABLE 3
SITUATION OF WATER SUPPLIES IN URBAN AREAS OF THE SABARMATI BASIN OUTSIDE THE CAPITAL, GANDHINAGAR

Attributes	Hard Rock Region	Central Alluvial	Southern Region*
	Public Sector		
User perceptions of Public supply quality	48% pressure adequate, quality generally good	58% pressure adequate, quality generally unsatisfactory	72% pressure and quality good
Cost of supply	Rs 7.81/m^3	Rs 6.8/m^3	Rs 5.7/m^3
Tariff charged	Rs 1.61/m^3	Rs 1.23/m^3	Rs 1.21/m^3
Per cent tariff recovery reported	60%	61%	60%
Loss to government	Rs 6.84/m^3	Rs 6.04/m^3	Rs 4.97/m^3
Population willing to pay more	51%	36%	39%
	Private Sector		
Dependence on private sources due to inadequacy of government supply	25%	18%	2%
Cost of supply	Rs 20/m^3	Rs 26/m^3	Rs 23/m^3
Tariff charged	Rs 45/m^3 summertime Rs 34/m^3 rest of year	Rs 41/m^3 summertime Rs 33/m^3 rest of year	Rs 44/m^3 summertime Rs 34/m^3 rest of year
Profit for private sector	Rs 25/m^3 summertime Rs 14/m^3 rest of year	Rs 15/m^3 summertime Rs 7/m^3 rest of year	Rs 21/m^3 summertime Rs 11/m^3 rest of year
Population supporting privatisation of water supply	25%	25%	22%

** Water in abundance in this region*

for the convenience of having water delivered to one's house, it probably also includes the cost in time and labour for households to gain access to water when government supplies are insufficient.

The Gujarat situation is very similar to the situation in Kathmandu in at least in one key respect: private water tanker markets are highly fragmented and unregulated. People drill wells, tankers supply water with no assurance of quality beyond their personal reputation and private purification companies operate with little governmental control.

Chennai

Water supply for domestic use in the Chennai urban area has been a source of concern for decades. In recent years, the ability of the Metro Water Board to provide water has fallen far short of demand. The official situation is summarised in the Table 4.

As the table indicates, water delivery meets only about half the demand in Chennai. This world not be too small fraction if supplies were unrestricted and delivered at the

TABLE 4
WATER SUPPLY IN CHENNAI

Year	Pop. 10^6	Water (MLD*) @ 158 LCD	Demand (MLD) @ 460 LCD[1]	Actual supply (MLD) domestic/ industrial	Cost to MWB** per m^3 (Rs)	Supply as % of requirement	Supply as a % of probable demand
1995	4.19	662	1927.4	300/65	8.8	45%	16%
1996	4.28	676	1968.8	295/65	8.23	44%	15%
1997	4.37	690	3015.3	345/68	9.3	50%	11%
1998	4.46	705	3144.3	381/48	10.2	54%	12%
1999	4.56	720	3283.2	413/37	15.11	57%	13%

** Million litres/day*
*** Metro Water Board*
Source: Metro Water Board

highly subsidised rates found in other urban centers. Demand is restricted because, in water-short years, piped water does not reach significant portions of the city on a regular basis. In July 2000, for example, only 59 LCD of piped water was available. In response the Metro Water Authority installed 4,525 tanks and hired 400 trucks with capacities of 9,000 to 12,000-litre to deliver water to under-served areas.[14] However, even these measures proved insufficient and residents often had to pay substantial bribes to truck drivers and to Water Authority officials in order to receive water.[15] This situation led to the creation of a flourishing and extensive water market in the Chennai urban area.

During the rainy season, approximately 2,000 private tanker trucks with capacities of 12,000-l each supply untreated water to Chennai. In addition, about 150 private companies purify and deliver drinking water in 12-litre cans, 1and 2-litre bottles and plastic pouches. Tanker trucks are estimated to make at least three trips a day during the rainy season, delivering about 72 MLD; the volume doubles during the dry season. The Metro Water Authority is only able to deliver 59 LCD to the 4.56 million residents (1999 figures), while the total delivery capacity of the tankers is approximately 269 MLD. Private tankers supply 35 per cent of the total demand and their supply capacity is approximately 54 per cent of that of the Metro Water Authority.

In Chenai, as in Kathmandu and Gujarat, the private water market is highly fragmented. Numerous small companies operate one or two tanker trucks each. They deliver water either from their own wells or purchase it from farmers and other well owners. Many small purification companies, each with its own facilities, also exist. Each operates independently and free of any regulatory monitoring of the quality of water it provides.

Prices charged for water in the public and private sectors vary greatly. The official rate for direct tap connections is Rs 0.14/m^3 and for supplemental tanker deliveries, Rs 50/m^3. During the rainy season, tanker owners charge their regular customers approximately Rs 400 for a 12,000-litre tanker (Rs 33/m^3); the price increases to Rs 450 during the dry season. They charge more for occasional customers, approximately Rs 500 and Rs 540 respectively. The rates go up during drought. In addition, it is reported that Metro Water officials[16] collect bribes of Rs 600 for a 9,000-litre tanker. When all these costs are considered, the rate of water supplied by private tanker total Rs 67/m^3, or USD 1.48/m^3.

The private and public water market commodity chains shown in the figures below indicate that the cost of water increases tremendously from the source to the end user. Farmers and other well owners typically sell their water to transporters at Rs 3.3/m^3 (USD 0.07/m^3), while consumers pay a minimum of Rs 33/m^3 (USD 0.70/m^3) for bulk untreated water during the rainy season and as much as Rs 20,000/m^3 (USD 442.48/m^3) for purified water when it is sold in 250-ml plastic pouches for Rs 5 each. Between the initial point of sale and the ultimate point of consumption, the cost multiples considerable. While this increase does reflect substantial service inputs (transport, purification, packaging, storage and cooling), the profits involved are also very large.

The extent of the water markets in Tamil Nadu's capital is well known and has led to formal proposals for greater reliance on market transfers as a source of water. According to the World Bank (1998); 'Estimates suggest that up to 400 million cubic meters of annual secure water supplies could be purchased from farmers for less than USD 20 million. This compares with the USD 400 million proposed Krishna and Veeranumm projects that would supply a similar amount of water to the city of Chennai. Similar opportunities are present in other locations, such as Jaipur and Hyderabad.' Other alternatives, such as bringing water to Chennai from the Cauvery River via the Veeranam tank, would cost roughly Rs 16/m^3, compared to the perhaps Rs 2/m^3 it would cost to buy water rights from farmers (World Bank, 1998).

Market and State Supply Synthesis

The picture that emerges from the three case studies of urban water markets in India and Nepal described above highlights the growing role that private water sources play in meeting the everyday needs of urbanites. The themes common to all three case studies are as follows:

1. **The growing role that private sources are playing within the overall water sector.** The case of Chennai, where, during some periods, private sources already supply as much as one-third of urban water needs, is extreme. In all locations, however, contributions from private sources have grown and now play a critical role in meeting water demands. There is clearly a dynamic interaction between public and private sector systems of supply: private systems move into the gap left by public systems.

2. **The highly subsidised nature of piped public water systems.** Water from public systems is generally highly subsidised and those subsidies are in large part, captured by the wealthy. People who can afford large storage systems, particularly cisterns, are freed from having to spend time, effort and money on frequently obtaining small amounts of water. Furthermore, because they have storage reservoirs, they are able to utilise whatever is available through the public system before having to buy water from other sources. When they do need to buy water, they buy in bulk and pay lower rates than those who can purchase only small quantities.
3. **The increasing differentiation and the high-end nature of water markets.** Most people who buy bulk water in tankers and purified drinking water in cans, carboys, bottles and pouches are high-end consumers. Water in these forms, particularly bottled drinking water, costs far more than water from public supplies. High-end consumers are increasingly willing to pay these higher costs for reasons of convenience and quality and not, except in the most extreme instances, because water is unavailable.
4. **The absence of any external assurance regarding the quality of water available through private markets.** In most cases, there is no external monitoring of the quality of the water tanker markets and bottled water suppliers supply. The Water Tanker Association in Kathmandu is the first evidence of self-regulation about which we are aware.
5. **The high cost of water for poor consumers.** Although water markets serve predominantly high-end consumers, low-end consumers often pay a far higher real price for water if the time and effort they spend obtaining is taken into account. In Kathmandu, for example, despite the relatively ready availability of water from traditional sources, the time women spend collecting it is equivalent to an implicit price of USD 27/m^3 (and IS higher during periods of real scarcity when waiting times can stretch to six hours or more). Actual costs when water has to be purchased by the pot at NRs 3/pot (or USD 4.05/m^3), are not cheap either. Furthermore, the quality of low-end supplies is often more questionable than that of high-end supplies. Only at the highest end of the market, when bottled or pouched water is bought on a regular basis, do the rich pay more for water than the poor do. Even then, the small, 250-ml pouches of water, which the poor are more likely to buy than large bottles of water because they are cheaper per item, cost far more per unit than bottled water does.
6. **The absence of any focus on the sustainability of the resource base.** Water markets are a reaction to scarcity or poor quality, but they do little to address the root causes of either condition. In the absence of any formal regulatory system, water markets do not protect the resource base or control product quality. They simply supply consumers based on their ability or willingness to pay.
7. **The presence of water markets demonstrates a high willingness and**

ability to pay for water in the middle- and upper-income brackets of urban populations. In all three case studies, water from private suppliers costs considerably more than water from municipal piped systems. Except at the low-end, where people pay for water with their time (rather than with cash), urban populations demonstrate a strong willingness and ability to pay far higher rates than those charged by municipal systems. Interestingly, in locations such as Ahmedabad, the demand for better quality water is greater than that for more of it.

8. **No official recognition of the dynamic role the private sector days in meeting urban water needs.** In all three cities, private suppliers meet a significant portion of the demand for water. Except in Chennai, where this issue is beginning to be investigated, the potential role of existing private water markets is not reflected in urban water supply policies or in development planning. Instead, major supply projects such as Melamchi in Kathmandu, Krishna in Chennai and Narmada in Ahmedabad are being designed or implemented to meet urban water demands. These projects will supply water at the same highly subsidised rates now prevalent in urban supply systems. At present most of these subsidies are captured by wealthy and upper-middle classes, the very same classes that have firmly demonstrated their willingness and ability to pay private sources for high quality water. While the poor will benefit from the new sources of supply, the wealthy will still, as in the existing systems reap the greater rewards.

MORE FUNDAMENTAL IMPLICATIONS

Although the urban water markets described in the case studies are dynamic and do address certain types of demand for water, their functioning raises a number of questions related to equity and sustainability and to how well these considerations are reflected in both the way the markets function and the prices of water within them.

Allocation and Equity

The equity of water allocation through market systems, particularly the informal systems outlined above, is a complex question. To begin with, it is important to recognise that existing patterns of water allocation are not equitable. Rights to water, particularly groundwater, are, in all three case study areas, based on rights of capture. Landowners, particularly those who already own wells, in effect have water rights that are limited only by their ability to pump water. From a practical point of view, the question that should be asked of water markets is whether they make the allocation of water more equitable or whether they introduce new patterns of inequity.

One challenge lies in defining equity. On a broad level, equity may be reflected in the value water assumes in its different uses and the number of people that benefit from

TABLE 5

INDICATIVE ESTIMATES FROM CHENNAI

Product	$\$/m^3$	Rs/m^3
Value of rice produced/m^3 of water	0.13	6.00
Value to the consumer of municipal water supplied by the Metro Water Authority	0.003	0.14
Cost to the Metro Water Authority of supplying water	0.34	15.11
Value of water sold by farmers to transporters	0.07	3.15
Value to the consumer of private bulk water deliveries	0.73	33
Value of bulk water deliveries during drought periods as represented by Metro bribes	1.48	67
Value of canned water (at Rs 1.25/litre)	27.78	1,250
Value of bottled water (at Rs 10/litre)	222.22	10,000

those uses. In both Kathmandu and Chennai, the water used by the urban population is taken from agriculture. The two measures of equity involved in such a transfer of water are the population benefited and the relative value water has for the different groups. The case of Chennai is illustrative.

Tables 5 and 6 were constructed using rough calculations and data from the Chennai water market survey. Assuming that irrigating one hectare to a water depth of one-meter yields about three tonnes of rice and that the value of rice is Rs 20/kilogramme, the total value of rice produced is about Rs 6/m^3, not counting other costs. Farmers sell water to urban areas for about half this rate. Given that there are costs other water involved in producing rice, particularly labour, water sales probably generate more income for farmers than growing rice does. At the Rs 0.14/m^3 subsidised rate at which the Metro Water Authority sells water to customers through the piped system, the cost of water is likely to be far lower than the returns from its use, even when this is rice production. This subsidy, which benefits primarily the wealthy portions of the urban population who have direct access to the piped water system, is likely to encourage the allocation of water to uses that have less current value than its use in agriculture. Consumers' willingness to pay for water in bulk deliveries for domestic use, as indicated by the flourishing private tanker business and the bribes paid to water officials, is five to ten times higher than the value of the rice produced with the same amount of water. Overall, except for the highly subsidised supply delivered through the urban system, it is clear that the economic value of water is far greater than in domestic applications in rice production.

The relative value of water in agriculture and in domestic uses can be looked at from another angle—the population whose basic requirements are met. In Chennai, the amount of water that would be supplied through the private tanker market if the wet season delivery rate were sustained throughout the year would be roughly equivalent to

TABLE 6

CONTRASTING WATER USE BETWEEN AGRICULTURE AND DOMESTIC USE BASED ON DIFFERENT LEVELS OF USE IN CHENNAI: INDICATIVE CALCULATIONS

Basis for estimate	**Water use** MLD	Water use: #of hectares irrigated (to 1 m deep/yr)	Rice production when water used in agriculture (Kg rice)	Total value of rice when water used in agriculture $	Population fed per year if each person eats 1 kg	Population whose water needs can be met if water is transferred to domestic use		Ratio people supplied with water: people fed	Value of drinking water at MWA cost*	Ratio value water: value of rice
Private water, rainy months	72	2,628	7,884,000	3,504,000	21,600	360,000	Assuming a 200 LCD use	17	$8,824,240	3
Private water dry months	144	5,256	15,768,000	7,008,000	43,200	720,000	Assuming a 200 LCD use	17	$38,544,000	6
Metro supply-1999	413	15,074.5	45,223,500	20,099,333	123,900	2,736,000	Assuming 60% of Chennai's pop. supplied	22	$223,102,600	11
Total metro req. at 158 LCD	720	26,280	78,840,000	35,040,000	216,000	4,560,000	Assuming all of Chennai's pop. supplied	21	$7,300,584,000	208
Total metro req. at 460 LCD	3,283	119,829.5	359,000,000	159,772,667	984,900	4,560,000	Assuming all of Chennai's pop. supplied	4.6	$266,285,114,900	1,667

**a conservative estimate well below private water market rates* the volume of water required to irrigate 2,600 hectares for that year. If this water were used to produce rice, the rice cultivated would feed about 22,000 people for a year. This same amount of water would meet the basic domestic water needs of 360,000 people—even if each person used as much as 200 LCD, a volume well above survival requirements of say 45 LCD recommended by WHO. Even if urban populations used water at the average rate of 460 LCD recorded in Gandhinagar, Gujarat, the number of people whose basic water needs would be met would still be four or five times the number whose basic food needs would be met by using the same volume of water in agriculture.

Since both water and food are fundamental requirements for survival, there is no question of one water use replacing the other. If water is viewed as the common heritage of all, then it is hard to argue that water transfers from agricultural to urban domestic uses are inherently inequitable. In almost any scenario, the number of people whose basic water needs are met will far exceed the number of people who are displaced from agriculture by such a transfer. The economic value of water is far higher in urban domestic uses than its in agricultural uses. As a result, well owners earn significantly more by selling their water to urban consumers than to farmers. While this situation could be taken to the extreme (leaving no water available on the market for agriculture), water transfers out of agriculture to meet real domestic needs do appear justified in terms of social equity. It is important to recognise that this perspective is based only on the number of people who currently benefit and on the economic returns of the water. It does not consider the potential implications for future generations or the current inequities in benefits or profits to the few who are able to capture and sell a common resource. It also does not take into account any secondary impacts—environmental, cultural or economic (including impacts on, for example, agricultural labourers)—on the water source areas.

There is one segment of the population that loses out in the water market game—low-volume consumers, those with no water storage capacity or in-home access to the municipal piped system. These consumers generally pay the most for their water, both in cash and in time and labour.

Efficiency and Sustainability

In the absence of either a volume-based water rights system or any other enforceable limit on groundwater pumping, the presence of a water market is likely to provide strong incentives for unlimited water extraction. As discussed in the section 'Water Markets and the Value of Water', prices in water markets generally reflect extractive values only and do not include values associated with leaving water in aquifers or streams. This is certainly the case in Ghandhinagar, Kathmandu, and Ahemadabad, where water has a high value relative to the cost of pumping and where there are no restrictions on the quantities extracted that could reflect *in situ* values. As a result, the water markets in these cities are likely to contribute to over-extraction and unsustainable uses of groundwater. It is important to note that in this respect urban water markets are not very different from agricultural uses.

In Tamil Nadu, the electricity consumed to extract groundwater destined for agriculture is free; in Gujarat it is provided at a flat rate based on pump horsepower. As a result, there is no marginal cost associated with irrigation. That cheap energy serves as an incentive to over-extract water has been well documented elsewhere (Moench and Kumar, 1995; World Bank, 1998). At least officially, the power consumed by pumps operated to extract water for sale in domestic use should be paid for. While this cost is relatively low compared to the market price of water, it should discourage excessive pumping when the demand for urban water is low. However, given the high value of water in urban markets, the impact of electricity tariffs is likely to be relatively small. Under current legal and other institutional arrangements, there is little significant difference between the incentive for urban water markets to over-extract groundwater and that for other users to do so. For all users, there is a strong incentive to pump as much as possible and little incentive to conserve.

Although water markets do encourage excessive extraction, because of the high prices charged for water, they also encourage efficient use at the consumer level. No survey has been conducted to contrast water use in homes that benefit from highly-subsidised municipal supplies with that in homes dependent on water purchased from private sources. However, anecdotal evidence indicates that differences in price and availability do have a strong influence on consumption patterns. The highest rates of water use are found in Gandhinagar, Gujarat, where the cost of water is the lowest and supply through the municipal piped system is good. Rooftop rainwater harvesting structures are also becoming common in Gujarat. Harvested water is used for watering gardens, washing clothes and flushing toilets and is used instead of the higher quality and costlier water that is purchased. In Kathmandu, many homes use low quality water from local wells for everything except cooking and drinking. Thus, the high prices established in water markets (or the large amounts of time spent in collecting water) do appear to have a significant impact on consumption patterns, encouraging conservative and efficient use at the household level.

Comparing the functioning of local water markets with large-scale, inter-basin transfers for urban water supply raises a series of interesting questions about equity. If inter-basin transfers, which frequently divert water that would otherwise be used in agriculture or for stream flows, are used to put pressure on municipal systems to deliver water at the current, highly-subsidised rates, urban users would probably receive water at a cost below the opportunity cost of that water in agriculture. This would not motivate them to restrict wasteful practices like neglecting leaks and using high-value, treated water for washing cars and watering gardens, practice which almost certainly underlay the high consumption of water found in Gandhinagar. In addition to encouraging wasteful patterns of use, of inter-basin transfers are inequitable. The World Bank (1998) estimates, for example, that water from the proposed Krishna and Veeranumm projects in Tamil Nadu will cost roughly Rs 45/m^2 (USD 1/m^3). This is far higher than the Rs 3.15/m^3 at which farmers currently sell water to urban dwellers or the Rs 6/m^3 implicit price of water when it is used to produce rice for sale in the market. Since government funds for constructing transfer schemes ultimately come from the population as a whole and, when used for domestic purposes, are unavailable for other social uses, building large transfer schemes is not justified, even when local sources of water are available. The inequity is compounded by the fact that the to local populations in the areas from which water is transferred are rarely compensated adequately.

In sum, current urban water markets play a major role in meeting local water demands and, in compare with major inter-basin transfers, appear relatively equitable, even for low-volume users, who pay more for their water. While unregulated local water markets do provide strong incentives for the development of groundwater overdraft and other unsustainable patterns of use, other aspects of water markets—like overall equity—appear beneficial. Private water sales compensate those who lose access to water (farmers, for example). In contrast, official compensation systems (as are activated in the case of water transfers) are known to be unreliable and often ineffective. Markets also encourage the equitable allocation of water since those who use more pay more and public funds (from subsidies) are not used to support wasteful or low-value uses.

Policy Implications

The case studies and analysis of the impacts of urban water markets on the equity of water allocation and the efficient and sustainable use of water presented in this paper have important implications for urban water management policy.

First, the fact that wealthy consumers with storage capacities and in-house connections to municipal systems almost certainly capture most of the subsidies for municipal water supply in all three locations suggests that such subsidies may be unjustified. Municipal water systems would be more equitable if lower subsidies allowed the systems to expand so that all customers had access to good quality water in sufficient quantity to meet their basic needs.

Second, equitable water access could be improved by ensuring that all customers have access to adequate storage facilities. Programmes that provide water storage containers to lower income households would increase the ability of these households to capture their full share of the public distribution system. It would also increase their ability to purchase water in bulk, which costs less per unit than purchasing small volumes.

Third, equity could be increased by controlling the flow of water through the municipal piped system and by ensuring that all portions of the network are equally serviced while at the same time encouraging the private market to meet only those needs beyond basic requirements. If the public system can deliver sufficient water to meet basic needs (but not more) to all portions of the urban population, then private markets will tend to serve only high-end customers, who will have to pay relatively high rates for the additional water they demand. This would also ensure that poorer households, which often pay the highest prices for water, if not in cash then in time and effort in collecting it, obtain municipal water at the same subsidised rate as the rest of the urban population.

Maintaining effective water markets is problematical in terms of the sustainability of the supply and the lack of quality control. There is, in fact, no guarantee that the water provided is suitable for human consumption. Regulation is needed to ensure that the activity remains sustainable and does not negatively impact other users and to provide a measure of quality control. It is important to recognise, however, that the need for regulation does not necessarily mean that the government must take control. Regulation can, for example, be undertaken through local organisations such as a strengthened version of the Tanker Association in Kathmandu.

If an effective mechanism for regulating water extraction can be developed, there is no need for a new or more thorough system of rights to allow urban water markets to function effectively. While systems of tradable water rights like those in the western US do have advantages, their development is, at best, a long-term process. Current water market structures already enable the reallocation of available supplies from lower-to higher-value uses and, at least in comparison with other forms of urban supply, appear to function in a relatively equitable manner.

BACK TO GLOBAL DEBATES

Global debates over water markets are rooted in economic theory and institutional experiences derived from the Western US and similar locations. Approaches derived from such debates tend to emphasise, as their starting point, the need for water rights reform. Clear water rights that are quantifiable and transferable are seen as a fundamental requirement for the efficient functioning of markets. Viable processes for establishing such rights, particularly in the short- to medium-term, have yet to be identified. Furthermore, analysts focusing on current attempts to reform water rights and establish functioning water markets in other regions of the world point out that water markets are often no more efficient or equitable than the surrounding social contexts. Markets, as Bauer (1998) points out, are influenced by 'many extra-economic factors and prior definitions, such as political decisions, legal rules, cultural attitudes and geographic and environmental conditions.' Attempts to create new water rights and rights-based market systems are, as a result, highly complex; and their results, unpredictable.

The information on informal water markets presented in this paper suggests the value of using an approach which does not involve large-scale institutional reforms. This approach is sequential and starts from an analysis of the existing situation. It focuses on the services water markets currently provide, the impacts (both positive and negative) they have, and the role they could play in meeting water needs on a larger scale. The key criteria for evaluating the functioning of current water markets should include equity. To achieve this end, several questions should be asked:

1. Are there any major third party or environmental impacts associated with water markets as they currently exist?
2. Are relationships across transactions relatively equitable? Are transactions coerced or are market structures skewed in a way that discriminates against the poor or other marginalised populations?
3. Do water markets provide key services in ways that, from a societal perspective, are more or less equitable than alternative avenues of providing the service?

Answering the above questions will result in the identification of relatively closely targeted areas of concern or opportunity. Concerns can then be addressed incrementally through governmental or other forms of action as appropriate. As already mentioned, in the case of urban supply, helping marginalised populations to afford storage for water could greatly reduce the price they pay and, as a result, increase the overall equity of urban water markets. Similarly, urban water supply systems that strictly ration the amounts delivered through piped connections while ensuring that all sections of the community have access to the basic minimum required could greatly increase equity. In this way, all members of the urban population would have access to a basic (and possibly subsidised) minimum supply while those who wish to use more could obtain additional supplies on the market. Environmental and third party impacts could also be addressed through very targeted action (such as pumping restrictions within vulnerable areas) rather than through a much wider process of institutional reform.

At the highest level, the above approach suggests a very different role for the state from that common in most discussions of integrated water management. Rather than viewing the state as the primary implementer or as providing a fully integrated framework for water markets and water management, this approach casts the state and civil society as tinkers. Their role would be to take a 'proactively reactive' stance—to seek out potential problems, respond to constraints, and build off the opportunities which water markets present. When viewed from this perspective, existing informal water markets represent a highly adaptive resource for meeting many local water needs. Whether or not and how they might need to be strengthened, regulated, enhanced or left to function undisturbed will depend heavily on the local context.

NOTES

[1] *Times of India*, Ahmedabad, 11/10/00

[2] The North Gujarat Sustainable Groundwater Management Initiative, A Proposal for Science-Based Coordinated Action, International Water Management Institute-Tata Water Policy Programme, Institute of Rural Management Anand, and Gujarat Ecology Commission.

[3] In 1990-1991, prices encountered in water market surveys for an approximately 10 litres/second flow were frequently Rs 40/hr and occasionally Rs 70/hr. Ten litres/second is equivalent to 36 m^3/hr or roughly Rs 1.1—1.9/m3.

[4] The North Gujarat Sustainable Groundwater Management Initiative, A Proposal for Science-Based Coordinated Action, International Water Management Institute-Tata Water Policy Programme, Institute of Rural Management Anand, and Gujarat Ecology Commission.

[5] This section is based heavily on a field survey conducted by ISET and NWCF in the spring of 2001 and an accompanying report written by Yarrow Moench. Significant portions of this report have been incorporated.

[6] All monetary values in this case study are given in Nepalese rupees—NRs whereas values in the Indian case studies in Indian rupees—Rs—are given.

[7] Gorkhapatra, July 31, 1999

[8] The calculation was done using the Tanker Association's estimate of 80 tanker companies in the Valley with an average of two trucks per company delivering 3.7 trucks loads per day.

[9] The exact level of supply by NWSC is unknown, but during the dry season ranges from 60 to 80 million litres/day with 40 to 70 per cent lost. While the exact contribution of the private market cannot be calculated it is significant.

[10] The sign states charges according to the capacity to transport it, rather than to the specific water quantity taken. A bicycle is charged NRs 10 and a car NRs 20; washing up to seven articles of clothing costs NRs 10; and bathing, NRs 2 per person.

[11] Based on a monthly salarly of NRs 2,500 (not uncommon for women at the lower end of the office spectrum) and a 40-hour work week.

[12] Personal communication, Dinesh Kumar.

[13] Personal communication, Dinesh Kumar.

[14] *The Hindu*, 7 July, 2000

[15] *The Hindu*, 8 August, 2000

[16] *The Hindu*, 8 August, 2000

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STATE IN PERPLEXITY: THE POLITICS OF WATER RIGHTS AND IRRIGATION SYSTEM TURNOVER IN TAMIL NADU

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INTRODUCTION

This paper attempts to trace the history of water rights and water-related laws in Tamil Nadu and their relevance to water resource management in India today. The paper discusses traditional water rights that have been enjoyed by user communities for centuries, their strengths and weaknesses, and how the state of Tamil Nadu appropriated these rights. It also explores problems associated with the state's management of water, the recent attempts to transfer water management functions (effectively water rights) to user communities as part of a 'System Turnover Programme' funded by the World Bank, and the policy implications of these turnover efforts. To this end, the authors present a critical analysis of the Tamil Nadu Farmers' Management of Irrigation Systems Act, 2000. In addition, two case studies—the Palar Anicut System (an ancient irrigation system in the former North Arcot District) and the Parambikulam Aliyar Project (a new irrigation project in Coimbatore District)—are included in the appendices, as a basis for analysing the state's appropriation of water rights and the bureaucratisation of water management.

Before focusing on the situation in Tamil Nadu it is important to place the legal and policy debates occurring in India in the wider context of South Asia to consider the questions of local water management. Debates over water rights and the legal frameworks governing water in South Asia represent the node where disputes and tensions control over water intersect. Tensions and conflicts among individuals, communities and governments, are inherent and stem from the differing perspectives and interests that each brings to specific water issues. Tensions and conflicts are neither unexpected nor necessarily negative. What is important is how laws and legal frameworks enable the tensions and conflicts to be negotiated (see Bruns and Meinzen-Dick, 1998). Ideally, formal institutional frameworks governing water should act as a template which guide society at every level to take action to address water management needs as they emerge and within the socio-economic and

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environmental context of the time. Moench and Dixit (2004) argue that existing institutional frameworks need to be sufficiently flexible to respond to the rapidly changing social context. Most statutory laws and legal frameworks in South Asia countries, however, are static and inflexible. Instead of focusing on basic principles and establishing decision making processes which balance the power of different interest groups, the current legislation tends to be context specific and regulatory. The state is seen as the manager and laws are tools with which to establish points of control over individuals and communities.

The study of water rights, legislation and system turnover in Tamil Nadu documented in this paper demonstrates the flaws in existing legal frameworks. Traditional rights systems and management institutions are in decline. A farmer, who owns a well or a pump has no incentive to help maintain a traditional surface irrigation system. Families who receive remittances from members working in cities or employed in urban non-agricultural occupations no longer depend on their farms as their sole source of food and income, and therefore no longer need to engage in water management. Legal frameworks that attempt to regulate membership in water user associations or specify the details of administrative decision making are not sensitive to social changes such as migration to cities. Requiring that an individual join an organisation for the privilege of using irrigation facilities using once freely provided water supplies is no assurance that he will invest time and energy in water management when other factors have ended dependence on that water.

Current debates over water rights and water-related legislation in Tamil Nadu unfortunately do not transcend beyond the specifics of each law. We believe, however, that effective approaches to water management will emerge only if the legal framework allows groups at all levels of society to take action on the issue affecting them. The transformation must start with an examination of the basic principles of water rights and the processes through which conflicts can be resolved not with focus over details. Focusing on key elements, such as the right and access to information, clear water rights and the legal authority to take action when these are violated would enable local communities to address water problems as they emerge. This type of approach is absent from most legal frameworks in South Asia. Instead, while laws may mandate 'participation' in management or membership in user associations, the ultimate legal controls lie with government agencies. Since the government lacks the ability to enforce these laws, the approach is ineffective whatever one's political or legal philosophy.

The Tamil Nadu Context

Rights over any resource including water are unnecessary and superfluous when that resource is abundant and free. Because some communities experience extreme conditions of flood or drought, some control and community participation is needed to alleviate the associated problems Floods inundate land and homes and, when natural drainage is obstructed waterlogging results, while droughts make it necessary to impose rules for the more efficient and equitable use of scant water supplies. Water has emerged as one of the most important natural resources for us to address in improving living human conditions as the goal of development. Indeed, in recent times, the increasing gap between the demand and supply of water has resulted in several management problems including allocation, maintenance of infrastructure, prioritising water use and the need to resolve conflicts that arise from perceived inequalities in sharing limited supplies.

Conferring water rights on users is an important institutional measure for regulating water use and resolving conflicts. With development of and the associated ever-increasing demands, conditions of scarcity, and the problem of free riders, it has become necessary to consider laws and rights relating to the use of water and other natural resources. Rules and regulations evolve over a long period of time to facilitate interactions among user groups and promote management of water supply systems. They reflect the socio-economic and political structure of society at any given time and they change as the context and requirements changes. Geophysical and climatic conditions, socio-economic and political conditions, and the level of technological advancement influence these changes.

Irrigation institutions were once controlled by kings and local chieftains and reflected the local power structures and production relations of the time. An organised and codified set of rules not only defined access to and control over water for a community, but also governed all the critical functions of water management. Despite their ages and the unequal access to means of production, these institutions successfully protected the rights to water enjoyed by user communities. In the Indian context, while each state clearly has a key role to play in facilitating water use and protecting water rights, colonialism and subsequent formation of a welfare state have altered power relations and contributed to the disintegration of rights over natural resources, particularly water.

In the context of the current water rights debate, it is necessary to distinguish between rights acquired over time (riparian rights) and rights acquired through the simple fact of physical access to the resource. Urban industrialists who gain control over the water resources in a rural area by sinking tubewells into aquifers to a far greater depth than existing village wells or who pollute water bodies by discharging effluents into them and thereby deprive local people of their rights to clean water, are classic examples of how rights acquired forcibly disregard and displace traditional rights. What rights did user communities enjoy in the past? How have these rights, which Singh (1991) calls, 'the right of a welfare state', been appropriated by the state? To what extent can the state follow the principle of equity in making water available to all users? Since corruption is one of the biggest and most prevalent problems in the democratically elected welfare state, how capable is the state of delivering water efficiently? The state takes away people's rights and by making cities and towns bigger by bringing more land under irrigation and thus under its jurisdiction. Are such acquisition justified? Water rights can be seen as a human rights issue, especially in situations in which marginalised people are powerless and cannot seek justice in a court of law. What is the role of the civil society in securing and protecting water rights? All these questions must be debated if progress in undertaking water management is to be made.

TRADITIONAL WATER RIGHTS IN INDIA

Two types of traditional water rights prevail in India: (a) riparian rights and (b) prior appropriation rights. A riparian right is a right vested in the owner of land that is situated adjacent to a river, stream or other watercourse. The right to use the water from such a watercourse is considered natural and was protected as long as the water flowed naturally. It was also written that interference with the natural flow of the water was wrong and that no owner of riparian land was entitled to obstruct a river with a dam unless in emergencies such as floods, and then only if it did not pose a problem for neighbouring landowners. In addition, an upstream riparian landowner had the right to use as much water as he desired as long as his use did not diminish the quantity of water enjoyed by downstream landowners. If a downstream landowner felt that there was any reduction in the flow of water, he could seek a remedy in a court of law. Similarly, a downstream riparian landowner did not have the right to flood upstream lands by building a dam. As for drainage, an upstream riparian landowner had the right to drain water through channels only if it did not affect downstream riparian lands. It must be noted that riparian rights were applicable only to natural watercourses and not to artificial canals or drainage systems.

Riparian rights continue to have relevance today, although their limitations began to be felt the area under state control expanded. To address these shortcomings, the government resorted to administrative measures based on the 'prior appropriation' doctrine, or, the rule of 'first come, first serve.' Under this doctrine, which was later written into law, individual states developed regulations for appropriating water from major water distribution systems. The fact that some states recognised both riparian and prior appropriation rights complicated allocation and the interpretation of water rights. Water rights are based on physical access to water, traditional practices and formal and informal rules governing access by individuals, communities, states and the nation. They also reflect the relative power of individuals and groups to either use water themselves or transfer their water rights.

Riparian, customary or traditional rights are important not just in India but in many parts of the world (FAO, 1979). In England, for instance, the right to use water belongs to the 'occupier' of the land; in Belgium water rights are vested with landowners and can be inherited; in France, Israel and Italy water rights can be bought with a license. In Africa, there are limited rights to water without state intervention: in Benin and Burundi, for example, water rights are generally conferred through certain customs. Mauritius and Kenya provide access to water for domestic use without any formal administrative sanction (FAO, 1979). According to Singh (1991), rights to water existed in the ancient laws in many countries and continue to exist as customary laws today. In general, customary law is based on the principle that land and water belong to the community and cannot be subject to individual rights of ownership or use except by virtue of membership within a community.

The practice of traditional water rights in India

The development of technology for agricultural water use has developed over a period of many centuries and its history runs parallel to that of human settlement patterns and the creation of village societies (Steward, 1955). Water rights were gained or acquired over a very long period of time. These traditional rights were recognised very early on by Hindu law and later by the British government in India. Although they varied from state to state, they did have some common ground, including community rights and informal arrangements. According to Singh, (1991) traditional rights had many advantages over statutory rights: "Customary law has been dynamic more in tune with the needs of the people than dogmatic about certain fixed notions of territoriality or ownership right. Limitless to space and quality, they are broader in approach than the legal systems."

The Easement Act of 1832 recognised the customary rights of the people of India and were legally entitled them to tap water flowing through an upper plot or another person's land (*ibid*). This Act, however, applied only to surface water and not to groundwater.

Traditional water rights in Tamil Nadu

In Tamil Nadu, particularly with respect to traditional tanks (large, ground-level water storage tanks) and traditional canal irrigated areas, water rights are ancient. These traditional rights, known locally as *mamulnamas*, were codified by the British in 1813. Historically, the community of water users undertook all the critical functions of water management, including the construction of small diversion weirs and canal networks. User communities in canal-irrigated villages were called *samudhayam*, and those in dry villages or villages whose only water source was tanks, *nadu*. The water rights enjoyed by these communities were acquired by working to construct and maintain infrastructure (sluices, canals etc.). Traditional water institutions involved two levels of people: The first, an honorary position known as *kavaimaniyam*, *nattamai* or *karaikarar*, played a supervisory role and enforced management rules. The second, known as *neerkatti*, *neerpaichi*, *kambakkaran* or *kammukkutti*, consisted of menial workers who performed hard labour. At the end of every season or year the labourers were paid in kind by the community. In many parts of the country, these positions were held on a hereditary basis.

Traditional irrigation systems were based on the right to water and other natural resources enjoyed by village societies and each community had complete control over the resources within its jurisdiction. These systems functioned smoothly. They had clear rules of management, such as system maintenance: water sharing, especially in times of scarcity; conflict resolution; and in collection of penalties for not participating in maintenance work. A hierarchy of functionaries undertook all these activities, and the caste system played a crucial role in allocating and preserving responsibilities. For instance, high caste farmers hold the position of canal manager while scheduled (lower working) caste hold the position of irrigation worker.

THE DECLINE OF THE KUDIMARAMATH SYSTEM AND ATTEMPTS TO REVIVE IT UNDER BRITISH RULE

Voluntary community labour for maintaining water systems, called *kudimaramath*, worked well until the advent of British rule. The British government was quick to recognise local customs and conventions and people's water rights; indeed, it tried to protect people's traditional rights through legal provisions. While carrying out village settlements in different parts of the country after the middle of 19th century, for instance, it paid particular attention to the *kudimaramath* system and its associated rules and regulations for water management. After that, however, the system began to decline. The 1852 Report of the Public Works Commission stated that there was little voluntary community labour and that labour was more or less forced in most districts (Raju, 1942). The decline was mainly attributed to the disintegration of village society and the repressive land tax imposed by the British. The 1901 Irrigation Commission identified factions, absentee landlordism and the decline in power of village headmen as reasons for the decline of the *kudimaramath* system.

Convinced of the importance of maintaining the *kudimaramath* system and fearing it would have to assume a heavy financial burden for the maintenance of irrigation systems without it, the British took steps to revive *kudimaramath*. In Madras Presidency (now Tamil Nadu), they resorted to legal measures whose first attempt was made in 1855, when then collector of Thanjavur, a district in the Madras Presidency prepared an irrigation bill decreed to prevent willful damage to irrigation structures. The Board of Revenue, however, rejected it on the grounds that it was not comprehensive. The next attempt was made in 1858, with the passage of the Madras Compulsory Labour Act. This act mandated compulsory labour for certain aspects of maintenance and included a provision for penalising those who did not comply, but this did not result in any improvements. Indeed the very principle underlying voluntary community labour was lost with its ratification. Not only were traditional irrigation systems decaying but, at the same time, the government failed to provide relief measures during the successive famines of the latter part of the 19th century. Because of so many people migrated to countries such as Sri Lanka, Burma, Malaysia, Singapore and Africa to escape the famine, the government was unable to mobilise the voluntary labour to perform the necessary activities

New legislation to revive the irrigation system was recommended by the Famine Commission of 1878 and the Irrigation Commission of 1901 (Baliga, 1960). In response, the government appointed a committee to study the *kudimaramath* and irrigation systems. Based on its recommendations a draft bill was prepared an in 1906 approved by the government, soon it faced serious criticism: it was strongly opposed by the public on the grounds that it was overly stringent and gave too much power to canal officers, and eventually dropped.

APPROPRIATION OF PEOPLE'S RIGHTS BY THE GOVERNMENT

The need for effective legislation on irrigation and water rights is dire. There were a number of court cases over irrigation issues against the government and most were decided in favour of the farmers: 'The landholders began to claim not only the river and streambeds but also the usufruct of the water, and the courts conceded these rights making it impossible for the government to regulate irrigation' (Baliga, 1960). The Irrigation Bill was passed in 1906, which sought to define the government's rights to regulate the collection, retention and distribution of water and was revised in 1911 and again in 1914 to make it more comprehensive. The government's main objection was with regard to the Bill's elaborate procedures for inviting comments from *ryots* (tenant farmers) while planning the construction of irrigation systems. It opposed mentioning that compensation was payable in case of crop failure. The Madras Land Holder's Association also opposed the bill on the grounds that it interfered with the rights of landowners and water users. After yet more revisions the bill was brought up for discussion in 1922 and 1924. In 1924, the bill was revised mainly to take care of problems created by new judgments of the courts and to deal with new issues such as water rates, *kudimaramath* and irrigation *panchayats* (councils). Though comprehensive it was rejected by the legislature on the grounds that it interfered with the rights of *zamindars* (landlords) and tenant farmers and that too much power was given to irrigation officers. The British Government of India appointed another committee to prepare a new Bill, which was passed in 1927. When the government proposed amending fixed water rates—fearing a decline in public revenue the legislative council rejected its suggestions and the Bill was never ratified. In 1930, the Madras Irrigation Cess Act which mandated a water cess (tax) on irrigation water was prepared but this bill did not even make it in the to the legislative council because it was not seen as comprehensive enough. In addition, it did not clearly specify the rights of landholders.

All subsequent attempts by the British government to pass acts between 1930 and 1946 failed though some specific acts were passed. They included the (1) Madras Compulsory Labour (Amendment) Act of 1935; (2) the Madras Irrigation Cess (Amendment) Acts of 1945; (3) Madras Irrigation (Voluntary Cess) Act of 1942; and (4) the Madras Irrigation Works (Repairs, Improvement and Construction) Acts of 1934 and 1945.

The objective of Compulsory Labour (Amendment) Act was to demand from *ryots* not only labour but also materials, such as earth, stone and gunny-sacks necessary for emergency repairs. The Irrigation Cess (Amendment) Act levied a higher cess on irregular irrigation and imposed an additional cess on land belonging to *zamindars* and *enamdars* (holders of grant land). The Irrigation (Voluntary Cess) Act enforced the *Kudimaramath* system; instead of making labour mandatory, the act mandated that landholder pay a cess equivalent to the labour required for an irrigation structure. The Irrigation Works (Repairs, Improvement and Construction) Acts allowed the government establish private irrigation works, supply farmers from these sources and levy charges for the water. These acts, all of which are still in effect today, are clear cases that the state has not only appropriated water rights but also exploited their material resources. In any case, despite all these legislative measures, the government never achieved success in reviving the *kudimaramath* system.

Since all previous attempts had failed, the government tried other methods to control irrigation including the issuance of a number of Government Orders (GOs). One GO dealt with the formation of irrigation *panchayats* in villages whose sources of water were channels or tanks. Depending on their location, these *panchayats* experienced differing degrees of success (Rajagopal, 1991).

IRRIGATION LEGISLATIONS AND CHANGES IN WATER POLICIES AFTER INDEPENDENCE

The Irrigation Bill of 1947

In 1947, the national government prepared a new irrigation bill along the lines of the Bill of 1924. It declared that water was the property of the state and that it had the right to control irrigation works under both *zamindari* (private) and *ryotwari* (government) systems. It also stated that no civil court had the power to prevent the government from undertaking any irrigation project and included several provisions related to *kudimaramath*, irrigation *panchayats* and water taxes. Though the Irrigation Bill of 1947 was not passed, other acts relating to irrigation were: the Malabar Irrigation Works (Construction and Levy of Cess) Act of 1947, the Madras Estates (Abolition and Conversion into *ryotwari*) Act of 1948 and the Irrigation Tanks Improvement Act of 1949. Later irrigation bills prepared in 1950 and

1953 were based on these acts. The Irrigation Bill of 1953 was meant to 'define and amend the law relating to irrigation and the levy of water cess', but it was never passed.

Acts regarding specific irrigation projects to be carried out under the Major and Medium Irrigation Programme under as part of India's National Plans were also ratified. The Mettur Irrigation Canal Cess Act of 1953, and the Parambikulam-Aliyar Project Act of 1994 are two examples. Other more general legislation like the Tamil Nadu Betterment Levy Act of 1955 and the Tamil Nadu Field Bothis Act of 1969 also became law.

Between 1960 and 1980, many amendments to these acts were made, but none provided an integrated management plan covering all aspects of irrigation. Below is a review taken from the Institute of Water Studies (1997) of some of the important provisions of these acts.

The provisions of irrigation acts in Tamil Nadu, 1865 to 1984

Tamil Nadu Irrigation Cess Act, of 1865, modified in 1980: This Act declared that the state had the right to charge for water in order to recover the enormous costs it had incurred in order to provide irrigation and drainage infrastructure for the benefit of a large proportion of farmers in Tamil Nadu, including tenants. Water cess arrears were to be collected as land revenue arrears, and to cover not only *ryothwari* but also *zamindari* lands. This is the first act that imposed a charge on water and became the basis for water pricing in Tamil Nadu. It laid down the foundation for the differential pricing of water based on the duration of water supply and the dependability of the irrigation source.

Tamil Nadu River Conservancy Act of 1884, amended in 1969: The River Conservancy Act, which was based on the North Indian Drainage Act and the Bengal Irrigation Act, provided canal officers with wide ranging powers to inspect, regulate, and levy charges for canal water supplies and to oversee repairs and activities such as the clearing of obstructions and the closing of channels. Rates were to be established at periodic reviews by the government. Where deemed necessary, the act also gave canal officers the power to acquire land from farmers and to settle disputes. Farmers were obliged to maintain watercourses in the best possible condition and to use them only for their intended purposes. The act also included provisions for paying compensation in case the state failed to supply water and for imposing penalties for the violation of any state rule or regulation.

Periyar Irrigation Tanks Preservation Act, 1933: Although in theory the *kudimaramath* system works well, there were practical problems associated with securing traditional voluntary labour contributions. The Periyar Irrigation Tanks Preservation Act, which was designed to preserve tanks that were in good working order, dispensed with *kudimaramath* and instead empowered district collectors to requisition labour from farmers as required for tank maintenance. The collectors had the power to employ whatever measures were necessary for carrying out repairs as well as to determine their cost, and, in times of emergency, could circumvent normal procedural channels to do so. Every landowner was required to pay an amount equivalent to one half of the average of their agricultural production from their lands assessed over three preceding years. This money was collected as land revenue arrears.

Tamil Nadu Irrigation Voluntary Cess Act, 1942: The Tamil Nadu Irrigation Voluntary Cess Act was created to replace the abolished *kudimaramath* system of voluntary labour using cess levied to generate funds for irrigation infrastructure maintenance. In contrast to the Periyar Irrigation Cess Act, which made payments compulsory, the cess levied under this act was a voluntary cash contribution. The state could levy an annual cess *if* two thirds of the farmers in the area in question agreed to it. The funds collected were utilised for annual maintenance repairs.

Tamil Nadu Irrigation Works (Repairs, Improvement and Construction) Act of 1943: The Irrigation Works Act was designed for carrying out repairs on *zamindari* land and private irrigation sources where maintenance had been neglected and food production affected. This Act entitled tenant farmers to require landowners to maintain the irrigation systems on their land. If a landowner did not comply, the government could carry out the work and charge the landowner. To assist landowners financially, the act entitled them to take loans from the government under the Land Improvement Act and to increase the rents, which tenants farming their land had to pay. If private irrigation sources went dry, the government could supply water and charge a fixed rate. In practice this act was ineffective, as tenant farmers could not force landowners to carry out maintenance works.

The 1945 amendment to this act lays down the principles of cost sharing for repairs and maintenance between the government and owners of private irrigation sources: the government would contribute not more than not four per cent of the incremental income from such improvements and only if they were carried out by the government. Heretofore, the entire cost of maintenance was borne by the owner, or *zamindar*, even if the works carried out also benefited *ryotwari* lands.

Tamil Nadu Irrigation Tanks (Improvement) Act of 1949: The Irrigation Tanks Act was passed with a view to preventing the deteriorating conditions that had resulted from declines in the command areas (the area irrigated by a tank) effectively irrigated. The act entitled the government to increase tank capacity on any type of lands, *zamindari*, *enamdari* or *ryotwari*. It also entitled the government to recover costs prescribed by the collector and provided for paying compensation to anyone displaced or otherwise negatively affected through the increases in tank capacity.

Tamil Nadu Irrigation Levy Betterment Contribution Act of 1955: Many irrigation projects have been taken up since independence as a part of the states' overall agricultural development strategy. The Irrigation Levy Betterment Contribution Act provides for capital investment recovery from these projects: beneficiaries are required to contribute financially to the government. In practice, however, because the state does not want to collect funds from farmers for political reasons even if it would recover investment costs, this act is ineffective.

Tamil Nadu Panchayat Act of 1958, amended in 1997: This act authorised *panchayats* to construct and repair minor irrigation schemes under *panchayat* control. It allowed for a cess to be levied on irrigated land, which as it categorised. six times the area of non-irrigated land, became a major sources of funding for local councils. Taxes collected from irrigated lands were not, however, used for their intended purpose of irrigation system maintenance.

Tamil Nadu Irrigation Works (Construction of Field Bothies) Act of 1959: In 1959 though many irrigation schemes had been built in Tamil Nadu, the total command area initially envisioned in governmental analyses of irrigation potential had still not been achieved. One main reason for this shortfall was the lack of field channels to convey water from distributary canals. The problem was that small distribution channels had to be dug through private fields, and farmers did not cooperate. The Irrigation Works Act facilitated such construction. Under this act, district collectors could require landowners to construct or improve field channels at their own expense. It also prohibited anyone from obstructing the flow of water in a field channel once it was constructed. Once again, there was little chance of enforcing this act it made no provision for imposing penalties under non-compliance.

Tamil Nadu Land Improvement Act of 1959: The Land Improvement Act is comprehensive as it covers the execution of conservation and improvement work on soil, groundwater and surface water in any part of the state. It makes provisions for institutionalising government drought and flood relief measures and for carrying out wasteland reclamation. For this purpose the act recommends creating boards at different levels state, district and river valley catchment.

Tamil Nadu Additional Assessment and Additional Water Cess Act of 1963: Water cesses in Tamil Nadu were originally fixed around 1865 when surveys and land settlements were carried out. No revisions in water charges were made in Tamil Nadu (although many other states had done so) until 1963, when a new assessment was made for wetlands and additional cesses of up to 50 per cent over the basic water cess were levied on dry lands. This act paved the way for significant increases in irrigation revenue.

Compendium of Rules and Regulations of 1984: Part I- Water Regulations; Part II- Flood Regulations: This compendium contains legislation regulating water distribution and flood control under different types of irrigation projects in Tamil Nadu. It defines the responsibilities of officials of various ranks in regulating irrigation water and specifies dates of sluice openings and closures and other technical parameters.

Standing Orders of the Board of Revenue: The Board of Revenue in Tamil Nadu prescribes basic and additional water rates for different categories of land (classified according to the duration of water supply: six types). The board requires new users to obtain permission from the government before land can be used for non-agricultural purposes.

All the legislative measures outlined above were motivated by the need to operate the irrigation systems in way that would raise revenues. There were no attempts to create comprehensive legislation which would lead to better management of the irrigation systems in the context of changing agricultural practices and water needs or involvement of water users in management.

Attempts to pass a comprehensive irrigation act

Like Tamil Nadu, many other states in India had a number of acts relating to different aspects of irrigation, but none had a comprehensive act. The plethora of acts created problems for attempts to improve management and to resolve conflicts quickly. The Irrigation Commission of 1972 aimed to address this shortcoming. It recommended that all irrigation acts be consolidated and simplified into one piece of legislation to be applied uniformly throughout a state or a even region. In 1977, the Indian Law Institute prepared a comprehensive Model Irrigation Bill and a special committee was created to examine it. The Bill was also circulated to all Indian states for their comment. The Tamil Nadu government gave it scant attention. In 1989, under the UNDP supported Water Resources Management Studies project the Tamil Nadu government, Institute of Water Studies, and the Public Works Department, made an attempt to prepare an irrigation bill along the lines of the one drafted by the Indian Law Institute.

Salient features of the draft Tamil Nadu Water Resources Act of 1989

In 1989, the Tamil Nadu government drafted a Water Resources Act whose purpose was to grant the state greater control over water resources, particularly their allocation and regulation; to promote equity in water use; to maintain a water resources database; to legalise and promote the conjunctive use of surface and groundwater; and to institute strict quality control measures.

Article 2 states that "existing water legislation is piecemeal and inadequate to address the increasing demand for limited water resources in the State of Tamil Nadu; that water for municipal, domestic, irrigation, power, industrial and related uses is vital to the maintenance and development of the State of Tamil Nadu" (IWS, 1989). The objective of the Act states unambiguously that all water resources are the property of the state and that the state is obliged to ensure the efficient, effective and equitable development of water among various users. In Article 4 the act also recognises and promises to protect all existing water rights: "It is the responsibility and authority of the Government in the public interest and benefit to develop, allocate, reallocate, distribute, manage, control, regulate and administer the water resources of the State, in all forms, whether atmospheric, surface or underground, including its use, reuse and drainage therefrom, according to the objectives, policies and principles of this act; except that the Government must recognise, preserve and protect existing water rights to the use of water subject to necessary control and regulation in the public interest according to the extent of actual and beneficial use' (IWS, 1989). Unlike all earlier bills this act also has a provision for regulating groundwater extraction. For the first time, an act recognised the need to monitor not only quantity but also water quality in the various river basins of Tamil Nadu: 'The State shall assess and monitor the quality of surface and groundwater, establish water quality and discharge standards, and develop plans and programmes for the improvement and prevention of water pollution' (IWS, 1989).

The Act prioritises the use of water, surface or groundwater, among different sectors during times of scarcity. First priority goes to domestic and municipal use (especially for drinking), followed by agricultural, energy, and industrial/commercial uses in that order. Several measures are proposed with a view to regulating groundwater use: requiring a permit from the Public Works Department to extract groundwater, promoting the conjunctive use of surface and groundwater, and adopting artificial recharge measures wherever necessary. The Act proposes implementing a more uniform, systematic and equitable means of cost recovery and cost sharing that involves the participation of water users in the construction, operation and maintenance of systems. The Act acknowledges that existing laws relating to water pollution fail to address how to maintain water quality at the source and suggests the forming of river basin authorities through which the Tamil Nadu Pollution Control Board as well as other state agencies could work.

The Water Resources Act further attempts to involve water users in the development and management of water resources. It requires the creation of a Water Users' Association (WUA), whose main purpose would be the operation, maintenance, improvement and rehabilitation of canal networks within a command area, to improve water supply conditions and to resolve disputes. The modalities for the formation of the association and its functions are clearly defined, and the active involvement of its members mandated.

A draft of this Act was circulated to all the states in the country for comment. Though it contained many important provisions, it did not receive much attention from the Tamil Nadu Government and was not passed by the legislative assembly.

FARMERS' PARTICIPATION IN IRRIGATION MANAGEMENT AND THE TURNOVER OF PUBLIC IRRIGATION SYSTEMS

Since the early 1990s, when the World Bank funded Water Resources Consolidation (WRCP) project began, there has been a significant shift in the governance of irrigation projects. The Tamil Nadu Government, for example, began to emphasise the participation of farmers in water management: in November 1994, it issued an order to this effect. The order, however, did not have legal sanction, although it might have been considered valid by judicial authorities (Raju, 1994). Farmers' participation has, in any case, emerged as a major theme in some irrigation development projects. Part of the funding for the WRC project was, for example, used to renovate major surface irrigation systems and turn them over to farmers to manage. The Farmers' Organisation and Turnover (FOT) programme, a component of WRC project has been given much importance. The main objective of the FOT programme is to shift the responsibility for maintenance and water distribution to farmers' organisations, or WUAs which have a command area of about 500 hectares. However, because of legal and other constraints, the formation of WUAs was always delayed. The World Bank therefore recommended legislation modelled on the Andhra Pradesh Farmers' Management of Irrigation Act, which makes the membership of the farmers within a water users' area delineated by the district collector compulsory. All landholders within a water users' area automatically become members of the WUA. There are three categories of associations within each area: a pipe committee at the outlet level, a farmers' council at the distributary level and an apex body at the project level. Elections, which are supervised by the district collector, are held within each association to elect the president and members of a managing committee for a normal tenure of five years. WUAs have the power to levy, collect and share water charges. To meet the costs of system maintenance, WUAs are given financial assistance in the form of state grants (Jayaraj 1998). The Tamil Nadu Government has announced plans for drafting an act modelled on the Andhra Pradesh Act.

Salient provisions of the Tamil Nadu farmers' management of irrigation systems Act of 2000

The purpose of the this Act is "to promote and secure distribution of water among its users, adequate maintenance of the irrigation systems, efficient and economical utilisation of water to optimise agricultural production by involving the farmers and inculcating a sense of ownership of the irrigation systems in these in accordance with the water budget and the operational plan' (Government of Tamil Nadu, 2000). The Act mandates that all farmers within an irrigation system who use that system become members of the WUA. Section 3, Clause 1, states that in order to form the WUA, the district collector has the power to delineate the area to be covered by the WUA. All landholders or cultivating tenants within that area automatically become members of the association.

Every WUA area is further divided into four to ten territorial constituencies. One of the important clauses of the Act is that if a farmer who owns land in more than one constituency within a single WUA is entitled to be a member of only one constituency of his choosing. This is crucial in preventing wealthy landowners from gaining too much power and influencing the activities of the WUA. The elected president and managing committee of a WUA represent all the component constituencies.

Two or more WUAs form a distributary committee and the presidents of all WUAs become *ex officio* members of this committees. Every distributary committee has a managing committee consisting of a president and no more than five members.

The government has the power to declare every command area, or part thereof, of an irrigation system and declare it a project area. A project committee is constituted for every project area. The president of every distributary committee in a project area is *ex officio* member of the project committee. A managing committee of the project committee consists of a president and no more than nine members elected from among the project committee members. Finally, the government may constitute an apex committee, with a chairman and a number of members elected by the government and with powers prescribed by the government. The purpose of the apex committee is to lay down the policies and guidelines for the implementation of the Farmers Management of Irrigation System Act for their respective area. This committee also has the final say in setting disputes amongst WUA members.

A motion for the recall of a president or any member of any farmers' organisation may be made by giving written notice signed by not less than one-third of all the members of the respective WUA.

The Main Functions of a Farmers' Organisation

The following are some of the functions of a WUA is required to perform:

- Planning and implementing a rotational water supply system;
- Maintaining the entire irrigation system, from the distribution source to the field channels;
- Promoting economy of water use;
- Assisting revenue authorities in collecting charges;

- Maintaining a register of water users;
- Maintaining an inventory database of the irrigation system;
- Removing encroachments on canals, drains and tank *poromboke* (a specific designation for public land);
- Resolving disputes among association members;
- Fundraising.

Distributary committees and project committees have certain prescribed functions. Most of these relate to the preparation of an operational plan based on entitlement, area, soil type and cropping pattern. They are also required to ensure the proper maintenance of the canal network, the equitable distribution of water among association users, the collection of charges and promotion of the economy and efficiency of water use.

Sources of Funding for WUAs: The Farmers' Management of Irrigation System empowers WUAs to levy and collect fees not exceeding Rs 500 per hectare per year from every water user. In addition, WUAs have access to other sources of funding such as annual and other grants from the state and central governments, financing agencies, capital income from the organisation's assets and donations. Funds raised must be deposited in a national or cooperative bank and the managing committee must maintain a sinking fund to facilitate the repayment of borrowed funds.

Government's Control over WUAs: Under the Act, the government must appoint officers from the Irrigation Department to implement decisions made by the managing committee. These officers have the power to direct all irrigation projects entrusted to them within the purview of the act: "Every farmers' organisation shall extend such cooperation or assistance, as may be required by the competent authority, and follow such directions or instructions as may be issued by the competent authority, from time to time, for carrying out the purposes of this Act."

The government can, if deemed necessary, appoint a commissioner to supervise and direct officers and collectors and to command specific actions from the officers or farmers' associations.

Settlement of Disputes; Offences and Penalties: The respective managing committee of each committee within a WUA settles disputes. Should its decision be appealed, the issue can be taken to the apex committee, whose decision is final. All appeals must be settled within fifteen days.

Violators of the Act may be imprisoned up to two years and/or fined of up to five thousand rupees. Furthermore, Article 39 states that money due to a farmers' organisation may be recovered as land revenue arrears and that under the Tamil Nadu Revenue Recovery Act of 1864 the Irrigation Department is entitled to collect that money.

Evaluation of the Tamil Nadu Farmers' Management of Irrigation Systems Act, 2000

For the first time in the history of irrigation legislation in Tamil Nadu, the Farmers' Management of Irrigation Systems Act provides a legal framework for encouraging and enabling the participation of all farmers from every level to participate in water management. Collective participation is facilitated through the formation of WUAs, which are free to dictate the maintenance and distribution requirements of their own irrigation systems. Each WUA can vote on how best to utilise government grants allocated to it. It has legal authority to levy and collect additional water charges to boost its financial positions and its respective apex committees has the final say in settling disputes, without necessitating the intervention of the courts.

A major breakthrough is that members of a WUA have the power to recall any committee member. This ensures that each elected committee member is accountable for his actions and is a strong deterrent to mismanagement. It also prevents the government from exerting its power over managing committees, as it can be over many other organisations such as cooperatives and *panchayats*.

Finally, after many failed attempts by the British colonial government to organise farmers to carry out maintenance work, Tamil Nadu finally has a comprehensive act which provides the framework to ensure the smooth management of irrigation systems. The Act brings water users together under organisations designed to make collaborative irrigation management efforts more efficient and effective. Although it is strong in some measures, it still grants too much power to the bureaucracy and leaves too much open to the government's will.

Traditional irrigation institutions were once strong and efficient, but for a variety of historical reasons were fractured and fragmented. The reasons for their disintegration should be understood before attempting to introduce new organisational measures in order to ensure that those new measures will work in the long term.

Traditional irrigation institutions, which evolved over a long period of time and exist in many canal— and tank-irrigated areas, are characterised by a variety of social arrangements and responsibilities. The technology of water use for agriculture developed over several centuries and evolved with the changing patterns of human settlement and societal structure (Basu, 2000). As Ullmann-Margalit (1977) quoted in Basu (2000) claim: "Norms as a rule do not come into existence at a definite point of time, nor are they the result of a manageable number of identifiable acts. They are, rather, the resultant of complex patterns of behaviour of a large number of people over a protracted period of time." It therefore follows that the success of an irrigation institution depends on the active participation of the members of a village or other societal unit, that participation only comes about voluntarily, and that success results from a sense of ownership and returns from investment.

Due to socio-economic, technological and/or institutional reasons traditional irrigation institutions are today either decaying or defunct.[1] Attempts to mandate the formation of the water user associations do not work because such groups must be voluntary and initiated at the grassroots level. This said, traditional irrigation institutions do still function to a reasonable degree in many parts of the state and country. How effective would it be to impose new, mandatory institutional arrangements over existing traditional ones? Is it ethical to alter norms and institutionalised practices that have evolved over long periods of time? These are questions that ought to be addressed before WUAs are mandated.

The Farmers' Management of Irrigation Systems Act governs water users in a village society. Users are required to be a member of their WUA and to pay membership fees. If a farmer owns a well, however,—and many do—he is not entitled to participate in any collective action. There is no cost to the well owner to pump water as, in most of India, the energy used for pumping groundwater is fully subsidised by the state. According to the Act 'every WUA shall consist of all the water users in such water users' association area as members' (Section 4.2). This conceives of users in a limited sense. If we are to understand that a WUA includes only persons who either cultivate or own land, the Act discriminates against other members of the village for whom water has traditionally had equal access to water. Furthermore, the Act excludes the landless from becoming members of a WUA and having any say in management decisions.

Certain sections of the Act are ambiguous and leave much open to *ad hoc* decisions. Section 12, for example, empowers the government to constitute an apex committee, which is to have overall control over WUAs. Who the constituent members of this committee may be, however, is not clear. Are members of a WUA of a Water Resources Organisation (WRO) or of some other institution? The answer is important because the apex committee makes most final decisions and settlements of dispute, and its members will influence the committee's decisions and might even undermine the strength and autonomy of WUAs. If, for example, the members of the apex committee are nominated from political parties, as is currently the case for cooperatives, the possibility for the misuse of power in favour of ruling parties is high.

Section 26 of the Act designates personnel from the WRO of the Public Works Department of Tamil Nadu as the competent authorities for implementing the decisions of a farmers' organisation, but, again, their exact role and powers are unclear. It only specifies that farmers' organisations must follow the directions given by these authorities. Section 46 (2) also empowers the government to issue orders regarding the powers of the competent authorities and requires farmers' organisation to comply with them: "The Government may issue such orders and directions of a general character as they may consider necessary in respect of any matter relating to the powers and duties of the competent authority and the farmers' organisation shall give effect to such orders and directions." Such sweeping authority may result in the misuse of power and would defeat the purpose of empowering water users in the first place. The subservience of WUAs to other institutions (the WRO, for example) is precisely the situation that prevailed before this act, which itself does little to protect water users from a system of water management dictated by the bureaucracy. The 'turning over' provision in this Act in effect has little meaning.

One of the most significant omissions in the Act is that it overlooks the presence of wells within a WUA area. As mentioned earlier, access to a well and thus to a private source of irrigation water can be a big disincentive for a farmer to take active interest in a WUA. Because of this, the greater the number of wells in an area, the less effective collective action in a WUA will be. In addition, the main thrust of the 73rd Amendment to the Panchayat Raj Act is to strengthen a democratically elected government, which should represent all sections of society, including village populations. The formation of a WUA under the Farmers' Management of Irrigation Systems Act, however, runs counter to this amendment.

STATE WATER POLICY REGARDING WATER RIGHTS

So far, this paper has discussed the evolution of Tamil Nadu State legislative measures governing water and water rights but has not addressed Tamil Nadu's water policy itself. It is interesting to note that Tamil Nadu did not have a policy for the coordinated development of water resources until, at the insistence of the Government of India and the World Bank, it drafted its own water policy in 1994. Until that time, most of the activities of the state had been undertaken on an *ad hoc* basis; the severity of the looming water crisis was not foreseen (Government of Tamil Nadu, 1994). Some of the goals of the state water policy are to establish a management information system for water resources, to give drinking water top priority, to provide adequate water for industries, to maintain water quality, to promote equity and social justice, to promote users' participation in water management and to provide a mechanism for resolving conflicts among users and between river basins within the state. The state's water policy goals have been as follows:

- Efficient management of watersheds to minimise sedimentation
- Removal and prevention of encroachment in water courses and bodies
- Restoration of the capacities of existing water bodies.
- Modernisation of physical systems
- Minimisation of transmission loss
- Minimisation of evaporation loss

- Adoption of modern irrigation methods
- Planning of water recycling and reuse
- Minimisation of pipeline leakage in drinking water systems
- Artificial recharge of groundwater
- Interlinking river basins within the state
- Planning cloud seeding
- Rainwater harvesting
- Desalination techniques

As can be seen, the state policies for water resource development goals are almost entirely technical; there is little community orientation whatsoever. Furthermore, the explanatory note to the policy offers details about the methods of achieving these goals but makes no mention of people's rights in water resource development. This again points to the trend, noted earlier, that people's traditional water rights are being appropriated by the state. Though the policy statement does mention farmers' participation in irrigation management, it does not define their water rights. Water resource systems are generally identified with those who have land, while the landless are ignored and excluded. Moreover, the extent of users' participation is limited to the operation and maintenance of systems at the local level only; there is no provision for the involvement of communities in system design and construction. This oversights demand a thorough review.

ANALYSIS

The foregoing discussion demonstrates that, in its initiatives to manage water resources, the state initially appropriated people's water rights and later tried, at least some how to turn those rights back over to the people. It is ironic that all governmental efforts were legal and though the state called for 'participatory irrigation management' none of its management efforts included a single user. Furthermore, the state's decision to turn over the management of irrigation systems to water users was not a 'spontaneous accomplishment', but came at the insistence of the World Bank. As part of the World Bank-funded WRC project, which includes FOT programme, the Tamil Nadu Government borrowed Rs 12 billion. The implementation of the FOT programme is currently in the initial stages. The state has resolved to turn over the management of irrigation systems to the people, although the current state of management is burdened with problems such as complete deviation from the original operational rules, gross mismatch between water supply and demand, low financial recovery rates, few resources available for operation and maintenance, corruption at all levels, and fragmented community action. In addition, the fact that substantial repair works has been neglected and thereby has accumulated over time has paralysed irrigation within many systems. It is not clear how effective the improvement works undertaken under the World Bank programme will be in solving the entrenched problem of neglect.

The substantive question is how the state can impose a non functioning or a malfunctioning irrigation system on the people. If the state does impose such a turnover through law, to what extent will the people accept it and what kind of collective action can be expected? Heretofore, the state was more interested in financial savings, either by reducing maintenance expenditures or by improving the financial outcomes of irrigation projects than in effective management.

The provisions in most acts passed by the government were regulatory in nature and related to specific operations and management. For a long time, the state played a major role in regulating water management and made no allowance for participation of the users. Despite the recent attempts to promote their participation, the new acts are not comprehensive. Moreover, there is no scope for involving farmers in the planning, design and formulation stage of an irrigation system. Existing rules and regulations concerning irrigation systems are managerial in nature (Raju, 1994). One important point is that by intertwining water and land rights the Acts pose problems of equity and social justice since they excludes the landless from direct access to and control over water.

There is a tendency to glorify traditional practices of all kinds, including traditional irrigation practices. In the past, farmers contributed to critical aspects of water management through spontaneous community action. However, those who support the revival of traditional systems fail to acknowledge their weaknesses and fail to understand that since significant overall development changes that have taken place and are occurring in the countryside the socio-economic context will no longer permit traditional irrigation systems to function the way they once did. The irrigation institutions of the past, for example, had clear social and economic hierarchies and, for that reason, the question of equitable water sharing did not come. They did not have democratic norms to appoint irrigation functionaries and though all decisions were made locally, canal managers made the final decisions. Even if these blatantly, undemocratic features could be altered the revival of traditional irrigation institutions itself would not be easy. Many factors have contributed to the disintegration of traditional irrigation societies, including changes in control over the land and other productive resources, changes in modes of production, changes in agro-irrigation technology and the widespread development of groundwater irrigation, and to deal with all of them is impossible.

Take, for example, the impacts of the development of groundwater irrigation. In 1993, the Janakarajan summarised the impacts of the development of groundwater as follows: "Land transfers from upper castes to the hitherto cultivating castes have been a fundamental change that has taken place in the villages, which in turn has resulted in the emergence of owner cultivation in the place of tenancy contracts. The changes in the mode of cultivation, coupled with the introduction of new technology, have induced farmers to go in for an extensive development of well irrigation, in particular wetlands. As a consequence of private control and ownership to irrigation water (viz., groundwater), farmers' interest in the collective effort for maintaining traditional irrigation systems gets weakened. … landlords who exercised a great deal of power in preserving and controlling the traditional village systems including that of traditional irrigation institutions, have lost their glory. Therefore, the traditional irrigation institutions in its normal course got disintegrated or are in the process of disintegration…" (Janakarajan 1993).

Another fault vis-à-vis community water rights will need to be corrected in legal documents. The state has sovereign rights to appropriate, control and regulate water, subject to protecting the interests of riparian right holders (the draft Water Resources Act of 1989, for Tamil Nadu essentially summarises the proceedings of many court cases which upheld the rights of the government as well as those of riparian right holders). The Farmers' Management of Irrigation Systems Act of 2000, while it does provide for greater user participation and reduce the state's role in water management, legalises water rights for landowners only, thus denying the landless of their riparian rights. Furthermore, to what extent landowners will be motivated to participate in water management remains to be seen.

CONCLUSION

The state should play the role of protector of water resources rather than of provider. This is crucial in a context in which the sustainability of water resources is at stake. Both civil society and the state have key roles to play in contributing to the sustainable development and management of water resources. At present, the relationship between the state and loal communities is one of distrust. The state mandates water user participation in management, but keeps the ultimate levers of control within its own bureaucratic machinery. In reality, individuals and communities have little power to manage their water—or, equally importantly, to challenge poor management by the State. The State must also provide a legal framework for effective pollution abatement, for the treatment and reuse of water and for technology dissemination. Legislation and policies need to be more balanced. Individuals and communities have the right to access essentials resources, and that right must be protected whilst ensuring sustainable use and development. The government machinery needs to focus on the basic principles and processes through which rights and other issues can be negotiated as socio-economic conditions change.

APPENDIX 1: WATER RIGHTS IN OLD IRRIGATION PROJECTS: THE CASE OF PALAR

Two case studies are presented in the appendices, the Palar Anicut System (an ancient irrigation system in the former North Arcot District) is described in Appendix 1, and the Parambikulam Aliyar Project (a new irrigation project in Coimbatore district) is described in Appendix 2. Together they serve as a basis for analysing the state's appropriation of water rights and the bureaucratisation of water management.

The Palar River, which originates in the Nandhi Durg hills, runs through the states of Karnataka and Tamil Nadu before emptying into the Bay of Bengal near the city of Chennai. The Palar River used to be the mainstay for both agriculture and drinking of at least two districts in Tamil Nadu. For many centuries, the river provided irrigation water, directly and through channels, for a couple of million acres. The river was used to feed a chain of irrigation tanks and generated hundreds of spring channels, which tapped base flow in the stream's gravel beds.

Before the construction of the Palar *Anicut*, farmers used to construct what are known locally as *kondams* to divert water to tanks and fields. Thousands of labourers drawn from many villages were organised to build *kondams* and carry out other irrigation activities. Since the *kondams* were washed away with every monsoon, farmers were involved in reconstructing them every year until the British government had a permanent *anicut* built in 1858. The *anicut* diverted water through four major channels into a series of tanks in the undivided North Arcot and Chegnalpattu districts. Today, the Palar Anicut System feeds 317 tanks in the region.

Both before and after the construction of the Palar Anicut System, water management functions in this region were organised by the local people through *kudimaramath* (voluntary labour). The construction of *kondams* required the cooperation of a number of villages that benefited from the same system. Certain principles were applied to organise farmers on a large-scale every year and local farmers enjoyed absolute water rights to water from the Palar River. There were also specific rules regarding supply to individual tanks: when supply from the Palar ran dry, *kondams* were built to divert the rainwater flowing through the canal. Similarly, there were a number of traditionally prescribed methods for filling up tanks under different water supply conditions. In order to enforce these, communities used to deploy labourers at crucial points of the diversion to ensure that water was not diverted to other channels not entitled to Palar River water. Thus, by using a system observed in almost every channel, the community ensured that water rights were enforced and protected. Water rights enjoyed by farmers were codified in a document called the *mamulnamas*.

However, the replacement of the *zamindari* system of land administration by the *kaniyachi s*ystem created an imbalance in the traditional system of water rights. Most significantly, this change increased the number of landowners dramatically and disturbed local power equations. Furthermore, since the centralised enforcing authority, the *zamindar*, no longer existed, local water management functions through community labour were disturbed. As a result, many system tanks fell into disuse.

These disturbing conditions forced the state had to intervene. It introduced what is known as the Tank Restoration Scheme to renovate and revive the tank irrigation system in the Madras Presidency. The scheme, however, was a failure: there was no marked change in the management of the tank irrigation system in the Presidency or in the Palar Anicut System.

Construction of the Palar Anicut System and the Bureaucratisation of Water Management

As mentioned above, villagers used to construct temporary *kondams* to divert water from the Palar to their tanks. The introduction of the *kaniyatchi* system and the subsequent changes in the land control institutions resulted in the decline in the *kudimaramath* system. Having no other source than the Palar River for water, farmers lobbied the government to build a permanent structure across the river which would divert the water to their tanks. Their efforts resulted in the construction of the Palar Anicut System in 1858, which marked the beginning of the government's encroachment on water resources. Farmers living outside the command areas of the Palar Anicut then placed renewed pressure on the government to undertake new schemes in the basin. Their insistence eventually led to the construction of the Cheyyar Anicut in the 1870s. The Tamil Nadu Government played a crucial role in negotiating with the government of Mysore, the northern riparian state, to increase water supply in the Palar River. In order to increase its revenue the Madras Government continued to increase the command area under the Palar Anicut and even constructed more *anicuts*. After conducting intensive investigations across the basin in 1930, the Madras state government concluded that the demand for river water for irrigation greatly exceeded the supply. It discovered that the efficiency of the Palar Anicut System had been undermined owing to siltation in the *anicut* and in the major channels. Based on committee recommendations, the government passed a General Order (GO) prohibiting the construction of new irrigation works and the extension of existing ones. In addition, the GO also banned the conversion of dry lands into wetlands and of single-crop wetlands into double-crop wetlands. (GO No. 1617-I, 19th June 1931). These restrictions were soon softened by a number of subsequent GOs. In recent times, after the introduction of green revolution technology in the mid-1960s, the Tamil Nadu Government further relaxed many of these rules in order to allow for more irrigation water. The wide-scale development of well irrigation in the basin is clear manifestation of the change.

In 1981, the government prohibited the sinking of wells or tubewells within a distance of 600 metres from the banks of the Palar River. Wells were also prohibited within 'two furlongs' (402 meters) of the heads of spring channels under the Palar River (GO MS. No.1198 PWD, 6th May 1961). Many farmers lobbied to have these restrictions relaxed, and with the passing of another GO reducing the required distance between a spring channel head and a well from two furlongs to one succeeded. Pumpset capacity, however, was restricted to five horsepower.

Implementing the 1961 GO proved difficult, and an additional order was passed in 1965 to resolve the problems. The new order stated that new wells should not interfere with the water table of existing wells. Yet another GO was issued in December 1978 (GO MS No. 1711, 23rd December 1978) which further relaxed restrictions for utilising Palar River water. Accordingly, the distance for sinking a well from a spring channel head was reduced to 400 meters and the distance from other sources, such as tanks, shrank to 50 meters. Pumping capacity was increased to eight horsepower. Permission to sink a well or install a pumpset would only be given in areas where the chief engineer for groundwater had given clearance. In a another new GO issued on 13th May, 1985 (MS No. 702), the required distance from a spring channel head was further reduced to 200 meters and pumping capacity increased to ten horsepower. Permission was given to regularise all pumpsets which had already increased their pumping capacities.

A final amendment to the GO was made in 1988 further relaxed the recommendations of the High Level Committee on Special Rice Production Programmes. The distance rule now no longer applied to tributaries or spring channels at all; it applied only relative to the banks of the main river. Furthermore, the rules applied only to those areas within the prohibited zone and not to an entire village. Spring channels that had dried up were excluded from the GO rules and it was left to the discretion of the collectors of North Arcot and Chengalput districts to decide whether the rules should apply or not.

The above account of the history of the Palar River irrigation system regulations is a good example of the manner in which the bureaucratisation of water resources has taken place across much of India. It also portrays how peoples' traditional water rights (especially in tank and spring channel commands) have, despite attempts to increase farmer management, gradually been appropriated by the state.

APPENDIX 2: WATER RIGHTS UNDER NEW IRRIGATION PROJECTS

While old irrigation projects were governed by traditional rights and by statutes, new projects initiated since Independence are run entirely by the state and central governments. The government carries out the whole process, from project formulation and construction to operation. Detailed guidelines exist for opening canals and dams, regulating water flow and monitoring the functioning of systems on a daily basis throughout the year. Operational rules and system maintenance guidelines for a project are created without the participation of water users affected by the project in question. Rules are framed to operate systems even up to the pipe-point level, which has a command area of less than 50 acres. The duties and responsibilities of irrigation officials at different levels are prescribed by the government and they are required to follow established guidelines. There is absolutely no scope for the involvement of farmers in the operation and management of the irrigation systems affecting them. New projects even affect the existing water rights farmers may have had. The case of the Parambikulam Aliyar Project in Tamil Nadu is indicative of the domination exercised by the government.

The Parambikulam Aliyar Project (PAP)

The Parambikulam Aliyar Project (PAP) is a new multi-purpose irrigation project that diverts a series of rivers that flow west-east to provide irrigation to the dry tracts of land in the Coimbatore and Erode districts of Tamil Nadu. The first phase of the PAP was initiated in 1967. At that time of the command area covered a total 150,000 acres in two zones and water supply was provided for 12 months. The command area was extended by about 100,000 acres in 1978. After the extension, water supply was provided once in 18 months by introducing a three zone pattern. Beneficiaries of the PAP challenged this decision with a written petition to the Madras High Court. In 1983, an agreement was reached between the farmers and the government of Tamil Nadu: the original beneficiaries of the PAP would be given first priority in receiving water. In 1993, after the government passed an act further extending the command area by about 175,000 acres, the total command area of the PAP reached 425,000 acres. The original beneficiaries again sought judicial redress, but the Madras High Court dismissed their petition stating that “the change in the circumstances warranted the passing of the enactment.” It further held that the action of the legislature in seeking to provide water to additional land could not be regarded as illegal. After hearing the petition, the Supreme Court upheld the decision of the Madras High Court. The Supreme Court observed that the legislature had the absolute right to alter pre-existing rights in order to benefit more people. The Supreme Court’s verdict is important in so far as it asserts the state’s powers and rights and repudiates the people’s prior appropriation rights.

NOTE

[1] For more details on the factors that led to the disintegration of traditional irrigation societies, see Janakarajan (1993).

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WHEN MANAGEMENT FAILS: EVOLUTIONARY PERSPECTIVES AND ADAPTIVE FRAMEWORKS FOR RESPONDING TO WATER PROBLEMS

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CORE ARGUMENT

This paper takes as its starting point a growing skepticism that 'integrated management' is an adequate—or, in some cases, appropriate—paradigm for addressing many water problems. The Global Water Partnership (GWP) has adopted the following definition of integrated water resource management (IWRM): 'IWRM is a process that promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems' (CGWB 1996; Global Water Partnership Technical Advisory Committee, 2000). It notes, however, that 'the concept of IWRM is widely debated and an unambiguous definition of IWRM does not currently exist' (*Ibid*), While the need for 'integrated' approaches (i.e. approaches that reflect the wide array of technical, social, environmental and other factors) is widely recognised, the objectives and processes through which it can—or, equally importantly, *should*—be achieved are unclear. This is reflected in the fact that the definition proposed by the GWP TAC is, in itself, vague and ambiguous. As a result, the meaning of 'integrated management' is left open to a wide variety of interpretations, most of which we believe are rooted in the terms themselves.

The Pocket Oxford Dictionary of Current English defines the verb 'integrate' as 'to combine parts into a whole' or 'to complete by the addition of parts'; it defines the word 'manage' as 'to organise; regulate; be in charge of…to cope with…to succeed in controlling.' Similarly, The World Book Dictionary defines the term 'manage' as 'to guide or handle with skill or authority; control; direct' (Moench, 1991; Barnhart, 1995). These definitions reflect the meaning many, if not most, individuals are likely to draw from the terminology of IWRM regardless of the nuances or perspectives discussed in expert forums. As a result, from our perspective, the terms capture much of the social psychology associated with integrated management. The goals of management within this interpretation are to control systems,

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directing or guiding them to meet the objectives of their managers. To do this in an integrated manner, the relevant systems must be brought together or combined into a whole. The meaning contained in the terms is one of controlling and combining. Despite the emphasis on local participation in some IWRM literature, our own experience in India and other countries indicates that the terms are often interpreted in practice as implying the need for a strong centralised bureaucracy with the authority and power to integrate and often directly control the wide array of government and private sector activities that affect water resources and their use.

Most efforts to address emerging water problems do, in fact, focus on managing both the water resource base and how it is used. They involve attempts to control or direct *dynamic* hydrologic and social systems. They also involve attempts to bring together, or integrate, elements of both the natural systems that determine the supply of water *and* the way water use by individuals aggregates to generate demand at a societal level. The complexity of such systems and the fact that they undergo constant processes of change makes effective direction, control and integration difficult to achieve or sustain. For one time the scale is wrong: social organisation is a slow process and by the time society is able to organise and create institutions that reflect the wide array of factors bearing on water conditions, problems are often beyond management or the context has already changed so fundamentally that the new institutions are inadequate or inappropriate. The situation is further complicated by the non-linear, indirect, nature of many interactions between hydrologic, social and other systems. There is, an inherent element of surprise and unpredictability regarding the impact of interventions or attempts to manage systems. In addition, the goal of integration is often itself a complicating factor. As the call for integration itself demonstrates, the organisations and structures comprising society are often in competition; integration necessitates overcoming this competition and identifying a common agenda. In some situations, however, there are such fundamental conflicts among goals that it may not be possible to develop a common agenda. Furthermore, the process of integration, which by itself may have little impact on a given problem, is often expensive in terms of time, expertise and financial resources. The building of bridges between organisations and institutions is often a time-consuming and politically or financially high-cost project with little certainty of success. As a result, tremendous effort is often spent to develop integrated management approaches which turn out to have little impact on actual conditions at the field level. The net result, as a web page for Development Gateway (a web site initiated by the World Bank) states is that "Integrated Water Resources Management has been discussed for a long time, but few countries or regions really practice it."[1]

Even where integrated management is being implemented it is far from clear that all key objectives are being met. Take the question of participation. Despite extensive discussion of the importance of participation and the widely accepted 'subsidiarity' principle (driving action to the lowest social level possible), the actual actions undertaken by many projects advocating IWRM appear to increase centralisation. Take, for example, the water resource consolidation projects now underway in several Indian states under assistance from the World Bank. To support integration, these projects often involve consolidating existing sectoral organisations into a new water resources department and a high-level planning unit. Similarly, attempts to encourage participation through the creation of stakeholder forums can consolidate power in the hands of those chairing the forums and actually sitting at the table (the 'representatives' of stakeholders) by giving their policy decisions the appearance of broad social support. Much depends on how representative a stakeholder forum actually is. While broadly elected representatives could, in theory, sit on such a body, in practice, representatives are often self-selecting.

The above limitations of integrated management as a paradigm imply the need to look at emerging water problems through different lenses. There are fundamentally only two ways to approach natural resource problems: society can either try to manage natural resource systems to meet its objectives (in which case integration is essential) or it can adapt to the limitations imposed by the conditions of local resources. The number of solutions is not infinite. Our research suggests that society has placed more emphasis on 'integration' and 'management' than it may really benefit from while at the same time discouraging adaptation, an area where humans have strong comparative advantages.

The bias toward management and away from adaptation is clearly evident in, for example, the use of the word 'reactive.' 'Reactive' is often used in a pejorative sense to describe inadequate government or community responses to floods, droughts and other 'predictable' water problems as a consequence of poor planning and management. There is relatively little recognition that 'reactive' or adaptive approaches may, in many cases, represent a more appropriate response to the unpredictability inherent in the interactions of complex changing systems. It is only recently that formal calls have been made for 'national adaptive measures' as an essential part of societal responses to global change (Fischer, Shah *et al.*, 2001). Viewed from the perspective of complex system interactions, the issue in responding to many emerging water problems is one of strengthening society's ability to react 'proactively' so that negative impacts associated with 'surprises' (such as floods, droughts and complex hydrologic interactions) are minimised. An adaptive perspective would emphasise social responses that build resilience and flexibility while de-emphasising interventions to directly control the complex interactions that underlie hydrologic systems or the relationship between hydrologic and social systems. Since integrated management approaches, are constitutionally limited, the further development of adaptive approaches is essential if society is to respond effectively to emerging water problems. To start this process we purpose the following preliminary definition of an adaptive approach to water problems: An adaptive approach is one that increases our ability to live with the natural characteristics of hydrologic systems (i.e. encourages adaptation) and attempts to increase the resilience of social, economic and environmental systems to predictable water problems while utilising only limited and carefully targeted interventions to directly control or 'manage' the water resource base and its use.

By highlighting the conceptual and practical limitations of integrated water management in this paper, we hope to encourage exploration of alternatives while at the same time focus integrated water management efforts on those critical—but, we believe, limited—points where it is essential and can be effective.

ORGANISATION OF THIS PAPER

The first section briefly discusses the integrated water resource management (IWRM) paradigm and some of the challenges to its successful realisation. The focus then shifts to an exploration of relatively speculative theory (but one grounded in experience and common property) of how people organise around water. We next consider the limitations for IWRM as a dominant paradigm which our research suggestion. Finally, we pursue a preliminary exploration of adaptive approaches.

THE INTEGRATED WATER MANAGEMENT VISION

Much has been written on integrated water management and the institutional requirements associated with it. While it is impossible to summarise this entire being of literature, the World Water Council document 'World Water Vision: Making Water Everybody's Business' (Cosgrove and Rijsberman, 2000) represents a particularly useful starting point because it attempts to synthesise the best management practices of the last 25 years into a 'vision' for the coming decades revisiting this vision is essential because, as the Global Water Partnership Technical Advisory Committee (GWPTAC, 2000) emphasise, 'IWRM has neither been unambiguously defined nor has the question of how it is to be implemented been fully addressed.' The vision is one in which the 'world's freshwater resources will be managed in an integrated manner at all levels, from the individual to the international, to serve the interests of humankind and planet earth—effectively, efficiently, and equitably' (Cosgrove and Rijsberman, 2000). The document advocates five actions to achieve the objective of integrated management (*Ibid)*.

- **Involve all stakeholders in integrated management**: This is a response to the current situation in which most water 'management' is undertaken by professionals through organisations focused on narrowly-defined sectors (irrigation, drinking water supply, etc.) and often excludes those groups whose livelihoods are most intimately linked to water—women, the poor and other users—from participating.

- **Move to full-cost pricing of water services for all human uses**: This is seen as critical to counter the distortions created by a long history of subsidies for water development and to communicate the full scarcity value of water to users.
- **Increase public funding for research and innovation in the public interest**: This is essential because—despite the broad reach of the vision exercises—it was found that: 'there are enormous gaps in our quantitative knowledge about freshwater ecosystems' (*Ibid*) and that there is little stimulus for innovation with regard to water conservation.
- **Recognise the need for cooperation on IWRM in river basins**: While the World Water Vision document focuses primarily on the international dimension, its advocacy of integration within river basins reflects widespread recognition of the disjuncture between hydrologic units (basins, aquifers, etc.) and the social-political units through which management is often organised.
- **Massively increase investments in structures for controlling and managing water**: As the World Water Vision authors rightly recognise, attempts to directly address the world's water problems would require massive investments—$180 billion annually, according to their estimates.

By 2025, the end of the period of their, scenario the authors envision the situation described below: 'most countries had legislation that facilitated community based activities. Some made it obligatory to develop basin plans… some governments reorganised their civil service and streamlined their legislation…Most governments adopted legislation that clarified ownership of water or rights of access… Around the world a wide variety of local organisations were developed as appropriate to local circumstances. Among these some were modeled on river basin organisations, others on conservation authorities, and some serving the functioning water markets. In 2025 all of them had one thing in common—representative participation by community women and men in decision making' (*Ibid*). In the scenario, gradual adoption of full-cost pricing for water services gradually sparked private investment in water services and the removal of subsidies reduced distortions leading to the over-exploitation of water resources. Specific changes, such as the removal of energy subsidies in India, played a key role in discouraging groundwater over-pumping. Full-cost pricing also encouraged the development of new water storage facilities. All of this was accompanied by 'a continuing strong government presence in establishing and managing frameworks of regulatory policies and laws that provided long-term stability' (*Ibid*). Continued public funding of research and innovation generated a wide variety of new tools for water management but had a particularly notable impact on the dissemination of information to end users and other entities: 'initiatives to share the data became widespread' and played a major role in education and 'most important, for river basin management' (*Ibid*). Environmental information was incorporated in education at all levels and by 2025 it was 'common that collective decisions should give due consideration not just to the next generation but to many future generations as well. And that view forms the basis for much of the discussion in catchment committees' (*Ibid*). Finally, governments voluntarily accepted 'the limitation of their sovereign rights to permit consultations and decisions based on integrated water resource management at the basin level… As more nations and communities applied the principle in their watersheds, it became clear that it was the right approach' (*Ibid*).

The above quotations from the World Water Council document capture the emerging portrait of 'best-practice' approaches to IWRM advocated by professionals and many international organisations. The vision is founded on a rationalist view of global society. In it, a vision of a global context in which local cultures and governments are, at their root, able to respond in a concerted manner to the highly complex and diverse dynamics essential to 'manage' both the water resource base and its use. This view assumes that governments are generally capable of long-term planning and willing and able to adopt politically difficult regulatory measures and legal changes to support the long-term objectives of water management. Cosgrove and Rijsberman (2000) paint, as they were mandated to do, an admittedly optimistic vision of coordinated, rational responses across the globe that together address emerging water problems. More skeptical perspectives on the ability of society in many parts of the world to develop coordinated approaches to water problems bring into question both the courses of action advocated in the World Water Vision document and their probable outcomes. Many of the elements central to success in achieving the vision do seem overly optimistic on both technical and social grounds. Key challenges include, for example, the following:

1. **The resolution of potentially inherent contradictions in water governance for integrated management**: The GWP/TAC points to a 'water governance crisis.' As the committee notes, 'sectoral approaches to water resources management have dominated and are still prevailing; this leads to the fragmented and uncoordinated development and management of the resource' (GWPTC, 2000). The GWPTAC goes on to state that 'moreover, water management is usually left to top-down institutions, the legitimacy and effectiveness of which have increasingly been questioned' (*Ibid*). It advocates instead increasing the participation of local communities and devoluting management powers to them. A difficulty arises, though, as integration, however, requires some centralised form of planning, regulation, information dissemination and coordination. Such coordination and control over regulation and information, however, are potent levers of power and—ones that are likely to strengthen the role of centralised

institutions. The effective integration and the devolution of power from top-down institutions to communities may, as a result, be mutually contradictory requirements. This is particularly the case where local organisations are relatively weak and where wider societal institutions, such as the courts, media, or even civil society groups, do not function effectively to balance power among interest groups. This can limit the ability of local organisations to gain access to basic data or other essential information for management. At the very least, this contradiction is likely to represent a continuing source of tension in any attempt to implement integrated water management.

2. **Development of the scientific information essential to actually control and regulate water resource and use systems that are themselves dynamic and undergoing rapid processes of change**: Processes of global climatic, social and economic change are continually altering the fundamental characteristics of such systems, and, *more importantly,* key components of the hydrological cycle (such as deep groundwater flow patterns) are impossible to monitor directly. In many societies even simple phenomenon, like precipitation, flow and sediment discharge, are not monitored systematically. In addition, while society may be able to predict and react to key changes in water systems, it is far from clear whether or not a scientific foundation strong enough to actually regulate or manage them can be developed.
3. **Emergence of a strong government presence in establishing and managing frameworks of regulatory policies and laws that provide long-term stability:** This implicitly involves a vision of the government as an adjudicator—proactive, able and willing to make politically difficult decisions in the interests of long-term objectives. Governments generally feel pressure to meet the immediate service needs and economic aspirations of the populations they govern but, not to meet long-term and often abstract questions of management. As the GWPTAC (2000) indicates, 'In many cases the biggest problem is not lack of adequate legislation but lack of the political will, resources and means to enforce existing legislation.' Lack of political will to implement IWRM may reflect the simple survival equation which faces all politicians. The unless large groups *demand* water management, politicians have little incentive to take the political risks associated with providing it. Furthermore, even if large groups understand the need for water management and support it in a general way, short-term considerations (can I irrigate my fields and grow enough to eat this year?) can weigh heavily against regulatory action to meet longer-term goals.
4. **Legal action facilitating community-based activities**: Many governments are deeply suspicious of community initiatives—particularly those based on representation—since they often challenge existing political power relations. In same areas the processes of stakeholder and community dialogue have proved extremely time-consuming, and some actors, including many in key government positions, question the viability of

community-based management strategies. As a result, regardless of the growing professional consensus regarding stakeholder and community involvement, there is a growing resistance to it in some areas. So vague!

5. **Clarification of water rights**: The models often held up for IWRM tend to be those developed in the Western US. These generally involve the formal allocation of use rights to individuals on a volumetric basis. Much of water management literature emphasises the importance of systems that allow trading rights between locations and uses as a foundation for water allocation and valuation through market mechanisms. This is, in turn, portrayed as one of the most important mechanisms encouraging efficient use. The argument for water right clarification is analytically clear, but it is likely that it will be extremely difficult to implement on the ground. Water rights systems in the Western US are the result of more than a century of evolution and are supported by extensive technical and judicial systems to monitor rights. In many other areas, such as the Islamic world, private rights systems face widespread opposition and run counter to deeply held traditions. Even from a technical perspective, the process of identifying users and clarifying their rights is extremely challenging: in India, for example, there are over 20 million wells, the locations and uses of which are mostly undocumented.
6. **Sharing of information**: Most authors point to the critical importance of public data and information as a framework for effective management. While it may be logical for entities whose primary concern is effective water management to share data, most entities such as private corporations or governments are motivated by other concerns. Information is power. As a result, sharing information often runs directly counter to the interests of the entities which hold it.

It would be easy to continue listing the challenges which face the implementation of the World Water Vision or any other IWRM approach to emerging water problems, but it more important to focus on their solutions. Many, if not all, of these challenges could be overcome if society were capable—and had sufficient incentives—to organise itself to do so. The most fundamental question, therefore, relates to the ability of society to organise itself in a manner that addresses the myriad water management needs now emerging. Water professionals often point to a 'lack of political will' as the primary factor inhibiting management. Our research indicates that this 'lack of will' points to something deeper than just the courage of officials, whether elected or otherwise.

Politicians are often weathervanes of social consensus: when they move too far beyond that consensus their support base erodes and they ultimately fail. To put it another way, politicians need to respond to the *demands* of the population rather than to their more abstract *needs*. Lack of political will often reflects an absence of consensus or an absence of true *demand* regarding, for example, social priorities (among which sustainable water management is only one of many) or the technical viability and social desirability of proposed courses of action. To return to the question of organisation, the presence or absence of political will is a key indicator of popular trust in the organisational and institutional as well as technical approaches proposed for solving problems. Without a broad understanding of and social support for approaches, the political will to implement them is unlikely to emerge. It is this dynamic—the link between modes of social organisation and political will,—that, we believe, lies at the heart of questions regarding society's ability to manage water resources. The next section explores how people organise around water.

HOW PEOPLE ORGANISE AROUND WATER

This section explores and synthesises a wide variety of experiences with how people tend to organise around water. These observations will then be related to organisational theories in the following section and, following that, to the questions of political will and the viability of integrated management as the dominant paradigm for addressing emerging water problems.

Two organisational factors that represent a major, if not fundamental, challenge to the success of IWRM approaches include:

1. The disjuncture (dictionary notes 'disjunction' is more frequently used) between common types of organisation and the array of functions IWRM requires: Our research indicates that a major disjuncture exists between the structure of demand for water services and different organisational forms. In addition, common organisational forms are inherent by limited with respect to the functions required of them;
2. The way organisations commonly begin or are initiated: Effective organisations rarely exist in the locations essential for IWRM and there are good reasons why this tends to be the case.

Organisational Types

How do people organise around water? We can distinguish least four primary organisational types that play direct roles in managing or allocating water:

1. Government organisations that are generally structured along sectoral lines and that play major regulatory, service delivery/operational or data-collection and scientific roles;
2. Private sector utilities and related service delivery organisations that provide specific water services to clearly defined client populations;

3. User-or community-based organisations developed to meet specific needs demanded by the user community from which they emerge;
4. Hybrid organisational forms—such as the 'districts' of the Western US, quasi-private sector government corporations, municipalities, etc.—that combine community, private sector and government characteristics.

All four organisational types operate in a context shaped by other related organisations and institutions. Public advocacy organisations like NGOs or networks, for example, are often influential but rarely play a direct role in water management. Instead, they seek to shape the activities and roles played by the above 'primary' organisations. Markets and market related institutions also shape the behavioural environment in which the above four types of primary organisations function. They are not, however, water management organisations in themselves.

In analysing the functioning of water management organisations, two factors appear to be of importance: first the structure of demand for water services; and, second, the structural factors affecting the ability of organisations to implement management effectively.

The Structure of Demand for Water Services

A key feature of primary water management organisations is that, at least initially, they were structured to provide a very specific and tangible array of services or functions. The primary role of irrigation departments or irrigation districts is, for example, to construct and operate the infrastructure that provides irrigation water to farmers. Water supply utilities, in contrast provide drinking water. The focus in community water management groups is often equally specific. Such groups generally emerge in the context of a very specifically defined need: the construction of a water-harvesting structure, operation of a local drinking water system, or the drilling and operation of a group well, for example. In most cases, organisational functions focus on the supply side—organisations operate and manage delivery infrastructure or attempt to regulate a river or aquifer system—but play a relatively minor role in the end-use side of the water equation. Very few organisations focus on the 'integrated' management of water to meet the objects of sustainability and efficiency.

While it could be argued that the focus on tangible, supply-side activities is a by-product of human history—the need for management in a wider sense has only recently been recognised—it may also reflect a basic feature in the way people organise. First, it is important to recognise that, in most cases, management runs counter to short-term needs. This is true from the perspective of individual farmers and of, most development organisations, whose main operations and sources of revenue are tied to construction and operation. Beyond this, however, the *organisational characteristics* of management may be fundamentally different from those associated with development. Business literature contains numerous recommendations for organisations to focus on their core strengths, core functions and core products. Business success occurs when organisations produce products that people *demand*—something often distinct from products people *need*. While society may *need* to manage water resources on an integrated basis, most users *demand* specific water services. Water services, particularly water supply, are the core products people demand from water organisations of all types. As the old joke from the Western US goes: "If you have a water problem, pour water on it and it will go away." The core strengths of most water organisations lie in supplying water precisely because people demand a supply of water.

IWRM involves a far more diverse and abstract set of activities designed to produce products (such as resource sustainability) that are generally far less tangible than water flowing out of a canal or tap. We speculate that the psychological implications of this truth may be important. In a general discussion of the business environment, Hawken *et al.* (1999) make the point that 'the University of Chicago psychologist Mihaly Csikszentmihalyi has found that people all over the world feel best when their activity involves a clear objective, intense concentration, no distractions, immediate feedback on their progress, and a sense of challenge'. These elements are unlikely to be present either for individuals or organisations involved in the diffuse set of activities required for integrated water management. Water supply projects tend to be time-bound and to focus an immediate goals and tangible results. Management, in contrast, doesn't generally have these characteristics; it is instead an ongoing process in which goals shift and results are often intangible. Psychologically, as a result, the people involved in long-term management processes are likely to lose their motivation and sense of direction. This psychological decay could be a major factor in undermining the ability of society to maintain a long-term focus on management objectives. The tangibility, feedback and reward of short-term water development projects could, to a large extent, explain why most water organisations focus on such activities.

Whether or not the above speculation is accurate, most efforts to initiate management involve the grafting of new functions onto organisations initially developed for service provision metamorphosing irrigation departments and canal companies into water resource departments or management districts is common. The parallel in the business world is the often addition of sidelines and functions that go beyond and complement the core activities of organisation. As the range of peripheral activities grows, however, organisations often face problems stemming from a dilution of their focus and difficulties in managing diverse sets of activities less clearly defined by client demand. Maintaining focus is challenge facing water organisations as they attempt to transform their role from development to management. It may represent a particular constraint for more broadly focused, *integrated* management initiatives because such initiatives necessitate intervention across a much wider spectrum than do more narrowly-focused management attempts.

In addition to facing a dilution in focus, organisations which make the transition from development to management encounter a major change in the structure of their interactions with users or clients. In general, the relationship between organisations and users in water supply projects ends with the single act of 'connection' where demand meets supply. The organisation builds or operates a supply system and users connect with it and draw the supplies they demand. The organisation generally has little to do with the details of how supply is used and there is relatively little need for regular interaction between individual users and the organisation. Where management (particularly integrated, demand-side management) is concerned, this relationship changes in fundamental ways. Since the success of demand side management depends on changing the behaviour of individual users. Successful management organisation must be able to influence that behaviour, either directly or indirectly. They attempt to change the structure of demand at the level of individuals rather than respond to the aggregate demands of those individuals. Organisations rarely have the skills or the other capacities necessary to interact in a regular manner with individuals and to create a new management relationship, one that goes against the simple supply-demand interaction. A succinct expression the 'structure of demand' challenge that organisations face is …..

1. because that most water-related organisations are structured to provide water supply services because society demands them. Water supply and development activities also have clear advantages:
   a. Being tangible;
   b. Involving relatively simple organisation-client relationships; and
   c. Generating psychological (and often monetary) rewards for the individuals and organisations involved.
2. Organisations face major challenges in supplying water management services for several reason:
   a. Social demand for such services is diffused;
   b. The diffused nature of management may be psychologically unrewarding for the individuals (and therefore the organisations) involved;
   c. Producing management services generally requires a wide array of activities outside the core strengths and functional experience of traditional water organisations; and
   d. Many water management functions can only be fulfilled by influencing the way water is used at the level of individuals or households and thus by changing the structure of demand. This task involves developing a fundamentally different set of relationships between organisations and users.

Structural factors affecting the role of organisations

In addition to issues relating to the structure of demand for water management, the four types of water service provider organisations identified above (government, user or community-based, hybrid and private) face somewhat different sets of structural issues in carrying out water management functions. These structural issues are rooted in questions of scale and incentives.

The structural challenges in implementing the diverse sets of activities required for integrated management which government organisations face that are rooted in their hierarchical structure. Most government organisations exhibit a linear chain of command running from ministerial levels in national governments down to field level operatives. Such organisation develop new supplies relatively easy using centralised decision making guided by small groups of highly trained experts. One-time activities such as the construction of water infrastructure are easiest to accomplish. Management, particularly that of the resource base rather of a focused piece of infrastructure, however, requires fine tuning interventions to local conditions. It also requires the ability to influence water-related actions at the level of individuals, communities and localised hydrologic systems. Two main avenues are available to government organisations who wish to influence action: to direct approaches like achieving control using regulatory and police powers or indirect approaches like working with and through local communities to achieve management objectives. As is widely recognised, problems enforcing regulations are a major constraint limiting the ability of government organisations to manage water resources in locations such as India (Dhawan, 1990; Moench, 1991; Moench, 1994; Moench, Palanisami *et al.,* 1997). As a result, increasing attention is being given to the second avenue. This requires an ability to work closely with local communities and fine-tune approaches in order to fit their needs and perspectives. Achieving this type of fine-tuning and influencing action at the level of individuals often requires a combination of technical and 'social process' inputs that are only found in highly-trained individuals. While it may be straightforward to marshal a few such individuals for a few high priority sites, this is far more difficult to do when the objective is to manage watersheds or aquifers at a *regional* level. Working at a large-scale is also often expensive and requires the ability to sustain visions over long periods like decades. The case of Sukhomajri, a village based watershed management project in India, and attempts to replicate it is illustrative of the challenges governments face in encouraging management at local levels (see Box 1). Replication has been problematic at least in part because government organisations lack sufficient staff with the training and orientation necessary to work effectively with local communities.

Beyond the question of human and financial resources lie the equally critical questions of communication, coordination, orientation and the decentralisation of decision making powers. These questions affect the ability of hierarchically structured organisations to project themselves far enough downward to actually affect the use and management of water resources at local levels. In many situations, local officials lack the authority and incentive to make basic decisions and adapt approaches to local conditions. To some extent, government organisations can be compared to thunderclouds in the desert: one can see rain falling but it rarely hits the ground. Whether the issue is framed in terms of transaction costs, information flow, coordination or the decentralisation of decision making authority,

BOX : 1

THE CASE OF SUKHOMAJRI AND ATTEMPTS TO REPLICATE IT

Shukhomajri, India, is a well-recognised example of successful community-based natural resource management. Watershed management in Sukhomajri was catalysed in the late 1970s by the reputed environmentalist P.R. Mishra. The concept was simple: create a resource that benefits all villagers (in this instance, a small dam for irrigation) and they will have a strong incentive to protect the source of those benefits, e.g. the watershed.

With substantial input from P.R. Mishra and others as well as significant investments from international donors (the Ford Foundation alone invested well over one million dollars), management at Sukhomajri took off. This result was substantial increases in crop production (see table) and a significant increase in income from other sources (milk production, grass collection, etc.). Having weaped the benefits, villagers participated actively in protecting the watershed success at. Sukhomajri depended heavily on the development of institutional mechanisms for conflict resolution (both within the village and between Sukhomajri and adjacent villages), the gradual building of village institutions and the development of mechanisms to ensure equity. These developments rested on the support of highly-trained social scientists and deeply committed activists.

Attempts by the Haryana Forest Department to replicate the Sukhomajri model were far less successful: in 1989, when one of the authors of this paper participated in a review of the 60 sites where replication was attempted, only four were termed 'reasonably successful.' Many of the dams constructed by the Department and communities were defunct and little in the way of watershed protection was occurring. In addition, there were numerous conflicts project and non-project villages and between villagers and government officials. At the time, our analysis suggested that the lack of trained inputs were a key constraint as the Haryana Forest Department staff had neither the skills nor, in many instances, the orientation to support community-based management.

Recent reports indicate that success at Sukhomajri itself is under threat (see *Down to Earth,* Vol. 7, No. 14 December 15, 1998). Villages and the Haryana Forest Department have experienced major conflict about grass and the villagers may, as a result, be losing motivation for management. Since external resources, whether Indian or other activists, may no longer be available to help the villagers and the government manage the conflict, the future of Sukhomajri appears uncertain.

hierarchically-structured government organisations have difficulty developing or supporting the evolution of effective management capacity at local levels, except where such activities are constrained to a limited set of high priority locations.

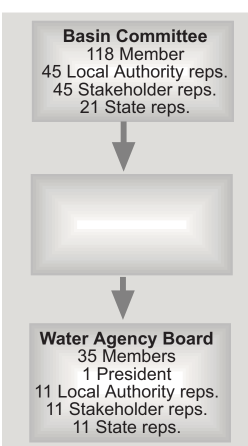
Decentralised, user-or community-based management institutions face the opposite organisational problem: aggregating the impact of initiatives from specific local contexts to a regional scale. The example of Sukhomajri is again illustrative. P. R. Mishra and others catalysed management in the very small-scale watershed above Sukhomajri. While effective at that local scale in the specific context of Sukhomajri, it has proved impossible to generate similar management across larger contiguous watersheds. The incentives for management in Sukhomajri are location specific and can't be recreated in all areas. Furthermore, even in Sukhomajri, management attempts have generated conflict with adjacent villages as well as with the Forest Department. Management of large basins requires coordination among many villages with differing degrees of incentives to cooperate toward meeting objectives that, in actuality, may not be all that common.

User-based management faces another structural challenge. The strength of user-based organisations is generally rests on their representative nature. Water-and forest-user groups, for example, typically elect representatives to a local governing body. Many users attend or at least are aware of meetings and provide input to their representatives and towards the decisions made by the governing body. Because users are closely involved with the management organisation, it often has the power (through social pressure and other levers) to influence the behaviour of individuals. Furthermore, being rooted within a local context, it can fine-tune management activities to the conditions of that context. However, professional resources for management are often limited in use-based management. Despite this constraint, where conditions suited for the development of common property resource management institutions exist, such organisations often can manage water resources at the local level. As discussed below, however, the conditions for effective management identified by extensive research on institutions relating to common property resources are difficult to achieve in many water management contexts. Furthermore, these characteristic constraints tend to increase exponentially with scale: the resources (time, financial and other) required for monitoring, communication, coordination and consensus-building increase as the geographical area under management increases. The conditions for effective common property management are, in effect, difficult to aggregate upward to the regional level, as is required for integrated management of river basins or aquifers.

The contrast between state and user-based organisations represents a real and immediate challenge for water management in South Asia. Virtually all government efforts are through large state organisations such as irrigation departments which very limited capacity for either working with local communities or otherwise influencing water use at regional and local levels. In contrast, virtually all NGO and community based management initiatives occur at the village level. Actions at this level have little impact at the scale of aquifers or river basins. In many countries there is a huge institutional 'gap' at the intermediate level—between the village and the state.

The main avenue for closing this gap is through the creation of hybrid institutions, such as river basin authorities or regional management districts similar to those found in the western US, for example these organisations generally combine a small centralised, hierarchically-structured, professional management unit overseen by the government or representative boards of directors. An illustration of this approach is France where policy and supervision are set by basin committees that comprise representatives from the state, local authorities and stakeholders. Policy is translated into action by water agencies, which are also governed by the same combination of representatives (see Figure 1). The basin committees are responsible for the development of broad water policy documents (Schémas Directeurs d'Aménagement et de Gestion des Eaux or SDAGE) which 'define the long-term aims for water quantity and quality and the measures that have to be undertaken to achieve their fulfillment' (Roche and Jaskulké, 2000). They also appoint water agency boards, approve their five-year implementation plans and, importantly, approve the taxes through which agency activities are financed. While these basin committees do contain local representatives, they are still highly-centralised organisations. There are only six major basins in France and procedures for the development of more local sub-catchment plans are still being developed (*Ibid*). Given their scale, it is unclear how representative the stakeholder delegates actually are.

FIGURE 1
THE FRENCH BASIN



Source: Pierre-Alain Roche*, presentation at IWA Conference Paris, 2000, updated by Elisabeth Jaskulke**

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How representative those on the board of directors of an intermediate-scale water organisation (special water district), is a point of concern in the US The governance structures of local districts and district characteristics both vary greatly. While many are governed by elected boards of directors, voting systems are often weighted. In addition, there may be restrictions on the eligibility of board members and some or all board members may be appointed by local or state government entities. Water districts in California and Texas are under the control of locally elected boards, while locally elected bodies share decision making powers with the state in Colorado, Kansas, and Nebraska (Bowman, 1990). In all other states, decision-making power is vested in a state agency. Even where districts are governed by locally-elected boards of directors their representative nature is open to question. As one author wrote in 1991:

> 'Voter interest in district elections is generally low, turn-out is often only a few percent of the potential population. Voting structures (which are frequently based on assessed valuation or acreage) often limit effective control to large landowners. Where members are appointed to the board of directors, provisions in the district enabling legislation often limit eligibility to special interest groups, particularly farmers. The net result is that historically dominant agricultural interests in water management are heavily entrenched in current governance positions. These interests are often buttressed by the presence of federal and state surface water supply projects where benefits were explicitly intended for irrigation' (Moench, 1991).

The net result is that, as Nunn and Ingram (1998) comment in relation to the values represented in district decision making, 'special districts could consider both direct and indirect values but are often controlled by a leadership elite, pursuing narrow goals with minimum membership participation'. In sum, existing experiences with hybrid 'participatory' organisations raise significant questions regarding the degree to which they are actually able to function as participatory entities bridging the divide between 'local' and 'state' approaches. This said, globally such 'intermediate level' forms of social organisation for water management are relatively uncommon and practical experience with them is limited, particularly in the developing world. In some cases they could represent an effective way to balance community involvement and a professional, 'state' structure with the capacity to mobilise and focus professional resources on narrow management targets.

There 'are major questions concerning the conditions under which quasi-government hybrid organisations can be formed and undertake IWRM functions in a way that actually represents stakeholders. As previously noted, such types of organisations are relatively rare except in a few countries. As a result, there are few theories regarding their formation and the conditions under which they may prove effective. Where they are found, their organisational structure has emerged out of a long history of institutional development. In the US, for example, quasi-government 'districts' governed by a local board of directors have been part of the fabric of governance for over a century in many fields—ranging from school systems to fire control—and the institutional form is well-known and has broad legitimacy. In most cases, the functions of districts dealing with water are narrowly targeted on services such as flood control, drainage, irrigation and the operation of domestic water supply systems. The boundaries of districts which deal with different aspects of water management or service provision often overlap and are rarely contiguous with hydrologic units. Furthermore, relatively few focus on integrated management. This said, some do carry out integrated management activities. These are typically what might be called secondary organisations: their client base is often composed of more narrowly focused 'primary' water service providers (this distinction could also be made between river basin commissions and water authorities or utilities that actually provide water services). As part of management, intermediate organisations play a major role in coordinating but have relatively limited involvement in actual operations. Outside the US, most quasi-government organisations are found in developed countries, where populations are educated and well-organised. They also occur in countries where civil society institutions are common and processes for political debate are relatively open and balanced (i.e. there is no single ruling entity that could perceive such organisations as a threat) and in situations where the professional resources required for water management are readily available. Whether or not such organisations could prove effective for IWRM in other areas is an open question and one with little experience that can be used to answer it.

The final organisational form, the private sector corporation, has at least two dominant structural features where IWRM is concerned: (1) its private, non-representative nature; and (2) its dependency on fees for services or products as a source of revenue. The private, for-profit and non-representative nature of private sector organisations often limits the role they can play in setting policies for public goods. Such organisations are generally perceived as stakeholders with their own interests that may or may not match wider public interests. As a result, their ability to play a leadership role in policy formulation is often constrained. In general, they are restricted to assuming support and implementation roles (in which they often excel). The second structural feature is equally important. Unlike government, community based or hybrid organisations, private organisations must have clients that are willing to pay for the management services they provide. They lack access to taxation or community donations as a source of financial or other resources. In situations where management benefits are long-term and intangible or where the beneficiaries are poor rural populations (as they are in many developing countries), the client base for IWRM by private organisations is often lacking. Private organisations can however, provide management services when other organisations—whether government, hybrid or community based—exist as a client base. Unless such civil society organisations already exist and create a demand for water management services, private sector organisations must market their products to individuals and other private organisations. Such clients demand management services that are private rather than public and that can be delivered on a short-term basis. Many of the benefits of IWRM are, however, public goods and can only be delivered over the long term. Individuals and companies want water to come out their taps. As individuals they are far less likely to pay for actions to ensure the sustainability of a large aquifer where the benefits are long-term and accrue to many rather than to the client alone. As a result, many areas lack a client base for IWRM by private sector organisations. This structural constraint may limit the role private sector organisations can play in IWRM in areas where other forms of organisation are already well-established.

How Organisations Begin

Aside from the structural constraints discussed in the previous section, the development of effective IWRM systems requires that society be able to create appropriate organisations when and where management needs exist. While we are unaware of substantive research on the process by which water organisations are formed, experience and analysis of recent history suggest that there are a limited array of pathways through which water management organisations have emerged. We term these 'leadership catalysed', 'accretionary evolution' and 'social decision' and describe them below. The limited nature of these pathways has two important implications:

1. Appropriate organisations are rare and the pathways to their formation often aren't available in many locations where it would be useful to initiate integrated management; and
2. Attempts to create appropriate organisations through government or other externally-supported initiatives are prone to failure. The success of such initiatives depends on windows of opportunity and other specific contextual factors such as the presence of a dynamic leadership.

Leadership Catalysed

The role of NGOs and similar grassroots organisations in water management and other local development activities is now widely recognised. This type of organisation is often able to develop close links with local communities and can be a very efficient catalyst for the development or management of natural resources. As anyone who has worked on a development project will tell you NGOs often work in very limited areas. In fact there are large regions where no such organisation is available to support water management or other development initiatives. This narrow focus may, in large part, be related to the manner in which such organisations start.

In many areas, individual 'charismatic' leaders play a critical role in the development of water management organisations. This is clear, for example, in community-based water management initiatives in India, where individual charismatic leaders—such as Salunke in Maharashtra, P. R. Mishra in Sukhomajri and Rajinder Singh in Rajasthan—have served as local level catalysts for regional water harvesting and management movements. These high profile individuals frequently work closely with other local leaders within individual communities to move the process of organisation formation forward. The role of charismatic leaders is not, however, limited to grassroots initiatives in developing countries. It applies to many government and private sector organisations in all parts of the world. In the US, for example, individuals played a major role in the development of organisations that are now central to effective water management. John Wesley Powell was, for example, the driving force behind the creation of the US Geological Survey while, at a more local level, many water management districts began as the result of initiatives by one or a few committed individuals. Most private sector and non-profit organisation are also the brainchild of dynamic, entrepreneurial individuals.

The role of individuals in the formation and operation of water management organisations is often ignored, at least at a formal level, in the formulation of water management or other development activities. Government projects, for example, are generally designed on the assumption that individuals make no difference, that someone can always be found or trained to do that the job, the presence of a leader isn't critical. This formal perspective contrasts sharply with actual behaviour: in virtually all projects that the authors have been associated with, the starting point is to find 'key' individuals who share the project's vision and can drive it forward. Our experience is supported by research. In a recent analysis of twenty-eight water management success stories in California, for example, the Pacific Institute for Studies in Development, Environment and Security noted that:

> 'Almost all successful water management projects brought competing and conflicting stakeholders together in cooperative arrangements. Cooperation, rather than confrontation, led to an understanding of different points of view and a willingness to explore compromises and creative solutions that benefited all parties. *Nearly every successful partnership had an individual or individuals strongly committed to the project. In many cases this leadership was vital for managing any stakeholder conflicts that did arise and keeping the project alive'* (Wong, Owens-Viani *et al.,* 1999)

What does this mean for IWRM? The fundamental implication is that IWRM is unlikely to take off except where individuals with a compatible orientation and leadership ability are positioned to catalyse and give direction to the organisations needed. Charismatic leaders can catalyse the formation of extremely dynamic and effective organisations. Such individuals are, however, a scarce commodity in many parts of the world. Furthermore, even if projects are able to offer substantial salaries or other inducements, there is no guarantee that individuals with the required understanding and leadership capacity will assume ownership of a project and drive it forward.

Accretionary Evolution

A second major way in which water management organisations have been formed is through the addition of managerial functions to organisations initially developed for other purposes. Many of the water management districts in the Western US, for example, were initially formed as mutual irrigation companies. Small groups of settlers started them as a group mechanism for building canals and delivering irrigation water to their members. As new needs emerged over time, some of these companies evolved into quasi-government districts and, in addition to their irrigation supply functions, began to manage rights systems, water use within their service area and, occasionally, larger functions. Accretionary evolution is a common process in the development of government management organisations. In India, for example, staff from the Geological Survey of India comprised the core group when the Exploratory Tubewells Organisation was formed in the early 1960s order to provide professional support to groundwater development efforts. The Exploratory Tubewells Organisation became the Central Ground Water Board (CGWB) in the 1970s and took on the role of monitoring and assessing groundwater availability. Recently, the CGWB was also designated the Central Ground Water Authority, the nodal government agency for regulating and managing groundwater resources in India. Although it has yet to develop significant managerial capabilities, this is the clear objective behind its re-designation. At an even larger scale, institutional reform initiatives underway in a number of Indian states with support from the World Bank are attempting to re-cast irrigation departments into much more integrated water resources departments.

The development of organisations capable of effectively supporting IWRM activities through accretionary evolution is limited by at least two interlinked factors: organisational culture and, as in the case of catalytic leaders the individuals involved.

Organisations often have strong internal cultures where reorganisation and the addition of new functions often don't change, at least not rapidly. When functional changes are of a fundamental nature and clash with existing cultural characteristics, major problems are common. This is likely to be the case as water organisations attempt to move from a developmental to a managerial role. In India, for example, irrigation departments have traditionally been hierarchically structured and had strong technical capabilities. They have had little, if any, capability for interacting with the users they serve; in fact, they often have a history and culture of conflict with those users. Making the transition from development to participatory integrated management—a function that demands a close relationship with users and strong social skills—implies, that there will be a fundamental change in the institutional culture of irrigation departments.

The role of individuals in the process of 'accretionary evolution' is also crucial. While decisions to add managerial functions to existing organisations tend to be made by governing bodies (boards of directors, governments, etc.), individual perspectives can make a big difference, as recent experiences in the preparation of a World Bank project for Rajasthan illustrate. In that case, five years of discussions with the chief hydrologist of the Rajasthan Ground Water Department (RGWD) focused heavily on establishing pilot management projects through community-based organisations and on improving basic data collection. This emphasis shifted substantially in the final stage of project preparation when the chief hydrologist retired and the high-level government secretary he worked under changed. These personnel shifts led to a fundamentally different orientation. The focus of activities the RGWD wished to undertake through the project changed, thus bring about a corresponding change the types of groundwater management organisations that will likely be developed.

Organisational culture and the role of individuals in the ‘accretionary evolution’ of organisations have significant implications for attempts to promote IWRM as the dominant solution to water problems: First, while it is difficult to create new organisations for water management, reorganising existing organisations and changing their institutional culture can be equally challenging. Second, the rebuilding of existing government departments or other organisations may be just as dependent on the presence or absence of charismatic individuals as the initiation of new ones.

How relevant to policy is the issue of individuals? Individuals, after all, affect *all* organisations. We believe that the critical dependence of catalytic and accretionary types of institutional formation processes on individuals makes individuals critical for policy. It makes little sense to develop approaches if the individuals required to put them into operation are unavailable. Dependence on individuals suggests that policies need to be formulated in an adaptive-reactive manner so that approaches can build off the initiatives and vision of key individuals rather than trying to forge ahead when key individuals are either unavailable or do not share the same institutional development vision.

Social Decision

A third process of organisation formation occurs when large-scale movements in society generate broad support for the creation of organisations to address particular needs. This could occur at local levels where village communities decide to form water management organisations without the catalyst of an externally-initiated project or dynamic leadership. It can also occur at the national or regional level when consensus emerges in policy and decision making circles regarding the need for an organisation which then leads to its formation. Examples of this type of formation process include the creation of the US Environmental Protection Agency as an outcome of growing social awareness in the late 1960s and early 1970s. It also includes the recent restructuring of water laws and organisations in South Africa.

The key difference between this and the accretional processes is that it involves the creation of new organisations in response to widely-felt needs that are identified and acted on without the support of an individual charismatic leader or a targeted development project. Since formation in this manner appears to depend on wide social consensus, the development of organisations for IWRM through this avenue depends on building a consensus in advance of starting any action on the ground.

Summary

Empirical observations regarding the way government, private sector, community-based and hybrid organisations work on water indicate that very few emphasise the provision of IWRM services within hydrologic units. In most cases, organisations of all four types supply narrowly focused, highly 'tangible' water services such as irrigation or domestic water supply.

Where organisations do work on integrated management, their actual functions emphasise coordination (between a wide variety of organisations providing focused services), information provision and regulation. Most such organisations exist in locations where water problems are major and threaten the sustainability of regional economies. In addition, most such organisations exist in locations where the institutional terrain is already rich—e.g. a wide variety of focused water service organisations are already present and a broad base of individuals with appropriate training and cultural perspectives are already present.

The development of new or restructuring of old organisations for water management is not a trivial task. It depends heavily on the ability to locate key individuals capable of catalysing change or on the (relatively rare) occasions when widespread social concern and agreement on the importance of an issue create a window of opportunity.

In the next sections we argue that the above observations are not merely a byproduct of history but reflect more fundamental considerations of how people organise around common goals. In essence, 'primary' organisations, the first to form, tend to be narrowly focused on the provision of specific, tangible services precisely because they meet the very tangible needs of individuals for specific water services. While such organisations do involve common efforts, virtually all individuals within a service area benefit directly and have a strong incentive to contribute. Integrated management organisations are rare for good reason: the services they supply are often inherently intangible public goods which provide few, if any, direct personal benefits to the individuals involved. We believe that such organisations are only likely to emerge where local water 'crises' threaten key uses and where the primary institutional terrain is sufficiently rich and professional to create a demand for (and generate understanding of the importance of) intangible water management functions.

THEORETICAL PERSPECTIVES

The purpose of this section is to use current organisational theories to explore where and when different types of organisations are likely to be able to emerge and manage water resources successfully. Most recent theoretical analysis of natural resource management at local and regional levels is contained in the growing literature on common property and open access resources. This literature provides a large and relatively integrated set of perspectives that addresses where and when communities of users come together and create institutions for the management of natural resource. This section will focus first on common property resource management theories. Source this body of theoretical work doesn't fully address the management of natural resources either by the private sector or by the state, the subsequent sections explore insights from other organisational perspectives.

Common Property Institutions

In most cases, integrated approaches are intended to produce an array of public goods through the management of water resources that are either open access or common pool. An extensive literature related to the management of natural resources of this type has developed over recent decades. Most of it focuses on the management of resources at the local level by villages and communities which utilise locally available forest, water and other resources. This literature highlights an array of factors that research has indicated are common to the successful management of common pool resources (see, for example, (BOSTID, 1986; Ostrom, 1990; Ostrom, 1993; Bromley, 1998). Some of the most important factors include:

1. Small, primary management group size often accompanied by the nesting of institutions where some management functions to occur at regional or hydrologic system rather than local scales. This follows from Mancur Olson's frequently quoted passage in *The Logic of Collective Action* (Olson, 1965) in which he notes that: 'unless the number of individuals is quite small, or unless there is coercion or some other special device to make individuals act in their common interest, rational, self-interested individuals will not act to achieve their common or group interests.' It also follows from Ostrom's (1993) argument that scale issues can, at least to some extent, be overcome by nesting institutions;
2. Clear systems of rights or rules-in-use governing access to and utilisation of the resource
3. Clear boundaries of the resource and the user group;
4. Mechanisms to control free riders (including ways to restrict access non-members or those not holding resource use rights);
5. Clear systems for monitoring the condition and use of the resources, including documentation of the benefits from management;
6. Relative economic and cultural homogeneity among group members;
7. A high level of and broadly felt need for management;

8. A proportional equivalence between the costs of and benefits from management; and
9. Effective mechanisms for enforcement.

An important consideration is that many of the factors influencing successful common property resource management appear to be heavily influenced by scale. Research on scale in the social sciences has, as Gibson *et al.* (2000) comment, 'been less explicit, less precise, and more variable' than it has been in the natural sciences. Many researchers working on ecology and population dynamics have, however, found that 'predictions are scale and level dependent and that a single mechanism rarely explains patterns found at different levels' (Gibson, *et al.,* 2000). As a result, models developed to explain phenomena at one scale may not apply at other scales. This may be the case with proposals for common property-based approaches to groundwater management. As the area managed increases, the number of users it is essential to involve in management is likely to increase proportionately. This is likely to complicate monitoring, reduce control over free riders, dilute the homogeneity of the management group and introduce greater number of perspectives regarding the need for and objectives of management. Looking at this problem from a transaction cost perspective is illustrative. If most members of a user group have to agreement on management goals, then they all need to be involved in dialogue and convince each other and themselves that a given objective is both appropriate and achievable. The amount of dialogue and number of meetings necessary to achieve this is likely to increase exponentially with the number of voices and perspectives involved. Where communications are difficult, as they are in many developing countries, the logistical cost of organising could itself be a major factor inhibiting the development of common property management institutions beyond the village level.

Scale considerations may be among the primary reasons why most successful instances of common property resource management, particularly those in developing countries, have occurred at the village or community level. Aquifers and watersheds, however, often occur in areas used by hundreds—and, in some cases, thousands—of villages. As Ostrom points out, the question of scale is not just a physical one. According to him, Olson, one of the original theorists who worked on collective action, 'considers it an open question whether intermediate size groups will or will not voluntarily provide collective benefits. His definition of an intermediate size group depends not on the number of actors involved but *on how noticeable each person's actions are*' (Ostrom, 1990). This represents a particular challenge to the development of water management institutions, particularly those for groundwater management in developing countries, because points of diversion (wells or irrigation channels) are widely distributed, often across private lands, and (most importantly) are rarely controlled by any large organisation. As a result, the actions of individuals are often difficult to monitor or 'notice', even within relatively small physical areas. It is important to recognise that the situation in less industrialised countries is often fundamentally different from that in more industrialised ones. As William Blomquist has documented as the case in California, society can develop institutions responsible for effective groundwater management (Blomquist, 1992). The cases he studied, however, all involved a relatively small number of actors, many of which were well-structured organisations (irrigation districts, agribusinesses, municipal water) that controlled a large number of wells. In this case, the institutions for water users were nested from the scale of a household or individual farm up to large aggregated districts. This contrasts fundamentally with the state in most developing countries, where the fact that groundwater is used by thousands of individuals operating outside of any organisational structure precludes the development of higher level institutions through which individual water use incentives or issues can be aggregated to aquifer scales.

Beyond scale, the conditions for common property resource management may depend heavily on the degree to which the resource itself is structured. Some resources, such as irrigation or drinking water systems and (to a lesser extent) rivers, are highly structured; they have well-defined inlets and points of use. Such systems contain easily identified points for monitoring and control. Other systems, such as forests, can be structured in the sense that their boundaries can be clearly defined and access can be reduced to a limited number of easily monitored points. Groundwater resources, in contrast, are constitutionally much less structured. Its boundaries are difficult to define, its flow is difficult to observe and its points of access are often highly scattered. The lack of structure in groundwater resources can create fundamental challenges for the development of common property institutions. As with scale, the lack of structure is likely to complicate monitoring, reduce control over free riders, dilute the homogeneity of management groups and introduce a large number of perspectives regarding the need for and objectives of management. As Ostrom (1990) points out: 'Organising appropriators for collective action regarding a CPR is usually an uncertain and complex undertaking.... A major uncertainty is lack of knowledge. The exact structure of the resource system itself—its boundary and internal characteristics—must be established... For a groundwater basin...the discovery of the internal structure may require a major investment in research by geologists and engineers.' As any hydrologist can testify, uncertainty in the structure of groundwater basins remains high whatever the investment. In many situations, and particularly where resources for basic hydrological research are limited, the lack of structure may represent a fundamental constraint to management.

Society often responds to complex management challenges, such as those arising from physical scale and structural considerations by developing institutions and technologies gradually. Rights systems, for example, are institutional arrangements for regulating access that have often evolved over long periods of time and have been subjected to gradual modifications as pressures for their definition have changed. In the Western US, for example, European settlers familiar with riparian rights systems developed an appropriate system of water rights to reflect the need, in an arid region, to transport water out of basins. Systems of groundwater rights, the equivalent of these riparian systems have also, in some areas, evolved into 'correlative rights', an approach that attempts to limit volumetric pumping rights developed through prior appropriation to sustainable amounts. Rights systems in the Western US evolved over several centuries of use. Once crudely-monitored 'traditional' arrangements, they are now formal systems with large bodies of case law supported, in at least some instances, by highly-sophisticated technological systems for monitoring. These systems have effectively transformed what was initially an open access resource into a closely-monitored and-structured form of common property. In doing so, at least part of the social and institutional foundation essential for common property resource management was created—e.g. clear, socially-accepted rights systems supported by the types of monitoring capabilities essential to control free riders and restrict access by non-members.

The institutional foundation for common property management of water resources is often absent, particularly in developing countries. Water rights systems which govern access to the resource frequently are neither codified nor, except at the very local level, monitored. Surface and groundwater monitoring systems are often rudimentary; and periods of recording, short. These shortcoming have both conceptual and practical implications. Conceptually, analyses of institutional arrangements for water management often treat society as a slow-moving variable, a stable base on which institutions capable of governing or influencing fast-moving variables (such as the changing conditions of natural resources) can be founded. In many parts of the world, however, societies are changing far more rapidly than natural resource conditions are. In India, for example, the reach of communications and television has penetrated many remote villages in less than a decade. We don't know what the social changes this end to isolation along with economic globalisation, will bring but they are likely to be great. Demographic, projections suggest that India will be more than 50 per cent urban by the year 2020, a fundamental shift from the rural dominance of today. Groundwater levels are be declining rapidly, but the social foundations for management institutions may being changing even more rapidly. As Gibson *et al.,* (2000), interpreting Partha Dasgupta, point out: 'the interface between fast- and slow-moving variables produces some of the important phenomena'(Gibson, Ostrom *et al.,* 2000) Overall, at a conceptual level, it is far from clear that stable institutional foundations for water management can be created given how rapid the social change many regions are experiencing is. Even if the foundations for institutions could be create in the future, on a practical level their current absence reduces the ability to control free riders and, equally importantly, makes it difficult to document either emerging problems or the benefits of management.

The last point is a critical one as common property institutions have tended to emerge where both the need for and benefits from management are clear. IWRM is generally focused on broad objectives, including, for example, sustaining the resource base and protecting of ecosystem functions. The benefits from fulfilling such objectives are often intangible and may not even be seen as benefits by many users. Other benefits—such as arresting the decline of groundwater levels in aquifers—may be more tangible but users may attach little importance to them. The issue of benefits has at least three components: (1) whether or not the benefits from management actually accrue to the individuals who invest in that management; (2) whether or not individuals see and believe in the connection between interventions and benefits; and (3) whether or not users value the benefits they receive. In the case of river basins, for example, maintaining dry season flows in the lower parts of a basin may require conservation by upstream users. In this situation, the benefits of management do not accrue to those who must restrict their use in order to generate them. Even where the benefits of management do accrue directly to users, the connection between the management intervention and the benefit itself is unclear. In the groundwater case, for example, establishing higher energy prices to encourage conservation could reduce extraction. If, groundwater levels rise after high prices are improved, farmers may still attribute the improvements to changes in rainfall or other related factors rather than to the management intervention, in this case the pricing regime. Finally, farmers may not perceive the value of the benefit. This is likely to be the case when management involves reducing demand, or getting of all users to cooperate, or when benefits take the form of avoided costs. Take, for example, the case of demand-side strategies for reducing groundwater overdraft. In this situation, all users must conserve in order to reduce the rate of water-level decline and the benefits that accrue—the avoidance of increases in pumping costs and aquifer depletion—are less immediately tangible than, for example, water flowing through a newly-created irrigation channel.

As the example illustrates, common properly institutions may find demand-side management—a critical component of any integrated strategy—particularly complex to address. Most demand-side management restricts how water is used, often by providing economic incentives for conservation (in which case the group must create these incentives by increasing the cost of water use for its members). This raises obvious questions regarding, for example, the equity of payment structures and the willingness of groups to charge themselves enough to actually affect use patterns. Demand-side approaches can also implement function through formal or informal regulatory mechanisms that restrict, for example, irrigated area, crop types or the use of specific technologies. Since the incentive for individuals to get a free ride may be high, effective monitoring and enforcement mechanisms are needed regulatory approaches may involve changing water rights systems too. When large numbers of people are involved, the transaction costs in terms of friction and conflict within communities and problems achieving enough participation and representation to blind legitimacy to politically contentious decisions are also likely to be very high. As Dahl deserved in a comparison between Greek city states, modern nation states, increasing scale results in major tensions because of limited participation, increasing diversity and increasing conflict (Dahl, 1989). Overall, demand-side management through common property institutions raises a host of questions that can be bypassed if management is limited to small scales or focuses on much more straightforward supply-side interventions.

These observations is a long way in explaining why most water management organisations focus on supply-side interventions. Many local organisations, for example, build and operate irrigation or drinking water supply systems. Where management is a concern, local organisations tend to focus heavily on the construction of structures (such as those for water harvesting) or on physical activities such as watershed treatment. Only

BOX : 2
WATERSHED AND WATER HARVESTING MOVEMENTS IN INDIA

The need for demand-side interventions to address the groundwater overdraft prevalent in many parts of India has been discussed for over a decade (Moench, 1991; Moench, 1995; World Bank and Ministry of Water Resources - Government of India, 1998), but virtually all local initiatives to address water scarcity have focused on increasing supply. In Gujarat, for example, numerous NGOs (VIKSAT, SVRTI, AKRSP and MAHITI) are engaged in water-harvesting activities. In addition, the Swadhyaya Movement, a religious and social reform movement led by Shri Pandurang Shastri, has catalysed large-scale efforts by farmers to recharge groundwater by diverting field runoff into existing dug wells. Although a few NGOs (notably SVRTI and VIKSAT) have tried to promote water-saving schemes, these have not taken off or been adopted by local communities to any great extent.

Community-based efforts to limit water demand are limited to two well-documented instances: (1) the *pani panchayats* of Maharastra, where individuals have agreed not to grow water-intensive crops (Dhawan, 1995; Salunke and Rasal, 1995; CGWB, 1996); and (2) a few sites in Alwar District of Rajasthan where Tarun Bharat Sangh works. In both places, farmers reached informal agreements to limit cultivation of water-intensive crops and, with the support of external actors, made substantial investments in harvesting additional water supplies *(ibid).*

Water harvesting has received national attention in books such as *Dying Wisdom* (Agarwal and Narain, 1997) and in actions such as awarding with Rajender Singh, the leader of Tarun Bharat Sangh, the prestigious Ramon Magsaysay prize in 2001. Similarly, during the drought of 2001, the Central Ground Water Board (CGWB) published numerous advertisements in national newspapers promoting its work on water harvesting and highlighting similar work by NGOs. Demand-side management, in contrast has received no such high profile attention.

in a few instances have local organisations moved beyond supply-side interventions to demand-side interventions. This is clearly illustrated by the history of local movements for water management in India (see Box 2).

The above history suggests that the viability of common property institutions for integrated water management may be inherently limited demand. In addition, the transaction costs of management at an aquifer or basin-scale may be prohibitively high. The institutional foundations of management, such as rights and monitoring systems, are often absent and could require many decades to evolve. This may be a key reason why organisations such as irrigation districts have evolved where the institutional terrain is rich rather than in locations, where it is poor such as is the case in most developing countries. Management benefits are often intangible and accrue to third parties rather than to those who actually invest in particular interventions. Finally, any integrated management strategy requires introducing changes in individual patterns of use of a difficult task for any organisation.

Water Management by the State

The core observation of this section is a simple one: state organisations tend, at least initially, to be involved in providing focused water services, not integrated water management, and this narrow, single-purpose orientation continues to dominate most state agencies. Gilbert White documents the case in the US; where most agencies initially focused on ‘one or two purposes with perhaps a few related aims. Examples include the Corps of Engineers (navigation and flood control), the Bureau of Reclamation (irrigation and power), the Federal Power Commission (power), the Forest Service (forest management), the Soil Conservation Service (soil conservation), and the Bureau of Biological Survey (wildlife)’ (White, 2000). Only later (in the mid-1930s) did these organisations began to focus on multi-purpose objectives. Even now, despite widespread rhetoric regarding basin management and the importance of basin organisations, the Tennessee Valley Authority, one of the worldly first multi-purpose basin organisations, remains the only one of its kind in the US in countries such as India, too, government agencies such as irrigation, public health and engineering departments, focus narrowly on their respective tasks and reject management functions. Watershed management is example of receiving more attention and numerous local movements do support it, but, as Gilbert White (2000) comments, ‘even now, no national programme seeks to conduct representative watershed planning for the entire country.’

Where IWRM is concerned, the roles of the state are often ambiguous and contradictory. The work of Ostrom and others in the common property research stream provides one coherent vision of the role states ‘should’ play. The concept of nested institutions suggests that the state, as one the highest in-country institution, should play a major role in creating the framework within which more local, ‘operational’ institutions exist and function. Among the design principles she identifies for sustainable irrigation institutions, Ostrom (1993) suggests that the state should at the very least recognise the right to organise. It could also play a key role in monitoring, arranging for collective choice, enforcement (particularly of high-level sanctions), conflict resolution (a functioning court system), and the provision of information. The concept of nested institutions also suggests that states should provide high-level institutional arrangements such as formal water rights systems, legal and regulatory structures and possibly economic incentives that affect the value of water in ways that faster management at sub-state levels. Overall, the role of the state should be to structure and circumscribe water resources in a manner that creates the conditions needed for the development of more localised management. Common property theory says little about the roles states *should not* play although the general tenor of the theory emphasises the principle of subsidiary (e.g. locating management at the lowest level of society possible).

In practice, state roles in relation to IWRM are far more variable and nebulous than the roles suggested by common property theory. States often directly implement water projects, particularly those designed to supply specific water services, but they tend to shy away from redistributive and regulatory roles. This bias is very clear in both India and Nepal, the countries where most of the research for this paper was conducted. The government of India, in particular has focused very heavily on activities that support water development but has adopted very few, if any, regulatory actions (see Box 3).

There may be basic institutional reasons why democratic states such as India follow paths that unintentionally undermine the possibility of integrated management. As Gibson *et al.,* 2000) state (citing Peterson, 1981), 'because local governments are under the condition of mutual competition, they pursue more developmental and allocative policies than redistributive policies.' Political parties also compete and, in a parliamentary system, are subject to direct pressure by their constituents due to their need to maintain a majority. The demand-side management of water, a key part of any IWRM approach, is inherently redistributive. As a result, except where broad-based and strong social consensus about the need for water management and a specific demand-side intervention, political pressure is likely to render the change difficult if not impossible to implement. While such pressures may be less in non-democratic states, leaders must have very strong reasons for pursuing unpopular policies. Thus states may be limited in their ability to fully support the regulatory and redistributive aspects of IWRM. In other words, it is unclear whether states can really fulfill the 'high-level' framework functions they need to in order to enable common property management institutions to function at local levels. Thus, while the concept of nested institutions is clear, how it could be made operational is far less so.

In addition to political and institutional constraints on integrated management, other considerations also apply to the role of the state. In Ostrom's view of nested institutions, the

BOX : 3
STATE ROLES IN GROUNDWATER DEVELOPMENT AND MANAGEMENT IN INDIA

India's support for groundwater development took off in the 1960s, when irrigation was identified as a key lever for increasing food production and catalysing rural development. This support grew in the 1970s and 1980s as part of the 'green revolution' and has continued to the present. Key state roles in relation to groundwater development have included:

1. Provision of subsidised credit for wells and pumps through the National Bank for Agriculture and Rural Development;
2. Extension of the electricity network into rural areas;
3. Provision of electricity for irrigation pumping at highly subsidised rates (free of charge in some states). For much of the past three decade, diesel for irrigation and other uses; has also been subsidised
4. Resource monitoring, technical support and a limited amount of drilling (particularly for drinking water) through groundwater agencies at central and state levels.

Support for groundwater development has led to an exponential increase in the number of wells in India. Since the early 1950s, the number of mechanised wells has increased at an annual rate of roughly 13 per cent. Now power consumption by agriculture, most of which is for groundwater pumping, exceeds 30 per cent of total power consumption in many states. In some states, such as Haryana, it exceeds 50 per cent (World Bank and Ministry of Water Resources , Government of India, 1998). Overdraft was first raised as a concern in some hot spots in the mid-1970s only emerged as a major concern in the mid1990s (Moench, 1992; Moench, 1993; Dhawan, 1995; CGWB, 1996). Today water levels in many arid regions are dropping at rates that average 1m/yr over large areas; some small locations report much higher rate.

Dropping water levels has led to many calls for increased regulation and management of groundwater resources. The CGWB circulated a model bill for groundwater regulation as early as 1975, but it was never adopted in its entirety by any state. More recently, the Supreme Court of India mandated the formation of a groundwater authority to regulate extraction and manage the resource base. The CGWB was in consequence designated as an authority and now has much greater responsibility for promoting management and encouraging state governments to form authorities capable of regulating groundwater usage. Actual regulatory actions have, however, been minimal. Substantial attention has been given to the role of subsidised power in encouraging groundwater overdraft. The World Bank, along with other organisations, is actively promoting the reform of the power sector. Reducing power subsidies to agriculture is a major emphasis (Moench, 1995). Other subsidies, in particular those for new wells, are also seen as a point of leverage. Although regulations have been in place for several decades, restricting subsidies to areas with sufficient groundwater resources, enforcement has been patchy at best.

Groundwater regulation and the reduction of subsidies that encourage over-development are politically problematic. Some authors argue that regulation is more a source of corruption than an effective tool for management (Dhawan, 1989). Political attempts to limit credit flows to areas where overdraft is a concern have pressured groundwater organisations to manipulate basic data, thus allowing subsidies to continue (Dhawan, 1990; Moench, 1991). Attempts to reform power prices have also been politically difficult and have generated substantial opposition (World Bank, 1999; World Bank Study Team, 2001). Much of the problem may be due to the nature of politics in India: subsidies for power and water generate votes; regulation doesn't (Moench, 1994). There is, as a result, an inherently political tinge to all debates over the relative benefits of water management and water development, however unsustainable it may be. Government departments wishing to maintain the support to their constituencies often limit access to basic data and seek to maintain their roles as developers. Little practical attention is given to questions of water rights, conflict resolution or the larger framework within which local areas could develop effective common property institutions for groundwater management.

state is an enabler. The alternative is that the state be a doer, a primary implementer of IWRM activities. States are multi-functional institutions, composites of numerous departments and organisations that are, in effect, agents of the state. Each agent has its own structure and agenda, one that (as with political parties) frequently conflicts or is in competition with the structure and agenda of other agents. This often takes the form of battles over budgets, staffing or the philosophical approach to programmes and activities. Such competitions renders the coordination of the many departments and agencies represent a major challenge. As White (2000) points out in his analysis of US water management history during the 1900s, 'there is strong social resistance to incorporating all related social aims in humans' use of the environment into one coherent programme. It has been practicable to organise separate programmes for irrigating dry lands, making streams navigable, controlling some floods, promoting forest growth, preserving fish populations, countering severe soil erosion, and reducing water pollution. But it is very difficult to combine all of those aims in a single programme or set of objectives'. Internal bureaucratic competition may constrain the extent to which integrated management can be implemented, at least where it requires extensive coordination between departments. The alternative, making most water management activities that require integration fall under one single department of IWRM (the approach effectively promoted in the water resource consolidation projects supported by the World Bank in India), is equally problematic.

Combining functions into one department will centralise policy and decision making and complicate issues of participation and representation. If the department focuses primarily on the legal, regulatory and planning 'framework' aspects, then it will face the issues raised by Gibson *et al.* (2000). If, instead, it combines those functions with actual implementation (e.g. the construction, operation and maintenance of facilities), other challenges are likely. Among the numerous potential issues, two are particularly important: transaction costs and organisational capacities.

Transaction Costs

The transaction cost point is a simple one. Recent work on transaction costs in the business literature suggests that 'because of the added bureaucratic costs that *unavoidably* attend the decision to take a transaction out of the market and organise it internally, the firm is advised to integrate only for 'compelling reasons' (Williamson, 1999). Williamson goes on to state that 'Because internal organisation experiences added bureaucratic costs, the firm is usefully thought of as the organisation form of last resort: try markets, try hybrids (long-term contractual relations into which security features have been crafted), and resort to firms when all else fails (comparatively).'

This same argument applies even more strongly to attempts to create large centralised organisations capable of undertaking the multiple functions central to IWRM.

Organisational capacities

Theories of business organisation, particularly those which focusing on organisational culture and notions of core competence, provide important insights into the challenges any integrated approach is likely to face. The first point is that 'culture matters' (Ellis and Thompson, 1997). Virtually all proposals for initiating IWRM involve the reform of existing water organisations and institutions. Water organisations, most which have been involved in development for decades, generally have strong engineering cultures. They are typically hierarchical and have virtually no culture of participation or collaboration. The implementation of integrated management, however, requires a highly participatory social process (GWPTAC, 2000). This necessitates making a radical change in the nature of state water organisations. As Marcussen (2001) points out:

> 'Culture is in a company's background, attracting and energising those who feel comfortable with it, perhaps repelling others. Over time, culture develops norms, practices and folklore that enhance its strengths but that can also get in the way when radical change is required.'

A second point is that the core competencies and culture of most government water organisations are, in many instances, diametrically opposed to the core competencies required for IWRM. Resource-based theories of the firm are based on the assumption that firms own different resources and that this enables them to develop different strategies but that 'strategies that are too far from the firm's competencies and capabilities are inherently risky' (Javidan, 1998). Competencies are derived from two things, resources and capabilities. Resources consist of physical and capital assets, human resources (including management, training and experience) and institutional resources such as culture and reputation. Capabilities are functionally-based and refer to the ability of a corporation to exploit its resources (Barney, 1991; Javidan, 1998). Most government water development organisations lack both the resources and the capabilities to implement IWRM. Their manpower often lacks the organisational management capabilities, training and experience required. In addition, their culture and reputations are generally ill-suited to participatory processes. Furthermore, most lack the functional capabilities necessary to redeploy existing resources to fundamentally different sets of activities. Most government organisations are, for example, bound by bureaucratic rules. They cannot easily replace existing staff after work and decision making rules. As a result, they cannot easily change their functional capabilities in ways required to develop fundamentally new competencies. IWRM, because it requires fine-tuning activities to local conditions, generally demands that a community be skilled in dialogues and organising and have the freedom to negotiate and make a wide range of decisions. Staff in water development organisations such as irrigation departments generally lack the skills, mind-set and decision making authority to fulfill these functions.

To development new competencies—the obvious response to the gap—is no minor task. Studies of attempts by private sector firms to bring about changes indicate extent of the challenge (Liedtka, 1996; Javidan, 1998). States which attempt to restructure existing hierarchically-structured water organisations so they can fulfill integrated management functions face similar problems. Most state organisations evolve by accretionary evolution, the addition of new functions to a pre-existing and complementary core set, yet the collaborative functions required for IWRM, generally conflict with the existing mind-set, skills and organisational context. As Hendry (1999), drawing on Douglass (1992), states, 'hierarchical collectivities are uniquely ill-adapted to change. Their natural tendency is to respond to threats by reasserting control and strengthening the authority structure.' As a result, attempts to add the new functions to existing state water organisations are likely to fail.

To summarise, our analysis, which is based on both theoretical considerations regarding the nature of a state and practical examples of state activities, indicates that state roles in water management reflect fundamental considerations regarding the nature of human organisation as well as logistical or process considerations such as capacity and recent regional history. States are institutions that grow in a gradual, evolutionary manner, and is true of as all human organisations, respond to stimuli. Water management capacities only emerge where water-related constraints make a significant impact on society and draw the attention of users and charismatic leaders. State responses, whatever form they take, generally focus narrowly on constraints rather than on the wider question of integrated resource management. As a result, state capacities evolve by accretion in a limited manner changes rarely stem from any initial integrated vision. State interventions also tend to emphasise solutions, however partial or inefficient, that are developmental rather than re-allocative. These interventions bring immediate and tangible benefits with as latter disruption as possible.

States are reactive, rather than proactive, institutions. At best, states respond to the *demands* of society and not to its *needs*. As a result, any management paradigm founded on an image of the state as a proactive 'visionary' player is likely to fail. This is, perhaps, a fundamental flaw in the concept of IWRM. Integrated management requires proactive, 'visionary' leadership which can identify needs and respond to changing demands *before* stress results in irreversible damage to basic resources and states just don't provide it.

Private Sector Involvement in Water Management

Countries throughout the world have begun to emphasise the private sector and the role it could play in delivering many of the services that governments often provide. Water management—or more correctly water delivery and disposal—is a major focus of current efforts at privatisation. In many countries, public water supply utilities are being privatised or, particularly in the case of irrigation systems, turned over to users. Given the inadequacy of states in providing IWRM, it is important to reflect on the wider potential of the private sector.

On a conceptual level, private sector organisations tend to emerge where clearly defined clients with the willingness and ability to pay demand a fairly clearly defined service or product. While many elements of the water management equation could easily be provided by private organisations, significant questions about granting the private sector a leading role exist.

1. **Conflicts with the fundamental theory of the firm**: According to Ostrom (1990), 'In the theory of the firm, an entrepreneur recognises an opportunity to increase the return that can be achieved when individuals are potentially involved in an interdependent relationship. The entrepreneur then negotiates a series of contracts with various participants that specify how they are to act in a coordinated, rather than independent, fashion. Each participant voluntarily chooses whether or not to join the firm, but gives up the entrepreneur discretion over some range of choices. The participants become the agents of the entrepreneur. After paying each of the agents, the entrepreneur retains residual profits (or absorbs losses).' In the case of IWRM, the increased return is, essentially, the diffuse set of benefits that flow to society as a result of management activities. These are often difficult to capture (a challenge that relates to the next issue: the lack of a clear clientele). Furthermore, the entrepreneur (or in this case, manager or management organisation) is often not in a position to negotiate contracts with water users. Many may not want to join in management voluntarily or to become, in effect, agents of the management organisation.
2. **The absence of a clear clientele**: While the clientele for some water management services can be clearly defined, in many situations, water management is intended to produce an array of public goods whose benefits accrue to diverse and mobile sections of the general population as well as to more narrowly-defined interest groups. Water use, particularly in the case of groundwater, tends to be highly dispersed and localised. Unlike, for example, energy, which is managed almost entirely by narrowly-focused and highly professional utilities, the water sector is fragmented and often composed of many small users with letter ability and little incentive to pay for management services. From the perspective of a private sector organisation, there is no clear clientele, except possibly governments, which has the incentive to pay the cost of management.
3. **The absence of a clear product**: The product from water management initiatives is often poorly defined in the minds of the dispersed sets of beneficiaries. Water supply activities generate clear, tangible, products, like water flowing out of a tap or irrigation

channel. The products of water management are, in contrast, often far less tangible. They take the form of, for example, avoiding diversions from streams or ensuring the sustainable use of an aquifer. Those who ultimately benefit most from the sustainable management of water resources often have no direct contact with the resource base or its use. Take the case of food security. The ability to sustain high levels of grain production during droughts, and therefore possibly to stabilise food availability and prices, is particularly beneficial to the poor, many of whom live in urban areas. Maintaining grain production in years of low precipitation often depends on the sustainable management of groundwater resources, which is, in many areas, the primary buffer against drought. Many beneficiaries, such as the urban poor are unaware of how important groundwater is in their own situation and therefore have little direct incentive to support sustainable management. The product of groundwater management, in this case food security, is not clear in minds of beneficiaries, nor would they bee keen to pay for it through higher average food prices. To further cloud the situation, the availability of grain and the ability of the poor to purchase it are dependent on a host of factors (such as trade and income opportunities) that extend beyond production dependent on local groundwater. As a result, whether or not sustainable water management actually results in food security benefits can be unclear. This example is typical of many situations which involve the benefits of water management.

4. **The political, value-laden, nature of management objectives and the tradeoffs necessary to achieve them**: Water management is highly value laden. Objectives such as 'sustainability' or the maintenance of specific environmental characteristics are highly valued by some sections of the population but and viewed as ridiculous or inappropriate by others. Furthermore, objectives (such as the maintenance of in-stream flows) frequently clash with deeply embedded patterns of behaviour (such as the right of upstream populations to divert water for their own use). As a result, management objectives are often, highly political. Achieving them objectives is also often highly political since, particularly in the case of demand-side management, it requires changing water allocation, use economics and socially or legally embedded behavioural patterns. Private sector organisations are poorly suited to be forums for the types of social dialogue and negotiation necessary to define objectives or implement approaches. Such debates are more suited to governance arenas, i.e. the state and the political processes through which it operates. Thus, private sector organisations cannot play a leading role defining management objectives or approaches although they can and often do fulfill functions essential to management.

An examination of the role of private sector organisations in water management around the globe reveals a pattern of intense involvement in targeted functions where, as is true for states, products and clients are clear. The private sector is actively involved in the construction and operation of water facilities (irrigation systems, drinking water systems, sewage systems, water harvesting structures, etc.) as well as in consultation and information provision. Client are not, as often as not, government. Private clients are often motivated by the need to meet government regulations rather than by any interest in water resource management *per se*. The products of private sector organisations tend to be narrowly focused—water supply or sanitation services or, in the consulting case, reports and information tailored to the needs of specific clients. In no case we are aware of does the private sector playing a leading role in IWRM. In fact, there is no logical business model for such a role.

Integrated Management and Theories of Social Organisation

The above sections point toward a core question about IWRM that has not been adequately addressed either in theory or practice: does water management, particularly 'integrated' water management, fall in a section of institutional and organisational space that human society is ill-equipped to address? To put it differently neither the goods produced by integrated water management nor the conditions under which it would need to be implemented fit well with the effective functioning of any of the three organisational forms which ordinarily provide society with specific types of private and public goods. Figure 3 in view point by Marcus Moench illustrates the challenge.

The 'natural' spheres of activity for community-based, government and private sector institutions, while they overlap to some degree, are largely district. Community-based institutions emerge and function in the array of conditions which two to three decades of research on common pool resource management have identified. In developing countries, most community-based institutions function at the village level, far below the scale essential for managing aquifers or river basins. Furthermore, unless key conditions (like a clear user group and the ability to control free riders are met) such institutions are unlikely to function effectively. In contrast, state institutions for natural resource management tend to operate effectively at regional scales but have great difficulty in regulating or influencing individual and group behaviour and in responding to the diversity of conditions and management needs at local levels. There is also an inherent tension between the centralising hierarchical requirements essential for coordination and the participatory, collaborative requirements necessary to get communities 'buy into' management. Furthermore, the capacity to engage in participatory social processes falls outside the core competencies of most state water development organisations and the development of such capabilities is complicated and runs counter to basic organisational incentives. As a result, state organisations have a limited ability to influence water demand and to tailor management approaches to conditions in individual aquifers or watersheds. On a more fundamental level, as we argued elsewhere, state organisations are generally reactive: the emerge in response to demands within society rather than to more broadly defined needs. The failure of state based central planning models, of which IWRM may be a microcosm, points to a core limitation in the ability of states to manage complex systems on a long-term basis. The private sector requires that there by clear products targeted to the demands of clients, who, in turn, are willing and ability to pay. These requirements are absent in many water management contexts. The situation is complicated by the highly political, contested nature of management objectives and the interventions required to achieve them. All this points to a disjuncture between conceptual formulations of the need for IWRM—formulations which tend to have been produced by water management, rather than social organisation, specialists—and the way different components of society function. In essence, the model of IWRM does not 'fit' well with common—and probably inherent—features of social organisation.

A Cultural Theory Perspective

One way of thinking of the disjuncture between the requirements of IWRM and organisational characteristics is in terms of scale and style. Organisations capable of functioning in an integrated manner at a large-scale tend to be hierarchical. They have a central point of organisation and relatively clear lines of communication and command. This style works relatively well for focused tasks involving a limited array of decision makers. They are recognised as being well-suited to coordinating labour on a lagre-scale (Jacques, 1990; Hendry, 1999). As management grows more complex, however, hierarchical organisations fare less well; their ability to address details and nuances is limited by information flow and processing. Furthermore, hierarchical organisations struggle to 'push' actions through at the grassroots level and to sustain interventions. This last ability depends on being able to reach a consensus with elements of society outside the hierarchical collective. Organisations find this ability difficult to develop and in facts, often see it as a threat. Community-based (or egalitarian) organisations face a different problem. While they often grow out of local consensus regarding problems and management needs, this type of consensus tends to erode as scale increases. More people mean more perspectives, more debates and far higher transaction costs in reaching any management decision. Reaching a consensus regarding the management of an aquifer, which may underlie hundreds to thousands of villages is, problematic. At this scale, egalitarian debates often become embedded in other issues—questions of power, conflicts with hierarchically-organised units of the state, debates over who decides, and access to water itself and to the decision making process. As a result, little real movement occurs.

The dissonance between hierarchical and egalitarian modes of organisation is exacerbated by the growing presence of individualistic, market-based modes of organisation in water management and many other aspects of society. Hierarchies (whether government agencies or private corporations) compete with each other and with egalitarian forms of organisation in a context increasingly shaped by individualistic actions within a market. Beyond the formal market competition to supply water services, there is competition for people (individuals now have far more ability to move out of villages or out of government jobs than before), power (government agencies compete with each other for position, budget, etc.), and legitimacy. Whether the unit of market transaction is money, votes, or people, organisations of all types are operating in an increasingly competitive environment.

The work of Mary Douglas and others in the cultural theory stream points to a 'fundamental cognitive conflict between the legitimating logics and moral orders of her different cultural types' (Hendry, 1999). Since IWRM requires that market-based, hierarchical and egalitarian styles of organisation collaborate, it may face an insurmountable hurdle.

Summary

The above somewhat speculative analysis points out certain basic gaps in our understanding of social organisation and how it relates to the way in which emerging water and many other natural resource problems can be addressed. First of all the very starting point at which problems are defined as 'management' challenges may be fundamentally flawed. While it is beyond the scope of this paper to explore the disjuncture between patterns of social organisation and a 'management lens,' some of the most significant gaps are:

- **The functional boundaries of various types of organisations or social structures have been poorly explored in relation to IWRM:** Integrating the management of aquifers or river basins requires performing certain sets of functions (regulation, the creation of economic incentives, education, stakeholder dialogue, scientific monitoring and analysis) across administrative boundaries (national, state and district lines) and a range of geographic and time scales. As argued above, *these functions may harmonise with the private sector, community-based, government or market organisational forms found in most countries*. Only in a few locations, such as the Western US, are hybrid, 'intermediate-level' organisations capable of functioning at the scale of hydrologic units such as irrigation districts common. The functional limitations of different organisational types appear to stem from key issues in the water management equation including:
- **Incentive gaps:** The incentives organisations have to implement integrated management approaches have not been carefully investigated. There are clear reasons why community, government and private sector organisations—and the individuals within them—have little incentive to implement management approaches. These include the political unpopularity of many types of management interventions, lack of social demand for management, the long wait before seeing results, and a process of dynamic change rendering the effects of management unclear.

- **Tangibility gaps:** Organisations are rewarded for high-profile interventions whose results can be easily understood. While this is generally the case with activities which create new supplies, many of the most effective demand-side management avenues are indirect and intangible. The result is a major tangibility gap.
- **Gaps in ability to control (either top down or bottom-up):** Demand for water ultimately depends on the actions of highly dispersed individual users. Organisations of all types are severely limited in their ability to control individual behaviour.
- **The limited social capacity available for staffing organisations with individuals capable of fulfilled an integrated management mandate:** Managing water resources in an integrated manner implies the development of government, private sector or community-based organisations with the capacity and vision essential first to understand and then to intervene effectively in complex, dynamic and highly political situations. Furthermore, to be able to adjust their strategies as conditions change organisation need flexible individuals trained to work in an interdisciplinary and participatory manner change. Even in industrialised societies, these capacities are scarce and can only be marshalled in a limited number of high priority situations. In developing countries the absence of this type of social capacity is often highlighted reason attempts replicate pilot projects fail. Management models that require capacities that are unavailable are flawed, at least until such capacities can be developed.
- **The key role of individuals has been observed but not yet incorporated into organisational theories related to water management:** The personalities, relationships, attitudes, legitimacy and history of individuals have a huge influence on whether or not management is successful, but this role is almost never explicitly discussed or effectively addressed in organisational theories. Minds are recognised as scarce resources in the analysis of economic organisations (Williamson, 1999), but they are rarely discussed in the context of water management organisations. If the characteristics of key individuals are of fundamental importance to IWRM, then processes for replicating and selecting such individuals need to be a core part of organisational and institutional theories.
- **The evolutionary nature of organisations in response to stimul's and need is poorly reflected in management theories**. Management theories envision far-sighted, rationalist and planned responses to the short- and long-term needs of a particular resource, in this case water. Society, however, has limited resources and faces multiple demands on its resources and its attention. It generally responds in a fragmentary way to problems or constraints. As a result, the capacities of management organisations tend to develop gradually by evolutionary accretion. The reasons for this fragmented evolutionary response may reflect certain fundamental features of social organisation as well as very rational reasons for, at least initially, avoiding more comprehensive interventions. Society forms organisations or implements management approaches only

> when social consensus regarding the nature and importance of specific problems *and* the actions necessary for solving them reaches high levels. Consensus is more difficult to create for broad-based integrated management initiatives than for immediate and narrowly-focused concerns. Rational reasons for avoiding large-scale integrated approaches include; 1) *uncertainty* (when systems are poorly understood and outcomes unknown, it may make sense to focus narrowly on constraints rather than on complete management); 2) *focus* (organisations often function better when they are focus narrowly on specific tasks, such as the provision of irrigation; 3) *discounting* (alternative investments may have higher returns); and 4) *lack of management resources* (individuals with the required capacities, scientific data, etc.). Taken together, the process of organisation and the rational reasons for delaying integration indicate that there is major gaps between the theory of integrated management and the way social organisations evolve.

Overall, the disjuncture between concepts of integrated management and patterns of social organisation is great. This suggests a potentially fundamental flaw in using the concept of IWRM as the primary paradigm for responding to emerging water problems.

From a water resource perspective, IWRM may be the technically correct approach. Technically correct approaches are, however, irrelevant if their applicability is limited by fundamental constraints with regard to the process and nature of human organisation. The flaw in a technical approach may lie as much in its social viability as in scientific foundations. Other approaches ones that reflect the 'reactive,' piecemeal nature of social organisation may, while possibly being less optimal technically, be more effective.

LIMITS OF INTEGRATED MANAGEMENT

The above arguments suggest that the effective implementation of IWRM approaches may, for fundamental reasons related to the nature of human organisation, be confined to a limited array of conditions. Integrated management requires a very high degree of social consensus regarding the necessity of management and practical mechanisms for achieving management goals. It may only be possible in locations where institutions have already evolved substantial management capacity and a culture supportive of management through a prior history of attempts to manage narrowly-focused problems. The availability of charismatic individuals with the necessary vision and leadership qualities to catalyse collaboration between individuals and organisations may also be a prerequisite. Finally, effective management requires that there be basic data about and scientific understanding of the resource base and its dynamics along with the social and economic factors influencing water use. At least in the immediate future, such conditions are only likely to be fulfilled in a very limited number of very high priority situations, such as where water problems represent serious and immediate threats to the availability of supplies for major urban centres or critical agricultural regions. These conditions are far less likely to be met in the vast majority of regions, where water problems represent a persistent and often long-term concern but have relatively little immediate implication for individuals or high-profile environmental resources. In such locations, management responses are likely to be fragmentary and often limited by political palatability and the cost of potential interventions.

The above considerations explain, to a large degree, the variation in management interventions found in different locations in South Asia and in other parts of the world. In most situations, society has responded to water scarcity by focusing on easily implemented and politically popular supply-side interventions. The high-level attention now being given to water harvesting in India is typical. While technical research has consistently indicated the necessity of demand-side management as an equal (or dominant) element in attempts to address groundwater overdraft and other water scarcity concerns, a large proportion of financing, policy changes and field implementation activities focus on water harvesting. Legislation allowing the regulation of groundwater has only been passed only in a few states. Furthermore, where such legislation has been passed, its application is restricted to a limited number of conditions. In Maharashtra, for example, extraction can be controlled legally only if drinking water supplies (the highest priority use) are threatened. Government departments and NGO activities emphasise water harvesting over all other types of intervention. The Central Ground Water Board (CGWB) for example, has adopted a major water harvesting programme and has produced many publications highlighting its activities in this area CGWB Board, (1996; 2000). In contrast, CGWB's activities in promoting effective demand-side management have been minimal despite its recent designation as a national 'groundwater authority' with responsibility for promoting legislation and regulation. In addition, little progress has been made in implementing effective economic incentives to encourage demand-side management. Electricity prices for groundwater pumping, for example, are highly subsidised and generally structured on a flat-rate basis. In some states, power for pumping is provided free of charge. In others, even where the total amount charged is a significant fraction of the service cost, the flat-rate annual payment (which means that farmers face declining average costs) provides no incentive to conserve water once it has been paid. The role of power-pricing in encouraging groundwater overdraft has been a major policy concern for over a decade but actual movement toward full-cost pricing has been limited.

Beyond the above issues, debates over the status of groundwater resources are perhaps the most telling indication of the problems facing the integrated management of groundwater resources in India. The CGWB is supposed to publish regular reports on the status of groundwater resources throughout the country. Although information for this report is readily available in the organisation, the last publication was in 1995—and that was based on data from 1989-90 (CGWB, 1995). According to scientists at the CGWB, publication of more recent information has been blocked by disagreements with individual states about how to analyse and present the data. This points to a serious lack of consensus regarding both the extent of groundwater problems and, more fundamentally, the actions the government of India should take to address them. Virtually all demand-side management interventions would require re-pealing politically-popular subsidies and imposing politically-unpopular regulation. Since publishing an updated assessment of groundwater conditions would probably focus attention on such issues, politicians and the government have strong incentives to delay publication until growing social consensus at the grassroots level forces them to act. For a variety of reasons, consensus may never be reached and, as a result, the political conditions essential for implementing demand-side management may never be created. It is far easier to focus on popular, 'do-able,' projects such as water harvesting.

The patterns seen in India are common in many other parts of the world. In the Western US, water experts joke that 'if you have a water problem, pour water on it and it will go away.' Extensive regulation of groundwater extraction has occurred only in a relatively limited number of high-profile locations, such as southern California and the 'active management areas' in major cities in Arizona. Even in such areas, the political consensus supporting demand-side management was only achieved using the carrot of new supplies. A few countries, notably Jordan and Israel, have developed and implemented national-level institutional and economic structures for demand-side management. These countries are, however, two of the most water-stressed in the world and there is widespread social and political consensus regarding the fundamental importance of IWRM.

BEYOND MANAGEMENT: AN ADAPTIVE RESPONSE APPROACH

Previous sections of this paper highlighted the limitations of IWRM and our introduction pointed toward 'adaptive' approaches as a complement and, in many situations, an alternative. What does this really mean? Our starting point is philosophical and conceptual, but this foundation leads toward practical courses of action.

Before moving on, it is essential to re-emphasise that our reservations regarding IWRM *are not equivalent to rejecting the need for and possibility of management interventions.* Instead, on point is that the goal of comprehensive integration is likely to be both unachievable and often undesirable. Instead, more fragmented opportunistic management or other response strategies often make more sense and, equally importantly, are far more achievable. A recent book compiling twenty-eight water management success stories in California represents a case in point (Wong, Owens-Viani *et al.,* 1999). Only two of the success stories discuss 'integrated' or 'comprehensive' approaches to water management.

All the others involve locally-tailored sets of interventions designed to achieve specific, local objectives. From the perspective of true integration or comprehensive management, these initiatives are fragmented and not part of any consistent approach to water that applies over a watershed or other hydrological unit. From our perspective, they represent opportunistic dynamism—a plethora of adaptive responses that take advantage of opportunities inherent in local contexts.

A Philosophical and Conceptual Starting Point

The philosophical starting point for our approach to water problems rests on an evolutionary view of human society and a perspective on water resource systems that emphasises their dynamic, variable nature.

An Evolutionary Perspective on Society and its Institutions

At its root, our view of society is an evolutionary one, it is a view based on theories of evolution driven by the processes of innovation, competition, contestation, selection and implementation. Human society and the institutions and organisations which comprise of are dynamic: it is constants undergoing a rapid evolutionary change. This complex change is reflected in social mores, demographic shifts, economic globalisation, technological innovation and a host of other developments. The nature and direction of the change is not random; it is a product of contestation and selection. Individuals, groups and institutions continuously contest the views and directions of others as they seek to mould the world to meet their own material or cultural objectives. As one or a group of social voices dominates, the institutions or directions they advocate are selected and the direction of change shifts toward their objectives.

As with any evolutionary perspective, process is of fundamental importance. Where society and its institutions are concerned, the evolutionary process is itself a product of four sub-processes: ***innovation, contestation, selection*** and *use*. Innovation, the generation of new ideas, is the social equivalent of genetic mutation. It is the most fundamental point where the 'new' is created. The process of contestation, in which ideas compete for resources and social legitimacy, is the sieve that separates viable innovations from those than end up in the proverbial dustbin of history. It is also the basic mechanism by which problems are identified, opportunities emerge and demands are articulated. Selection, the step from demand to action, is as important as the first two processes. It is the process of choice. In economics, it is the transaction, the mechanism that determines what will actually be done. Finally, there is use, the process of doing or using that which has been selected. Remove innovation, efficient, competition driven contestation, an unbiased mechanism for selection, and transparent use or implementation and society will, almost inevitably, take courses of action that poorly reflect problems, demands, opportunities and options. The most fundamental points of leverage for addressing social need (whether it is related to water or to other issues) are, as a result, those that catalyse innovation, encourage competition, and enable or guide the processes of contestation, selection and use. This view of society is nothing new. It is closely related to a broad stream of literature about economic organisation and sociology that draws on concepts initially developed in evolutionary biology.

Human organisations, made up as they are of individuals, each with his own objectives and perspectives, are embedded in the process of evolutionary change. Except in rare cases where one set of voices clearly dominates, states and other institutions are themselves contested terrains. As a result, rather than being able to articulate a clear, long-term unitary direction, their courses of action reflect the evolutionary pressures they face from within (driven in part by the perspectives of leaders and staff) and from without (driven by competition and contestation). Society's institutions are inherently clumsy. Organisations tend to developed to serve narrow missions and then they either fade as social demand for their functions wanes or the add functions by 'accretion' as new demands emerge, opportunities arise or staff and leaders change. Organisations also change course (at least temporarily) as leaders who reflect different sections of society take command or (more fundamentally) as new cadres of employees, trained and educated in a new context, are hired and subsequently modify the culture of the organisation. Organisations respond well to constraints or to targeted needs in essences, the points in social space where consensus exists within the larger process of contestation—but, in the absence of key individuals to provide leadership, they rarely react to larger or more abstract concepts where consensus is difficult to develop. Even where strong leadership exists, organisations are rarely able to sustain their focus over the period of time essential for managing long-term, complex management problems. Social pressures change, cultures evolve and leaders or staff move on. As they do, alternative competing perspectives emerge, causing organisational directions to shift. The net result is that institutions and organisations, when viewed from the timescale of natural processes, are inherently reactive—clumsy, evolving organisations in a clumsy, evolving society.

The importance of systems

The reactive, evolutionary nature of society and its institutions place it firmly within the conceptual frameworks developed for understanding ecological systems and processes. Humans and their social institutions are driven by the same competitive pressures that cause other organisms to adapt. Like many other natural organisms, humans often respond to competition or problems by adapting. This is both a strength and weakness. As argued above, society is poorly structured to manage—in the sense of control—resources effectively over the long term. It is much better at adaptation—reacting to constraints or system characteristics than at proactively changing whole systems to meet it needs. The position of humankind within systems has another important implication: people experience problems when the systems on which they depend are suddenly disrupted or unexpectedly fail. Adaptation on the other hand, is often possible only if systems evolve gradually. This building the resilience of society its ability to respond to rapid change or catastrophic failure is central to the proposed adaptive approach.

Given that the nature of human society to inherently adaptive, it may be suggested that humans are more likely to be able to address water problems by adaptation, living with nature, coping with predictable disruptions, and building the resilience of their support systems than by managing the resource base in a comprehensive, integrated manner. The argument here is both philosophical and pragmatic. Philosophically, we see human society as an integral part of natural systems, a part that should work within the framework of those other systems rather than attempting to control them. Pragmatically, as argued above, we don't see a dominantly reactive human society as having the capacity to 'control' or manage complex and dynamic natural systems except under a relatively narrow range of conditions.

A Dynamic Perspective on Water Resources

Our perspective on water resources is similar to our perspective on the nature of society in that it emphasises dynamic variability, extreme events and ongoing processes of change as the defining characteristics of systems. This contrasts with the traditional emphasis on means (or averages) and bounded variability as core system characteristics.

From this perspective, water resources are one aspect of a dynamic and changing hydrometeorological system. Whose fundamental defining characteristics are fluctuation and variability. This variability shapes the environment *within which* human and other ecosystems exist and *to which* they are adapted. While statistics on rainfall, stream flow and other similar parameters help us understand the range of short-term variability, they provide at best limited insight into long-term variability and the frequency of extreme events. Even where long-term records are available, hydrological systems can't be fully characterised because they are changing in concert with wider climatic changes. The target is constantly moving as the system changes. More importantly, the 'here and now' products of variability are the primary factors affecting water availability for people and the environment. Rice seedlings don't care if the average rainfall for the region is 1,000 mm, what they notice is that it hasn't rained in two weeks. Averages are close to meaningless in the context of dynamic fluctuating change. Even in the normal flow conditions of the Himalayan rivers averages have little meaning.

In addition to doing nothing, two courses of action are available in response to water related constraints. The first is to manage the resource base by attempting to modify variability and change within set bounds that meet objectives for water supply, stream flow and so on. This is the traditional approach. The second is to recognise variability and change as inherent, ecologically-important parts of hydrologic systems and attempt, wherever possible, to adapt our uses and needs in ways that respond appropriately. Philosophically, we see approaches that attempt to adapt human use systems to the characteristics of natural systems as part of a fundamental respect for the ecosystems of which we are a part. Pragmatically, while society may have the capacity to respond to immediate problems, it lacks the capacity to manage dynamic, changing hydrologic systems. In most regions, records are short-lived (and are of questionable meaning given the nature of climate change), hydrological information is limited, institutions are weak and the politics of water are complicated. Society doesn't, on a practical level, currently have the capacity to constrain variability and thereby 'manage' water throughout most of the world. Proactive response to variability and change—targeted actions to immediate challenges as part of an overall philosophy that emphasises adaptation—is much more achievable.

From the Philosophical to the Practical

At the beginning of this paper we defined an adaptive approach to water as one that increases society's ability to live with the natural characteristics of hydrologic systems (i.e. encourages adaptation) and attempts to increase the resilience of social, economic and environmental systems to predictable water problems while utilising only limited and carefully-targeted interventions to directly control or 'manage' the water resource base and its use. The goal of an adaptive approach is to ensure that, within the process of evolutionary change, systems are sufficiently resilient in the face of water-related disruptions to be able to maintain production of the basic social, economic and environmental services on which we all depend. On a practical level, this implies that what an 'adaptive approach' comprises—as what can be done practically in different situations-and how that differs from a management approach must be explored. Practice, however, flows from the conceptual frameworks through which we view our world. As a result, moving from the philosophical to the practical requires an intermediate step—a more detailed articulation of the evolutionary process and what it means.

Articulating the Evolutionary and Adaptive Processes

As previously discussed, we see the most fundamental points of leverage for addressing social need (whether related to water or to other issues) as those that catalyse innovation, encourage competition, and enable or guide the process of contestation, selection and use. We also view the resilience of systems in the face of disruption as an important characteristic—a critical feature enabling adaptation while avoiding catastrophic failure. Since the above points of leverage form components of a dynamic, iterative evolutionary process (as opposed to a linear planning process) it is appropriate to start with the concepts of competition and contestation.

Competition and Contestation

If one views the world as a market in which ideas, approaches, institutions and organisations exist in a competitive ferment, contestation is among the most basic driving forces. Dominant ideas, approaches, institutions and organisations face little competition unless alternatives are available. Furthermore, there is little pressure to change unless dominant elements are contested. Alternatives may exist, but without champions there is little incentive for them to grow or be widely adopted. Competition thus depends on innovation—the generation of 'the new.' Incentives for investigating and ultimately selecting from the 'new' depend on contestation. Unless existing patterns of behaviour are challenged, there is little incentive for society to adopt new methods and ways of business, even if they are available. On its own, neither the availability of alternatives nor pressure against existing patterns is sufficient to encourage change. For that, the two together are inseparable requirements.

In their writings, Dreze and Sen argue that freedom and development are closely linked (Dreze, *et al.,* 1995; Sen, 1999; Sen, 1999). While contestation exists in all societies, freedom of expression, access to information and the power of the vote are among the most powerful tools facilitating contestation and allowing for the movement of ideas and issues from the grassroots to higher social levels. Sen argues that differences in contestation underlie the reasons behind effective responses to famine in South Asia and ineffective responses in China. In the later case, controls over information flow and organised protest isolated the country's leadership from both knowledge and pressure when famines occurred. As a result, the nation didn't respond effectively.

Competition and contestation are unruly forces. As anyone who has studied global environmental debates is aware, they often can lead to deadlock. Furthermore, in democratic societies it can be argued that contestation underlies the tendency of politicians to resort to quick, politically-popular measures rather than to interventions that would have much larger—but possibly less visible—benefits (Aiyar, 2001). Since this is the case, if an adaptive approach to addressing water or other problems is to succeed mechanisms for channelling the forces of competition and contestation in ways that lead to productive change are, as a result, essential. Our research suggests that the following four mechanisms are essential:

1. **Generation of and access to information**: Unless individuals and organisations have access to the full range of knowledge society holds on a given issue, they cannot develop fully informed opinions or positions. The generation of new information is also central, particularly in areas such as water management where information about the

resource base and its dynamics is often fragmentary. In economics, perfect information is one of the core theoretical (and never fulfilled) preconditions for perfect competition. The same argument holds in the market for ideas, approaches, institutions and organisations. Without information, none of the other functions central to water management (such as education, identification of equity issues and the development of technically viable strategies) can occur.

2. **The right to organise**: As Ostrom (1993) recognises in her book on irrigation organisations, the right to organise is essential for the formation of local organisations such as those involved in irrigation. This in fact, is true for any organisation, at least those outside the government. Remove the right to organise and communities and other groups will be unable to develop and test alternative forms of organisation for addressing water problems or needs. Without such alternatives, competition cannot occur. Furthermore, without the right to organise there is little possibility for pressure groups that are able to challenge and contest existing institutions, organisations or approaches to form.
3. **Transparent and unbiased mechanisms for conflict resolution**: The importance of conflict resolution mechanisms is also emphasised in Ostrom's work (Ostrom, 1993). Competition and contestation are likely to lead to deadlock unless effective mechanisms for resolution exist. Effectiveness depends on the degree to which particular decisions are viewed as socially legitimate and thereby not open to further challenge. Whether conflict is resolved through formal systems (courts, arbitration, etc.) or through informal systems (community-based systems, etc.), transparency and impartiality are central to the creation of legitimacy.
4. **Resources**: Access to information, the right to organise and mechanisms for conflict resolution are important mechanisms but, particularly where economically or politically marginal communities are concerned, are often insufficient to ensure competition and contestation. Access to financial and other resources is often essential if people are to be freed from the day-to-day routine of survival and thereby to put effort in to the analysis of alternatives and then into contest dominant paradigms. Access to resources through, for example, global and local philanthropy, represents an important point of leverage for encouraging adaptation.

The first three of the above mechanisms represent some of the key points of leverage at a constitutional level where interventions can be made to encourage adaptive approaches to water management. The last is a key enabling element and points toward the importance of private philanthropy or social venture capital as a key force for change within society. In addition to the above four elements, there may need to be more explicit recognition of balance of power concepts and the creation of institutions that enable their realisation.

Selection

Competition and contestation do not lead to action unless the alternatives they generate are selected. In markets, the point of selection occurs when entities (individuals or groups) actually purchase a good or service. The process is more complex in the environment of competition between organisations and institutions.

Formal decision making processes (in state institutions, government organisations and at the community level are one point at which selection occurs. Selection also occurs through a myriad of others pathways when leaders, groups or other individuals 'decide' what they are going to do. In fact, this latter process is probably dominant.

In cases where alternatives have different cost structures, selection can be influenced by market and pricing mechanisms. This is, for example, the case with water utilisation and demand-side management, in which water prices of water or of inputs such as power greatly influence the incentives individuals and groups have to select more or less efficient technologies. Processes for selecting institutions and alternative approaches to responding to water problems generally aren't directly influenced by efficiency or clear input prices. They are, however, heavily influenced by the incentives decision makers have to choose them. These incentives can range from political or social benefits to underlying ethical or ideological factors associated with individual leaders or groups with effective decision making powers. Improving the selection process represents a potential point of leverage but is as yet poorly understood. The keys to improvement probably lie back in the conditions for competition and contestation—access to information, the right to organise and unbiased mechanisms for conflict resolution—we identified above.

The absence of an explicit call for 'participation' in the selection process of alternatives is important to note. We view participation not as something that is granted to but as something that is forced (or binding) upon governments and organisations when society is empowered. Access to information, the right to organise and transparent, unbiased mechanisms for conflict resolution are the primary wells from which the power to force participation springs. This is not to say that formal mechanisms to encourage participation and representation in formal decision making processes are unimportant. Legal or democratic representative frameworks that provide broad access for stakeholders to formal processes for decision making are an important avenue for improving the quality of selection.

Use

It matters little if an approach or organisation is selected unless it becomes alive, implemented and used in an active manner. Incentives lie at the heart of 'use.' Where water efficiency technologies are concerned, financial or other savings, such as labour, generally provide one incentive for actually using them. Other incentives can emerge from other sources, such as the ethic of conservation.

The idea that incentives lie the heart of 'use' also applies to organisations and institutions. Many governments around the globe are now promoting community-based organisations for natural resource management. In some cases, these are proving effective, i.e. the approaches are being 'used' or implemented by the communities. In many other cases, however, community based organisations remain weak or are not actually functional. The core issue here may relate to incentives. Our research indicates that the growth of economic opportunities outside of local communities along with exposure to images of global life through the electronic media are changing the incentives individuals have to invest time, energy or other resources in community-based organisations. When why are not they joining a community organisation to control groundwater overdraft, for example, small farmers in Gujarat and large farmers in California's Central Valley often respond with one or another statement along the following lines:

1. 'Yes, I know the water level is dropping. But the crops I produce through groundwater irrigation are paying for my son's engineering degree. We won't be here in five years so why should I care?'
2. 'Yes, I know the water level is dropping, but the prices for crops fluctuate so much that I can't afford to make investments with return periods of more than a year or so. Furthermore, even if I save water, no one else will.'

The core points here are that use depends on incentive structures and that these structures extend well beyond immediate economic returns. Clearly, understanding incentives in a broad sense central to encouraging effective adaptive responses to emerging water problems. Systems *will* evolve based on people's incentives to act or use different water related strategies. Shaping the direction evolutionary change takes requires an understanding of these incentives.

Innovation

Innovation is, as previously indicated, the core from which 'new' approaches, institutions, technologies and so on emerge. Without innovation, alternatives to existing practice will not emerge. Innovation is, as a result, a central part of the evolutionary adaptive response perspective on water problems.

Innovation is closely related to the processes of competition and contestation. Competition and contestation provide incentives for people to develop new approaches, technologies or institutions. Innovation, as with competition and contestation, is also encouraged by freedom of information and a minimum right to organise. In addition, innovation often requires resources. Here the concept of social venture capital—the justification which organisations such as the Ford Foundations often use in support of their philanthropic investments—is important. Seed funding, whether through private or other sources, is often a key point of leverage for encouraging the development of new technologies, ideas and approaches.

Beyond basic constitutional principles and access to resources, how innovation can be catalysed is a topic in itself—one that has been the focus of attention in many fields outside of natural resource management. Harvesting lessons from innovation in the high-tech world, for example, could generate key insights for approaches to water management.

Building Resilience

Resilience is somewhat separate from the other, process, elements of the evolutionary and adaptive approach. It is a characteristic of systems rather than a process in itself. We believe that building the resilience of social, economic and environmental systems to existing or predictable hydrologic disruptions should be the core objective of an adaptive approach to water problems.

What does building resilience entail? Research in systems theory indicates that resilience increases when there are several independent avenues through which certain desired characteristics are supported or generated. It is similar to the sustainable livelihoods approach now gaining popularity in economic development, which instead of defining people as, for example, 'farmers', emphasises the variety of pathways through which individuals and families support themselves. From a sustainable livelihoods perspective, agriculture is not viewed as an occupation isolated from income generating activities. The approach enables questions of development to focus on wide array of options for livelihoods rather than on just the economy of farming. It emphasise the end service people really care about rather than intermediate or component elements. In the context of water problems, the focus on resilience would, in a similar manner, draw attention away from water management *per se* to the wider, but more basic, set of values or services threatened by water problems. The question would shift from 'how the water problem should be solved' to whether basic services threatened by water problems could be rescued through any interventions, whether focused or water or not. Starvation during droughts is an illustrative case. The typical 'water-focused' intervention emphasises increasing water supplies so that food production can be maintained. A more adaptive approach would focus on diversifying income sources so that when drought occurs, families will have a number of fallbacks (including possibly migration) and won't be as vulnerable. This is discussed further in the next section, but before considering what an adaptive approach really means in the water context, it is important to note two basic ideas about resilience.

First, concepts of resilience often run counter to traditional notions of efficiency or optimality. 'The best way' only remains 'best' if the context is stable. When the context changes, another strategy may emerge as best. In addition, increasing efficiency generally requires specialising and avoiding duplication, the result is a narrowing of pathways through which a given service can be provided. Efficiency also favours either one vertically-integrated 'water management' organisation or a host of specialised organisations. Resilience, in contrast, kinds some degree of redundancy and duplication desirable. Promoting plurality of competitive approaches their approach argues will ensure a degree of efficiency. Since there are a number of pathways supporting the production of a given service, the failure of one or more makes much less difference to the sustainability of the end product.

Second, there is generally a contradiction between hierarchy and resilience. Hierarchical organisations are generally the least flexible or adaptive of all organisation types. As Hendry (1999), citing Mary Douglas (Douglas, 1992), states, 'Based as they are on very detailed and specific classification systems, hierarchical collectivities are uniquely ill-adapted to change.' The Soviet Union is a case in point: here, an extremely hierarchically organised economic and production system collapsed catastrophically when placed under stress (Castells, 2000).

Summary

The adaptive perspective is founded on the notion that competition and contestation within society serves as the driving forces for evolutionary change. These forces are enabled and strengthened by information generation and flow, a right to organise conflict resolution mechanisms and resources (social venture capital). Competition and contestation encourage innovation, the creation of 'the new.' New ways of addressing problems are then translated into action through selection and, ultimately, application or use. Selection and use are, in turn, heavily influenced by the economic, political and other incentives associated with new and existing approaches. Incentives thus play a fundamental role in the evolutionary process. Selection processes can be enhanced by formal processes that encourage participation and representation,—but most selection occurs through the actions of individuals outside such formal processes. As a result, factors that encourage competition and contestation, like stakeholder empowerment, are more fundamental than *pro forma* structures for participation.

The above factors drive change or in the case of water, the development of effective responses to water problems. Within this evolutionary perspective, we believe that actions to increase the resilience of water dependent services (or of groups that use them) are likely to be the most effective objective. Rather than focusing on the control of water systems as its end result, the notion of resilience focuses efforts toward the maintenance of the basic social, economic and environmental services we care about. While this effort does require a systemic perspective (Moench, Caspari *et al.,* 1999), understanding systems in a sufficiently holistic manner to identify points of leverage is fundamentally different from trying to manage systems in a comprehensive, integrated manner. This perspective opens the door for a host of effective local interventions.

Toward Practical Points of Leverage and Policy Implications in the Water Context

Since the objective of adaptive strategies is to increase the resilience of social, economic and environmental systems, information about these systems and the services they provide is the starting point for identifying adaptive strategies. The nature and consequences of water-related disruptions for core social, economic and environmental processes and objectives—the services we care about—needs to be understood. In addition, it is essential to have some insight into how such systems have already reacted to or are coping with water-related disruption.

What types of water-dependent services do we care about? Well in most situations people don't particularly care about the water system at all. Instead, society's core objectives tend to focus on:

1. **The sustainability of livelihoods**: Whether or not water-related disruptions are undermining the economic structures on which individuals, communities and regions depend for survival.
2. **The maintenance of key environmental values**: Species diversity and survival, regional environmental characteristics, basic systems functions (such as the removal of pollution), etc.
3. **Cultural survival**: The maintenance of the cultural and social characteristics through which communities and individuals define their identity.
4. What about need of a bureaucracy to sustain itself a la river linking project where does that behaviour comes?

Changes in hydrologic systems are only identified as 'problems' when they threaten one or more of these core objectives. In Israel and Palestine, for example, water scarcity is a major point of tension because it threatens agricultural livelihoods. The issue isn't just economic, however. Both Israelis and Palestinians define themselves culturally as agricultural societies, societies whose objective is to 'make the desert bloom.' Environmental concerns accompanying water scarcity, too. The pollution of water supplies for cities and towns, to say nothing of the decline in other water-dependent values, such as species diversity, exacerbate cultural and livelihood tensions. It is this nexus of livelihood, cultural and environmental impacts that make water both scarce and a 'problem.' (The three active groupings of cultural theory perceive scarcity differently: hierarchy seep it as, lack of supply; egalitarians as wastage and high consumption; and individualists as an opportunity.)

A Starting Point

Given the above context one starting point for developing an adaptive strategy would be to identify and understand the above types of core social objectives and how they are affected by water availability, quality and hydrologic system characteristics. The goal would be to identify 'points of leverage' and courses of action that could ensure the sustainability of livelihoods, the maintenance of environmental values and the survival of and culture that 'fit' within the constraints imposed by hydrologic systems and society's limited ability to manage them.

Some, perhaps many, of the 'points of leverage' would be standard water management interventions such as local initiatives to control pollution, maintain stream flows, reduce groundwater overdraft and so on. A basic difference between adaptive approaches and IWRM in relation to these 'standard' management interventions would be the recognition that economic, political and social factors place constraints on management, which are as important as technical limitations. As a result, an adaptive focus would emphasise the identification of local windows of opportunity (whether technical, social or political) that allow focused, relatively rapid action to address a water-related constraint. The approach would be constraint focused rather than system-focused and would emphasise tinkering—fixing local problems through local interventions—rather than comprehensive solutions (Moench *et al.,* 1999). While a systemic perspective supported by effective conflict resolution mechanisms would be important to avoid conflicts among interventions, the approach would not require large investments in centralised system planning.

In addition to locally-tailored, piecemeal water management interventions, an adaptive focus would also encourage the identification of new strategies. Many of the new strategies emerging out of an adaptive perspective would have much in common with disaster management. Take the case, for example, of India's response to the droughts and famines of the 1960s. Rather than attempting to avoid drought (an impossible course of action), India's strategy was to accumulate buffer stocks of grain and when drought occurred to initiate food-for-work projects. This ensured that food was available and that people had access to it. The strategy was focused on livelihoods and food supply system resilience rather than on drought *per se*. While far from perfect, it has been successful in avoiding a repetition of the major famines of the 1960s despite the occurrence equally severe—and unavoidable—periods of drought. Similar buffer strategies could also form a core element in an adaptive response to water problems. There would, however, be important differences.

Despite their conceptual kinship with disaster management, adaptive approaches to water problems should be proactive. A significant flaw in India's drought response strategy has, for example, been the nature of its food-for-work schemes. In many cases these have involved attempts to increase water availability through the construction of water-harvesting structures in areas where new supplies are essentially unavailable and existing water-use patterns unsustainable. This type of response does address the immediate problem of survival but does little to reduce drought vulnerability or to help people adapt to the inherent variability of water supply in drought-prone areas. The result is an endless cycle of drought and relief.

As conceived here, an adaptive strategy would attempt to move well beyond the above cycle by viewing 'problems' such as drought as windows of opportunity for shifting livelihoods away from dependence. Rather than just attempting to harvest more water and maintain livelihood systems that are, over the long term, often unsustainable, a major goal of food-for-work or other 'relief' programmes would be to assist communities to develop livelihood systems that are less dependent on water or water supply variability than agriculture is. Identifying of appropriate interventions to support this transition requires an understanding of how people are already reacting to or coping with water-related problems. For example migration is a common response both to drought and to the opportunities and challenges communities due to globalisation. Understanding migration and its causes could highlight potential points of intervention that could reduce drought vulnerability and reflect what people are already doing in response to opportunities, aspirations and challenges. In this context, an adaptive strategy would build on and reflect existing social trends.

Our perspective on floods provides another example of how an adaptive approach might work in practice. In the past, attempts to control flooding often involved the construction of large dams to regulate rivers and of embankments to hold flood flows within existing channels. Recently, however, increasing emphasis has been placed on maintenance of wetlands and similar off-channel storage areas capable of holding flood volumes. In addition, flood management experts often suggest restricting development and relocating communities away from flood plains. All of these recent approaches would fit well as part of an adaptive strategy for reducing flood impacts.

Adaptive responses to floods do not rule out—and may, in many situations, encourage—the development of physical structures. In the Gangetic Basin, for example, construction of raised 'islands' could be an integral part of an adaptive strategy. Raised islands would provide a permanent, above-flood-level location for housing and other permanent structures. Unlike embankments, islands would not change the basic structure of the surface hydrologic system. Floods would occur, bringing with them the sediment that is a major of soil fertility in the basin and maintaining the channel morphology on which wildlife and vegetative communities depend. The floods would not, however, have the major negative economic and social impacts that are now associated with flooding, or more correctly, with embankments. Embankments block drainage and confine sedimentation to the streambed and to the floodplain between opposite embankments. As a result, precipitation in areas 'protected' by embankments (often in amounts can exceeding flows originating in highlands above embanked areas) can't drain back into the river. This, in turn, can cause permanently waterlogging in the areas that the embankments are intended to protect. Furthermore, sedimentation often causes the levels of streambeds to rise substantially. When its embankments fail, such a river is unlikely to return to a 'bed' whose height is well above that of surrounding lands. The construction of 'islands' rather than embankments would allow drainage to occur naturally and rapidly. Because such a physical intervention would work with (rather than attempts to control or change) the hydrologic system, it would help to maintain the original ecological and other benefits associated with that system. It would also increase the resilience of social and economic systems by reducing the impacts of flooding on them. As is the case with droughts, floods could be viewed as windows of opportunity to encourage adaptation. In this case, channelling public relief funds into building islands rather than into reconstructing dwellings or other structures in their original sites, would enable people to 'rebuild' their livelihoods in less vulnerable locations.

Enabling Adaptation

What are the practical points of intervention that governments or other entities could develop to encourage adaptation?

The term 'enabling' in the title of this section points toward the types of interventions we believe may be most effective. Whether in the provision of financial resources, information or regulatory frameworks, a central objective of interventions and institutions would be to enable communities and individuals to adapt to the dynamics of natural systems and to make use of the opportunities (whether political, social or technical) that are present in a given context. This implies a very different—but very practical—role for governmental organisations in providing information about and high-level regulatory and legal frameworks supporting adaptation. As one of the authors argued in a paper several years ago, most water legislation in countries such as India is written with the intention of controlling or regulating either the water system or its use (Moench, 1994). In contrast, legislation that, enables communities to form organisations and faster the allocation of power to then using some sort of representative process could result in the development of effective management organisations that are tailored to local conditions. Similarly, the focus of public investments would be on those that enable action, rather than those on that directly control the resource base. The most practical investments might be in long-term flood forecasting or drought warning systems combined with policies, such as land use zoning, that reduce the vulnerability of society to droughts and floods rather than in attempts to control flooding directly (some idea of what). This approach suggests that the most effective role for the state is to provide information and legal or regulatory frameworks within which people can respond as they see fit to the nuances of their local situation. Key points of leverage to enable contestation and adaptation could include:

1. **Creating enabling legal or regulatory frameworks**: High-level legal and regulatory frameworks that specify the right to organise and provide a supportive process for doing so must be developed providing legal and other frameworks that encourage contestation and enable conflict resolution are also important.
2. **Developing processes and criteria which encourage adaptive interventions**: We're concerned about the sustainability of water-dependent services and, in some cases, water resource characteristics (in-stream flow volumes, quality, etc.). Criteria, such as whether or not an intervention reduces vulnerability to predictable water-related disruptions (or, in some cases, more specifically protects valued water system characteristics) are essential as a baseline against which to judge whether or not an approach actually supports the sustainability or production of environmental, economic or social values through adaptation. Similarly, providing for processes that ensure interventions are measured against criteria is essential. The preparing of environmental impact statements in the US is an example of this type of system. Rather than specifying a management approach, the Environmental Impact Assessment (EIA) process mandates that new interventions must meet certain criteria (like the protection of water quality and wetlands, etc.). The process does not specify 'how' the impacts are to be avoided, it leaves that decision to the local level. (Though many developing countries have made EIAs mandatory, such provisions are lacking, we need to check such provision in India and Nepal)
3. **Providing seed resources**: Social venture capital has a critical role to play: it can increase access to resource for groups within society, which will use them to innovate, contest and compete by proposing alternatives.
4. **Increasing the availability of and access to information:** Basic research and data collection plays an important role in the natural and social science. Information is the framework on which analysis is based, and analysis, in turn, creates a valid basis for contestation. When information is weak or biased, there will be no factual foundation for informed debate, and contestation will revolve around ideology or perceptions only. To be useful, information must be accessible—physically and conceptually transparent and understandable for non-specialists. For these reasons, investments calculated to increase information flow to all potential users is key point of leverage. (The three different ways of organising society-hierarchical, equalitarian and individualistic use data differently, but conflicts over data are easy to resolve.)
5. **Encouraging experimentation and the development of multiple approaches**: Water management interventions that fit the adaptive approach and match local contexts,

should be tested and, if they succeed, replicated. Although they should be designed with a systemic perspective, they do not have to fit into a large integrated approach at the basin, aquifer or national level. If an intervention addresses a water problem (whether or not the intervention itself is water-related) and doesn't obviously conflict with other activities, it should be encouraged.

6. **Reducing barriers to informed dialogue and contestation**: It is important to break down regulatory barriers and reduce the control which existing government or other hierarchical organisations have over information or the right to organise and undertake management interventions Data should be democratising by encouraging groups to generate them.
7. **Providing education**: Since education is essential for informed dialogue and action, it is central to any enabling approach.

As a last comment, we return to a point made at the beginning of this paper. Viewed from the perspective of complex systems interactions, the key issue in an effective response to many emerging water problems is to strengthen society's ability to react 'proactively' so that the negative impacts associated with 'surprises' (such as flood, drought and complex hydrologic interactions) are minimised. In contrast with a strategy of management an adaptive perspective emphasises social responses that build resilience and flexibility and de-emphasise interventions that attempt to directly control the complex interactions that underlie hydrologic systems or the relationship between hydrologic and social systems. Potential adaptive courses of action can in fact, be judged by their ability to build resilience.

The adaptive perspective is relatively new. We don't claim to have investigated it fully or even to have fleshed out the concepts on which it depends. We are, however, convinced that 'comprehensive integrated approaches to water management' do not reflect the evolutionary nature of society and, in most cases, are an inadequate basis for responding to the water challenges society will face in the coming decades. Adaptation or working within the constraints of variable and evolving hydrologic, social and economic systems to decrease vulnerability and increase the resilience of key environmental, economic and other services on the other hand, holds great promise.

NOTE

[1] http://www.developmentgateway.org/topic/kiaq?kiaq_id=3865

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FLOODS IN SOUTH ASIA

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Floods are a major hazard in South Asia. The problem is particularly acute in the monsoon. While the monsoon provides the region with the water needed to support lives and livelihoods, the concentration of water at a particular point in space and time also creates hazards. During the monsoon cloudbursts, landslides, mass movements, and flash floods are common in the mountains. When flows reach the plains of southern Nepal, northern Uttar Pradesh, Bihar and West Bengal, rivers overflow their banks and inundate the land leading to the large-scale social and economic disruption. As they flow from the mountains to the plains, rivers also cut banks and shift laterally. In the upper regions, rivers cause erosion and transport sediment. The sediment mass thus transported is deposited in the plains. Fine sediments brought by floods enrich land productivity and are essential for the maintenance of the regional agricultural economy. At the same time rivers also bring coarse sediments whose deposition harms agricultural productivity. Flood events are, as a result, both disasters and central to the region's productivity.

The mountain chain and the contiguous plains of the northern Ganga watershed are parts of a common hydro-ecological system. The region encompasses a plurality of social systems within which hundreds of ethnic groups, scores of languages and almost all of the major world religions are found. This population is among the poorest in the world and the miserable living conditions it experiences are often attributed to the regular floods in the monsoon period and to the scarcity of water after the monsoon rains are over.[1] The cycle of floods and drought is the temporal outcome of the region's hydrological pattern—a pattern which is characterised by high micro-level variability.

With the rise in population, cities have grown and highways and railways have been built to serve them. Along with this infrastructure have come flood embankments for its protection. Poorly designed and located, this infrastructure interferes with the existing pattern of surface water flow and causes drainage congestion. Instead of protecting regions, embankments have generally exacerbated the flood hazard. The social impacts of this are compounded by increased immigration to the region. Often migrants end up living in a zone that is vulnerable to flooding because they have no opportunity to live in less hazardous areas. Increasing immigration adds to the poor who are often already living in vulnerable conditions. Endemic poverty and increasing competition as immigrants enter the labour force leave most local populations with little resources to cope with or recover from flood impacts.

FLOOD DISASTERS: CONCEPTS AND DEFINITIONS

Most work on flood disasters emphasises the significance of natural trigger events that arise irrespective of human activities.[2] This literature assumes that disasters are departures from 'normal' social patterns and that recovery from disaster means a return to normal conditions. Policy-makers, donors, and relief and development agencies treat flood disasters as isolated events that break the continuity of the 'normal' way of life. Most interventions to mitigate disasters are, as a result, *post hoc* responses made under the assumption that an emergency support in the form of relief will help overcome the short-term hardship situation. Such support aims at restoring the situation to what it was before the disaster. Even when floods affect the same community every year, government, donor, and non-government organisations respond by providing the same relief and rehabilitation measures each time.

Relief is the dominant approach championed by the regions' governments, NGOs and agencies. This perspective does not view social situation during 'normal times' between hazard events as important. Disasters occur when a hazard interferes with society. Hazards are seen as something separate and unique, not as an integral part of the context in which society exists. Often the terms 'natural hazard' and 'natural disaster' are used interchangeably. The focus is on physical events and most efforts are devoted to predicting the magnitude of such events using hydrological and meteorological science. This perspective assumes that disasters are an inherent outcome of natural hazards—that hazards cause disasters through their impact on people and society—it de-emphasises the role that social conditions play as a root of vulnerability to hazards. In the hazard-led perspective those affected by a disaster are not involved in the decision making about mitigation, which is top-down and bureaucratic.[3]

A growing body of recent research, however, shows that disasters are the outcome not only of natural hazards, but also of socio-economic structures and political processes that make individuals and families vulnerable.[4] Labelled as the 'alternative approach', this perspective focuses on the various ways in which social systems operate to make people vulnerable to disasters. This approach views natural hazards as significant and normal characteristics of the regions where they occur. Hazards are, however, not viewed as the primary or sole cause of 'disaster.' Instead, the perspective recognises vulnerability as equally important. Vulnerability, the capacity to anticipate, avoid, cope with, resist, and recover from disruptions caused by natural hazards, has as much influence on whether or not a 'disaster' happens as does the hazard itself.

In the developing world the 'normal' daily life of large section of the people is not greatly different from the living conditions of those hit by disasters. Even in normal times, many live in vulnerable conditions. Individuals and families in such vulnerable communities find it hard to reconstruct livelihoods following any disruption. They do not live in vulnerable conditions out of ignorance about the hazards or their erroneous perceptions of risk. Instead, most have little freedom to choose how and where they live. Low-income families, for example, often have no option except to live in vulnerable locations such as flood plains. They are forced to live there not because land use planning is poor, but because the prevailing agrarian relations in their society and the processes of social and economic exclusion make them unable to own property in safer areas.

Disaster is an outcome of both vulnerability and hazard. The later is related to natural events and is conceptualised as the probability that in a given period in a given area an extreme, potentially damaging natural phenomena will affect a given zone.[5] The magnitude of the phenomenon, the probability of its occurrence and the extent of its impact can vary and, in some cases, be estimated within a certain margin of error. The vulnerability of any physical, structural or socio-economic system to a natural hazard is its probability of being damaged, destroyed or lost. Vulnerability is not static but a dynamic process that depends upon the social, economic and political contexts that change over time, which will consequently affect the probability of loss. If societal vulnerability is exacerbated the loss will increase. On the other hand, strengthening social resilience capacity would reduce vulnerability. The magnitude of a natural hazard and of the vulnerability of all the exposed elements in a determined moment determines the risk of the hazard. Risk is related to disaster as it includes the loss and damage that can be suffered after a natural hazard including dead and injured people, damage to property, and interruption of activities. In other words, risk is a future potential condition likely to happen.

Evidence from a number of case studies points to the fact that the poor and dispossessed, at the margins of the region's social, economic and political system often suffer from disasters like floods. Because of asymmetric socio-economic relationships some people have no access to basic resources, such as land, food and shelter, health and education. The result is low social resilience. These social, political and economic conditions and their interrelationships during normal times determine why certain sections of the societies are more vulnerable to disasters than others. Relationships and structures dictate who has access to resources of various types, thereby who has more access to material benefits, and to social power and who can make decisions about their own lives.[6] Disasters are crisis points where the unresolved problems societies face during normal times come to a head in the context of a specific hazard event. Furthermore these unresolved problems affect the way people are affected by disasters. As a result, understanding the impact natural hazards are likely to have and the root causes of disaster requires analysis of the wide array of social, economic and institutional conditions that shape the vulnerability of individuals and communities.

Because floods disrupt society, they provide a unique opportunity where differential social relationships are exposed and can be analysed as well as a window of opportunity for change. During disasters, society is exposed thus allowing non-linear relationships to be examined.[7] In this sense, the study of disasters is a forensic moment[8] and an opportunity understand and to create new arrangements that will allow vulnerable groups and those repeatedly affected by disasters to reduce their vulnerability. Consequently, not just disaster relief but events between disasters, development initiatives and local power structures are important. To that end, strategies must strive to change those patterns of relationships and institutional arrangements that exacerbate vulnerability to disasters. Reforming these relationships lies at the root of strengthening the people's capacity to cope with disasters and should be made the focus of any approach to mitigation. Different groups, families and individuals affected by disaster should be involved in all stages of decision making and implementation.

These two perspectives on flood disasters bring in technology as an important factor. The hazard-led approach has focussed on relief and technological measures like dams and embankments to alleviate floods. This focus on technologically oriented solutions, instead of the social, economic and political factors that lead to non-adoption or mal-adoption of technological measures, has aggravated flood problems.[9] In India, for example, although engineers expressed doubts about efficacy of solutions like embankments, they became the chosen path of flood control after the advent of independence. Some levees brought limited relief immediately after their implementation, but their long term adverse impact is increasingly widely recognised. The doubts expressed earlier have been proven true which is manifest in the social and environmental ills that currently plague regions that have been embanked where problems due to drainage congestion, seepage and waterlogging are high.[10]

The focus on a broader political-economic outlook is important but must not, however, de-emphasise the need for understanding the specific details of each disaster. Improving our understanding of natural hazards is essential for minimising uncertainty. For example, while dealing with floods, questions like when, where, and why are important. A combined analysis of natural events, technology and their social context would provide a realistic understanding of a flood and how it will impact. Each of the perspective on natural events, technology and society is therefore necessary, but by itself none is sufficient. Thus an analysis must separate the contexts into physical, social and other subsystems, through which we begin analysis of natural events as well as of those processes that make individuals and families vulnerable. This is because the impact of a disaster is felt at the individual, family or community levels. In other words, our analysis will capture the interactions among various sub systems and locate the constraints among them in order to be able to design responses that are adapted to a given context.[11]

FLOOD EVENTS AND IMPACTS

Floods are a common phenomenon in the Himalaya-Ganga, the high-land low-land interactive system of the Ganga River System. Every monsoon landslides, swelling rivers, and floods take a heavy toll of properties and lives. The region is susceptible to floods because of one or a combination of the following natural factors: continuous rainfall and cloudbursts, snowmelt and rainfall combine, snow-melt, glacial lake outburst floods, *Bishyari* (the breaking of dams caused by landslides falling directly into river channels) and breaching of lakes and man made reservoirs.

One major cause of floods is hydro-climatological. The monsoon rain, which lasts from June to September, is marked by large regional and temporal variations. The rainfall is sharp and intense. The date of onset, and the magnitude, duration and intensity of rainfall vary at macro, meso and micro scales. For example, the amount of rainfall in the eastern, central and western Himalayas are different. The eastern region is wetter than the west. In the rain-shadow regions of the Tibetan plateau, conditions are dry and desert-like. In the mountains, orographic effects cause large local variations within a valley. Sudden cloudbursts, which account for almost 500 mm of rainfall in a single day, are common. In the Kulekhani catchment in 1993, 540 mm rainfall was recorded in 24 hour period. In 1998, the rain gauges installed in the catchment of Rohini recorded 3200 mm of rainfall in the three months of June, July and August, which is almost two times the average rainfall recorded in the nearby stations over the last several years in the same period. On August 3 one of the rain gauge stations recorded a rainfall of 459 mm in 24 hours.[12]

In Nepal the monsoon and the Himalayan mountain system give rise to about 6000 rivers of various lengths. The rivers can be broadly categorised into three types; snow-fed, rain-fed originating below the snow line, and rain-fed originating in the southern face of the mountain chain and the plains. The Mahakali, Karnali, Gandak and Kosi Rivers are the main tributaries of the Ganga River and originate in Tibet and the Nepal Himalayas. The Ganga River and its major tributaries also function as drainage channels.

In the four major river basins in Nepal—the Mahakali, the Karnali, the Gandak and the Kosi—rivers are perennial and derive their flow from monsoon run-off and snow-melt. There are six smaller basins, whose headwaters originate in the middle hills and whose low season flows are not augmented by snow-melt. These are the Babai, the West Rapti, the Bagmati, the Kamala, the Kankai and the Mechi. The East Rapti, the Arung, the Andhi Khola and the Trijuga have hydrological and morphological characteristics similar to those of the rain-fed rivers. They join the main rivers of the larger basins and are classified as tributaries of these larger rivers.

The Tarai is criss-crossed by several smaller rivers, which originate in the southern slopes of the Churia Hills and flow southwards into India. These rivers can be divided into six blocks: the Dhangadhi group in the far west, the Lumbini group, the Birganj group, the

Janakpur group, the Rajbiraj group and the Biratnagar group. All rivers flowing from Nepal join the Ganga or its tributaries in Uttar Pradesh, Bihar and West Bengal. The hydrology of rivers generally follows the pattern of rainfall. From July to September the rivers experience high flow; from October to November a period of decreasing flow ensues. From December to April flow is low. Pre-monsoon rains, snowmelts and thunder squalls increase flow in May. With the commencement of the monsoon in early June, flow starts to increase.

The Tarai group of rivers is the most capricious and causes the heaviest flood damage. The southern slopes of the Churia Hills receive some of the heaviest and most intense rainfall in the country. The rainfall results in high run-off in stream channels, which exhibit marked variation in flows. The peak monsoon flow of these streams can be a thousand times greater than its lowest flow. Some of these rivers are dry during the winter season, while in the monsoons they become active and cause immense damage.

The large rivers also exhibit seasonal variations. Even in rivers such as the Kosi the fluctuation can be sudden and high; a rise of 20 to 30 feet in 24 hours in its gorge is not uncommon. Incessant rain in the catchments leads to floods. For example, the highest and second highest floods in the Kosi, which occurred in 1954 and 1966, were the result of long duration rainfall in its catchment. In the smaller streams the impact of flooding is more localised, but it can become widespread depending upon the magnitude, extent and duration of the accompanying rainfall. At the end of the monsoon, when the land is saturated, the contributions of cloudbursts to overland flow is almost hundred per cent, and cloud bursts can lead to devastating effects as the recent flooding in the Rohini River indicate.[13]

In the high Himalayas, GLOF (Glacial Lake Outburst Flood) is a regular phenomenon. There are many glacial lakes blocked by the terminal moraine of Himalayan glaciers located above 4000 m elevation.[14] Glaciers have retreated rapidly in the last half of the 20th century, forming, in many cases, ice-core moraine-flanked lakes of melt water. Occasionally, there is a breach in a moraine dam and a lake empties in a very short time. The result is floods of great magnitude in downstream river reaches. The water carries with it sediment from the moraine dam as well as from the riverbeds and banks gouged out by the flow. The combined action of sudden flooding and debris movement washes away riparian farmland, settlements, infrastructure and many unsuspecting individuals in its wake.[15]

Debris flow resulting from mass wasting and landslides is often released into river channels, temporarily damming them. When a dam is breached peak flood of short duration results. Such an outburst of water and debris called, *bishyari* causes heavy damage along the river bank, which continues for several kilometers downstream of the point of origin. The flood peak is attenuated when the flood wave reaches wider river reaches. As they reach the Tarai plains, rivers deposit their coarser sediment load in the 'inland deltas' and cause them to move laterally. The shifting tendency is common all rivers. It is most dramatic in the Kosi River, which has shifted 150 km westwards in the last 150 years.[16] Intermittently, deposited sediment is washed away in large flood events and is ultimately transported to the ocean.

The occurrence of *bishyari* is highly stochastic and that development is too rapid to allow sufficient warning time. GLOFs also occur at random, but because the location of a glacial lake is fixed, the regions likely to be affected by a potential GLOF are identifiable. The areas, which could be affected by potential GLOFs and *bishayris,* are sparsely populated, and because the number of people killed or hit is small the intensity of the suffering of the affected populace can be masked. Also since the affected population is in the informal sector of the economy, the losses are poorly accounted-for in statistical counts. Floods in the Tarai, on the other hand, are regular and provide comparatively longer lead-times than those in the hills. In the 1993 monsoon, however, even in the Tarai the flood event of July was sudden. The flood in the Bagmati River in that year reached the maximum recorded level; its suddenness led to the deaths of about 800 persons in the Sarlahi and Rautahat districts of the central Nepal Tarai.[17]

Human intervention may also alter hydrological processes and contribute to flooding. Interventions in the flood plain change the upstream-downstream linkages while the introduction of structures like weirs and barrages leads to aggradation in upstream channels and during high flow exacerbates the impact of flooding due to the congestion of the drainage channels. Upland land-use changes may also influence the upstream-downstream linkages of hydrology at micro and meso scales. A growing body of literature indicates that in the middle hills it is not just the forest cover but also the hydraulic properties of soil and several other factors that determine run-off and flood responses. It has also been argued that terraces on hillslopes contribute to soil conservation and slope stability more effectively than reforestation.[18]

SOCIOECONOMIC SYSTEM

The conventional responses to mitigating flooding are of two types. The first response takes the form of post event relief and the second is structural solutions in the form of multipurpose projects and embankments. On plains of north Bihar, for example, more than 3,500 km of embankment has been built in the last 40 years. The embankments have resulted in the aggradation of channel beds, and, consequently the spill over of floodwater and waterlogging. The examples of the Kosi and other embankments in the Ganga plain are cases in point (Mishra, 1997). Due to deposition of sediment the beds of jacketed rivers are at a higher level than the adjoining lands. The other solution sought to provide respite from flooding in the lower Himalaya-Ganga has been the creation of reservoirs with multi-purpose objectives in Himalayan valleys. Some reservoirs have been built for flood mitigation purposes.

Multi-purposes dams have been built in the co-operative agenda of India and Nepal since 1950s. One initiative, the Integrated Treaty on the Mahakali River, which was signed in 1996, sets the stage for implementing the Pancheswar Multi-purpose Project on the Mahakali River. The other storage option is the high dam on the West Seti, which is proposed as a hydroelectric and not a multi-purpose project.[19] Both proposals, however, face disagreements over the articulation of rights to regulated waters even though the Mahakali Treaty proposes sharing benefits commensurate with costs.[20] The two projects are among the twenty nine reservoirs proposed in the Nepal Himalayas that would yield a gross storage of 100 billion m^3, and a net storage of 61 billion m^3.[21] When completed, the reservoirs are likely to yield a year round regulated flow of about 5000 m^3/s and will moderate flood peaks in the downstream river stretches of each site if the operation of the reservoirs is optimised for flood cushioning by leaving space empty for accommodating floodwaters.

In reality such optimisation is not likely to work and provide benefits because the disincentives to leave the reservoir empty are high. Floodwater does not yield any revenue to the government. Even irrigation water is a smaller revenue endeavour compared to electricity, which secures the highest revenue. There is also a systemic contradiction: the needs of electricity and irrigation require a full reservoir and those of flood control require an empty reservoir to accommodate high flow. Also in the reservoirs built flood cushion benefits has not been achieved. None of the reservoirs built so far in the region except the two reservoirs in the DVC project in West Bengal possess flood-cushioning space. In any case, in these two projects the original flood cushion capacity was whittled down to accommodate the concerns for electricity generation.[22]

Yet proposals for building new reservoirs dedicated to flood cushioning continue to be offered in the regional politics and have acquired prominent focus. Following the 1998 floods in Eastern Uttar Pradesh, the media attributed the impact to release of specified cubic meters of water from dams located in Nepal and the Himalayan Kingdom received much attentions.[23] Similar reports appeared in the media in Bihar. In September of the same year the Indian Prime Minister visited Gorakhpur, and remarked that "the rivers coming from Nepal are the main cause of the flood devastation in India. The talks with Nepal to build dams are ongoing."[24] With the exception of the 73 million-m^3 net storage reservoir in the Kulekhani River, none of the other proposed twenty-nine reservoirs have been built or any dam or diversion projects exist in the region. The reporting in the media was erroneous which the activist groups in Bihar questioned. The group issued press statement highlighting the fact that there were no dams in the Himalayan Kingdom except in the Kulekhani River.

LAXMANPUR, KURDALOTAN RSIYAWAL AND MAHALI SAGAR

Differences on the proposals like the Pancheswar Project and West Seti High Dam have not been resolved. Even if these differences are resolved questions about the logic of making investment in large-scale projects such as Pancheswar remain unanswered. One major irritant to adopting large-scale water projects with long gestation period is the mobilisation of finances. The preliminary cost of the Pancheswar Project is estimated at US$ 3 billion US$ half of which Nepal would be expected to provide if its claim to half the benefits is realised according the provision stipulated in the Mahakali Treaty.[25] This investment is about 1.5 times the 1998 budget of Nepal. Such investment incurs macro-economic risk for its economy, but this issue has not been carefully examined.[26]

Another risk associated with reservoir is sedimentation, which is a corollary phenomenon within the hydrological cycle. Sedimentation has remained a blind spot in the discourse on water-led development in the region particularly in Nepal.[27] Himalayan Rivers in the monsoon carry not only water but also solid mass derived from landslide, bank cutting and debris flow phenomenon that have geological rather than anthropomorphic roots. Suspended sediment is only a fraction of the entire mass of solid matter that flows in rivers. The total load consists of a large percentage of bed load, but these contribution is not accounted for in sediment budgeting. Sedimentation is a natural reality that cannot be totally overcome, but within which interventions for water development have to be negotiated.

The Kulekhani Reservoir lost its dead storage capacity just 13 years after impoundment began even though it was expected to have a 100-year life span. A debris flow into the reservoir triggered by the 1993 cloudburst filled a large percentage of its dead storage. In less than 24 hours, the Kulekhani catchment received 540 mm of rainfall and the reservoir level rose by 20 m in nine hours. In the same period 4.8 million cubic meters of sediment was deposited in the reservoir.[28] In the design the sedimentation rate was assumed to be 88,200 m^3.[29] Design of projects grossly underestimates sedimentation rates.

Constructing reservoirs will permanently submerge villages, agricultural land in the hills and displace lakhs (hundreds of thousand) of people of Nepal. Because people will be displaced, this endeavour should raise questions about equity. Unfortunately displacement is not an issue that has been seriously considered in the bilateral co-operative initiative on water development.[30] In the discourse on water-led development in Nepal, the social cost of intervention first began to be written about in 1989. Nepal also lacks expertise in handling the complexities of rehabilitating large population[31] including and of implementing environmental mitigation. The country's capability to rehabilitate victims of floods is equally limited. Land is scarce in Nepal and its Tarai has been an obvious site for resettlement, which has often been accomplished at the cost of forest cover. In any case the Tarai which occupies 17 per cent of the country's area already accommodates 50 per cent of the population. This pattern of resettlement cannot continue indefinitely into the future and alternative innovative solutions will have to be sought to deal with the problem of rehabilitating victims of floods.

A major problem is the actual response to flood mitigation, which, conventionally is perceived as the responsibility of the government. There are separate agencies to work on different aspects of floods, ranging from hydrology to relief and rehabilitation, but they are ineffective. There is a conspicuous absence of flood disaster management plans. Even multi-sectoral approaches have had little co-ordination and thereby have been of limited value in mitigating hardships caused by flooding.

RECONCEPTUALISING FLOOD MITIGATION

If one moves away from the structural flood control and disaster relief activities that characterise conventional approaches to flood mitigation and focuses more on the root causes of vulnerability, what are the points of leverage for mitigating disaster that could prove effective. While we don't have a comprehensive answer to this, several courses of action could prove both appropriate and effective.

What are the root causes of vulnerability? Lack of information on pending hazards is clearly one. If people know floods are likely to occur, they will take many actions on their own that mitigate the impact of flood events and reduce the frequency of true 'disasters.' Even a few hours or minutes advance notice of a flood could be of tremendous benefit—enabling people to move themselves, animals, household belongings and food out of houses to less vulnerable locations. Increasing awareness of flood probabilities within years (good predictions regarding the probability of higher than normal precipitation in a given year) and over the longer term could also be a key input to vulnerability reductions. Mass awareness campaigns may be important in areas where people are not already aware of natural hazards (such as locations well downstream of glacial lakes that are likely to break). In this case, there may be many things individuals and communities can do that, unlike communities where floods are regular events, they haven't already done. Moving housing or economic activities out of vulnerable locations is, for example, more likely to be viable in this situation because such sites are less likely to be already occupied as a result of earlier recurring events. Overall, information and information flow are critical to any new approach to flood mitigation.

Information alone won't, however, reduce many aspects of flood vulnerability. Another key component of vulnerability is infrastructure—housing, roads, irrigation systems, food storage facilities and the other components of the built environment that populations depend on for their livelihoods. In many cases, such infrastructure has been built without considering flooding or the need for massive drainage. If embankments worked, the infrastructure would be protected from inundation—so why worry? Clearly, however, rethinking the design of many elements in the built environment could be a major avenue for reducing flood vulnerability. A few examples of this will suffice to make the core point. Take the case of irrigation diversions.

Modern cement irrigation diversions are often irreparably damaged when flooding occurs. In addition, they frequently encourage the introduction of silt laden waters into the system itself and can result in clogging of the overall irrigation system. Both damage and clogging contribute to disasters because they disrupt the productive capacity of the system and, as a result, can impoverish the farmers whose livelihoods depend on it. The disaster, in this case, is due to income disruption rather than the direct impact of floods on individual farmers. In many parts of Nepal, traditional brushwood irrigation diversions were designed to be washed out when floods occurred and then reconstructed immediately afterwards. Similar approaches in which key infrastructure components are designed for protective failure and low cost replacement once a hazard is past could substantially reduce this source of vulnerability.

Another example involves housing and the location of similar productive infrastructure. At present, embankments are designed to keep water from flooding entire areas. If, in contrast, society focused on constructing protected locations—islands—rather than area protection, the impact of flooding would be mitigated in a number of ways. First, islands can be designed in ways that don't block drainage. As a result, the magnitude and duration of floods should be reduced. Second, islands are far less subject to catastrophic failure than embankments. As a result, even if some islands were overtopped during particularly major floods, society would have much more time to respond. Rather than abandoning all food and climbing into the nearest tree when an embankment fails, even in the worst cases far more time would be available to move people and critical assets (food, money, and other goods) into safe locations. The magnitude of losses would, as a result, be reduced.

Redesign for flood mitigation doesn't have to be at the scale of islands to play an important role in flood mitigation. A wide variety of micro-design changes could be equally important. Houses along major rivers in Europe, for example, often have flood doors that keep water from all but the most extreme events from entering. The inherent vulnerability of infrastructure to flood disruption is another dimension. Cellular phone systems, for example, are far less vulnerable to disruption than systems depending on fixed wires. Extension of cell phones to remote areas could mitigate flood impacts substantially by enabling communication of key information or needs before they become critical. Designing systems so that they are unlikely to be disrupted by floods is, as a result, a major avenue for mitigation. The infrastructure would, in effect, be adapted to flood conditions.

Portability is another consideration. Communities in India and Bangladesh often store food grains in large ceramic or brick storage containers that are inherently immobile. Alternative structures could be designed in ways that are mobile or that float above flood waters could protect critical food stocks. The same principle of portability could be applied to many other productive assets that are now lost during flood events because of their fixed nature as part of the built environment.

Beyond the built environment, income disruption is often the factor that transforms a given flood event into a disaster. As a result, mechanisms that maintain income flows and enable people to purchase food, obtain medical care and continue sending children to school while avoiding depletion of their savings are critical. Insurance is the conventional approach used for this in many countries and innovative forms of insurance or other financial mechanisms (such as income diversification) could contribute substantively to vulnerability reduction.

The overall point here is that there are a variety of micro and macro changes in the social context and built environment that could reduce the vulnerability of populations to floods. These changes recognise floods as a natural and, in many ways, inherent and important feature of the environment. As a result, they are designed to mitigate the negative impacts of flooding by designing the built, economic and social environment in ways that are adapted to it rather than attempting to control the flooding per se. Such adaptive approaches could form the basis for a reconceptualised approach to flood mitigation.

A recent study on community based flood adaptation highlight the following eight lessons as being relevant for the building of resilient community livelihoods in flood and drought affected regions of India and Nepal (Moench and Dixit, 2004).

First is the nature of livelihood systems within a region, more specifically, the extent to which individuals and households are able to diversify income strategies and incorporate non-farm components. Income diversification, particularly the development of non-farm sources of income, is the primary avenue through which households are able to maintain their livelihoods, even during floods. This is achieved by establishing a business or by securing outside jobs, either abroad, in cities or simply in regional labour markets. Diversification provides access to secure income streams that can be used to maintain consumption, avoid debt, rebuild agricultural activities and retain or rebuild assets. Because local agriculture is vulnerable to setbacks caused by its dependence on services like irrigation, diversification into non-agricultural activities is, in fact, often essential in order to 'ride out' bad years. The ability to diversify is critical to the maintenance of rural agricultural livelihood systems.

A Second factor reducing vulnerability is the ability of people to migrate or commute in order to obtain access to non-farm or non-agricultural sources of income. Migration and commuting help households obtain access to incomes unaffected by local problems. They are a core strategy in managing risk. The fact that much migration is long-term and driven by a wide variety of factors (such as the growth and diversification of national economies and the degradation of traditional livelihoods) only increases its role in flood and drought mitigation. This does not imply that all migration is good. Displacement caused by drought, flood, local impoverishment, other disasters or by conflict often leads to impoverishment. Even so, the role migration plays in maintaining the livelihoods of rural populations cannot be disputed. The flow of people across rural and urban boundaries, districts, states and national borders provides access to a diverse range of livelihood strategies that are absent in many rural areas.

Third is the ability of information, goods and services to flow in and out of an area. Such flows are as important as flows of people in determining adaptive capacity, or the ability to manage risk. During the recent drought in Gujarat, for example, fodder moved to rural areas whereas in the past people had to migrate to fodder. The presence of regional markets, government programs and large-scale co-operatives enabled people in rural Gujarat to access fodder produced in other areas. As a result, milk production in some areas actually increased, to some extent compensating for the loss of other sources of agricultural income. Income from non-farm economic activities also depends on regional trade and on the free flow of goods, services, finances and information into and out of rural areas. Systems that enable flow of this type, whether they be remittance from migrants, information regarding markets, support of cooperatives, weather or access to national financial markets through banks, are central to economic diversification *within* rural areas and thus to the ability to improve livelihood opportunities.

A fourth way to promote resilience in livelihood is the social capital and institutional checks and balances that households have access to, including education, community institutions such as self-help groups (SHGs), formal institutions such as government departments and banks, NGOs, the media and social networks. The social capital and institutional checks and balances present in rural areas are crucial on building resilience. Unless people have the skills required to identify and take advantage of alternative income opportunities, their ability to adapt is limited. Access to capital and social organisations is key since many activities, however small, require both an initial source of financing and the assistance of others. The need for money and support underlie the critical role of self-help groups (SHGs) and formal institutions. Unless banks are present in rural areas and are able to make the types of loans people require, people are forced to depend on local moneylenders and to pay the high rates of interest they charge. Institutions like SHGs provide credit for whatever investments are essential for rebuilding livelihood systems and can create a critical formal check on moneylenders and other informal capital markets. The presence of diverse and competing organisations and sources of information is essential both to 'keep such organisations honest' and to provide the diverse array of services required for building livelihoods in the face of unexpected but emerging natural events, climatic variability and similar other types of change.

Fifth is the existing pattern of vulnerability created by gender, income and social position. A pattern of differential vulnerability is the hallmark of the people of the Ganga Basin. Women and girls in areas are particularly vulnerable. The poor also suffer disproportionate hardship. Actions that address gender and other forms of differential vulnerability are essential if cooperative efforts are to be able to build societal security.

Sixth is the nature of the physical infrastructure (roads, houses, water supply systems, etc.). In many localities of the Ganga Basin, local hydrological systems have been altered by the overdraft of regional groundwater aquifers or by the construction of roads, bridges, railway lines, and flood control embankments that fundamentally alter drainage patterns and water availability. These conditions can exacerbate the risk to livelihood systems. Forms of infrastructure that are themselves adapted to hydrologic variability, in contrast, enable social adaptation and thereby minimise vulnerability. The challenge is to explore and identify points of leverage through cooperative efforts.

A seventh risk-reducing element is the access of households in regions to reliable water, health and hygiene services. A reliable water supply is essential for maintaining secure livelihoods. Unless they have access to clean potable water, households face major health problems and may be forced to migrate. In flooded areas, the quality of water supply systems can make a significant difference.

The eighth and final insight Moench and Dixit identify is the condition of the natural resource system, particularly the degree to which ground and surface water systems have been disrupted. Environmental degradation, particularly of water supply systems, is an indicator of vulnerability. Long-term declines in groundwater levels during normal years are, for example, a key advance indicator of a region's vulnerability to drought. Although the timing of a drought may be impossible to predict, the severity of its impact depends heavily on the ability of the local population to access groundwater. The recent discovery of arsenic contamination of groundwater is a potentially debilitating factor unless serious measures are taken to mitigate its devastation and alternative sources of water developed. Areas where development activities have included the construction of structures that impede drainage are likely to be vulnerable to floods. Overall, as has been widely recognised in a variety of situations around the world,[32] environmental conditions are central to determining how vulnerable a population is and how resilient they will be in the face of livelihood depletion.

CONCLUSIONS

A combination of complex factors causes floods. To improve the quality of the state's response to floods, South Asian nations must create infrastructure for day-to-day monitoring and

BOX 1:
NEW SKILL PROVIDES LIVELIHOOD

Thirty-years-old Babu Lal is just one of the many Dalits living in Kanakpur village on the bank of the Bagmati who struggle to feed their families two meals a day. He lives with his parents, his wife, and his two children. The sole bread earner in the family Babu Lal works in a *zamindaar's* fields as a daily wage labourer.

Once, when Babu Lal fell ill and was confined to bed, the family was forced to look for other sources of income. His mother took a loan from a money-lender for his treatment. Babu Lal could not return to work until he had fully recovered, his parents and wife worked as labourers to make ends meet.

After he recovered Babu Lal learned of training in weaving bamboo chairs. He joined the course and learned new skill and now makes a living by making chairs. His wife and mother help him make chairs which sells for up to Rs 100 apiece. He earns Rs 150-200 a day whereas earlier as a wage labourer he made about Rs 3,335 to 4,000 a month. With the additional income, he has been able to open a saving account in a local bank.He also paid the loan his mother took when he was sick and bought some piglet. Learning a new skill has made him more secure financially.

Source Moench and Dixit (2004)

BOX 2:
AN WOMAN TAKES CHARGE

Thirty-two-years-old Bhagya Devi lives in Kananpur village of Rautahat with her two sons, two daughters, husband and mother-in-law. Their main source of livelihood is agriculture. After they lost their land to a flood, her husband went to Punjab to work as a labourer. He returns home every year but spends half his income on liquor. Much against local traditions, she went out in search of work as a labourer to support her family. Her husband did not help her.

One day robbers attacked her. They raped her and also took away the little jewellery she had. This unfortunate incident devastated her. Not only does the society sneer at her but her husband rejected her because other men had touched: he made no allowance of the fact that she was not a consensual partner. The local *panchayat* intervened and advised the couple to stay together. Bhagya Devi consented keeping the interest of her children in mind and her struggle continued because of her young children.

She began planting vegetables on her four *katha* of land. Every day she leaves home for the market with a basket full of vegetables and takes pride in the fact that she brings home some income from the sale. She is not ashamed even to go against the social norms, which require that women veil, themselves. Self-reliant Bhagya Devi inspires other women too. Since she began earning independently, her relations with her husband have improved. He even consumes less liquor now.

Source Moench and Dixit (2004)

analysis because dealing with the problems of floods is hampered by a lack of understanding of the nature and causes of floods. A minimum requirement for improving flood forecasting is a fair number of rainfall and flow monitoring stations. The existing hydrological stations provide data of varying levels of reliability for only a few rivers and are inadequate. The establishments of a sound mechanism for data collection, analysis and interpretation should be intertwined with the establishment of a system for flood forecasting.

The problem is not of drought or floods but of risks which the farmers and the poor face at the micro scale. While relief and rehabilitation are crucial from the point of view of supporting the communities hit by floods, equally important are provisions such as risk and life insurance, and, in the case of agriculture, crop failure and livestock insurance.[33] Making the provision needs to be part of regular governmental functioning and overcoming the challenge of flooding is an issue of good governance. The institutional capability to respond to floods whenever and wherever they occur must be strengthened. The most important condition is that the response to flooding must, be, as is planning part of the daily operation, rather than *post-facto* relief.

The governments need to focus on the formulation of regulations, reviews, and inspections: on the creation of buffer stock to meet needs in case of flooding in isolated pockets, and on monitoring. Strengthening local bodies through political and legal empowerment will increase extent of impartial regulatory functions such as formulating rules, policies and mechanisms for adjudication. The voluntary sector, as the intermediary between the state and the community, should have a more active role in the mitigation of the impact of floods. We need to re-conceptualise our responses in order to meet the challenges of adapting to floods in their entirety. New methods and tools will have to be devised and internalised in the normal operation of our societal and governmental organisations.

A successful response to floods needs to view within the larger framework of governance. It is within this framework technological choice, its implementation and maintenance should occur. Successful response to flood is about building institutional capacity to forecast the event, preparedness and support that needs to be made available to individuals, families and communities to build their capacity. Our approach at the same time needs to create built-in system of checks and balances, allow space for lateral thinking, and provide the society with the pluralism in innovation, caution and regulation it needs in order to bring about stable transition in the management of the risks due to flooding.

NOTES

1 See Bandhyopdhyay, (1999)
2 See Blaikie *et al.* (1994)
3 Maskrey (1989) terms this the dominant approach.
4 This approach is also called the 'political-economy' approach *(Ibid)*.

5 See UNCHS, 1981.

6 Social relationship and structures are often consolidated and maintained by institutions, which formalise relationship among individuals; within households and families; among classes and groups; and among individuals the state and other social organisations, such as private companies and banks. Inequalities between classes, ethnic groups, and gender categories are often a result of, and reinforced by, these social institutions. (Duryog Nivaran, 1996)

7 Gyawali and Dixit (1997)

8 Douglas (1990).

9 See Burton *et al.* (1993)

10 The 1991 State of the Environmental report by CSE begins a systematic documentation of the problem due to embankments. Mishra (1997) marshals evidence that embankments have exacerbated flood hazard in the lower plain of north Bihar. Gyawali (1998) has provided theoretical analysis of different ways or organising and their responses to the flooding in the north Bihar.

11 For discussions of the mosaic nature of the diversity and how responses need to adapt to the context see Moench *et al* (1999)

12 In 1998 in the upper Rohini catchment in the three months of June, July and August 3200 mm rainfall was recorded. The normal rainfall in the region during the same period was 1502 mm.

13 *Ibid*

14 Active glacier lakes are located between the Kali Gandaki in central Nepal and the Kanchenjunga in the east.

15 For an elaborate discussion on location, causes, and lessons of past GLOFs, see Gyawali and Dixit (1998).

16 WECS (1987)

17 See DPTC (1994)

18 For a discussion of role of vegetation, see Gilmore *et al* (1987) and on impact of terracing on hill slope see Wu and Thrones (1995). A discussion of the debate surrounding The Himalayan Degradation Theory are found in Chapman and Thompson (1995)

19 The Memorandum of Understanding between HMG/Nepal and Snowy Mountain Engineering Corporation of Australia sets stage for this project.

20 For a elaborate discussion on the politics of cooperative water development see Gyawali and Dixit (1999)

21 There are two storage sites in the Mahakali Basin, seven in the Karnali, seven in the Gandak, five in the Kosi, and nine in other river basins (Gyawali, 1993).

22 R. Rangachari, former member of the Central Water Commission Government of India made this observation at the seminar on Eastern Himalayan Rivers held on 3 April, 1999, in Kathmandu.

23 Janeswar Mishra, the former Water Resources Minister of Government of India, visited Gorakhpur and remarked “Indian government should discuss with its Nepali counterparts about the release of waters from that country into India.” Agency Reports (1998)

24 See The Hindustan Times (1998). The emphasis on using dams in Nepal to alleviate flooding in the Northern Ganga plain is a theme common to all political parties. The Kosi High Dam at Barahachetra in Nepal is perceived as the social, economic and hydrological panacea for the state. See, Dubey Binod who quotes former minister for water resources Government of Bihar Jagdananda Singh in The Hindustan Times February 15, 1999 who said that “Nothing but the high dam (Kosi) can solve our problem.” Environmental groups in Bihar counter this point of view. They argue that the high dam will bring unmitigated disaster. See Barh Mukti Abhiyan (1997)

25 Article 3 of the Treaty says, “The cost of the project shall be borne by the Parties in proportion to the benefits accruing to them.”

[26] See Thapa, (1997), and Dhungel (1996)

[27] Most of the writings that highlight the potential of water led development make no mention of the risks posed by sedimentation in the Himalayan Rivers. The mainstream discourse of South Asia, does not acknowledged sedimentation as a risk. A document jointly prepared by IIDS, CPR and BUP in 1999 argues that soil erosion, landslide and mass movements can be significantly controlled through proper watershed management. A growing volume of scientific literature, however, points to the geologic nature of the sedimentation process in the Himalayas and suggests that watershed management is relevant on the micro level but does not affect annual sediment yield on a regional and river basin scale. See Carson (1980), Ives and Messereli, (1995), and Bruninjzeel and Bremmer (1989). Also see CSE (1991)

[28] Nippon Koei (1996)

[29] The World Bank (1975)

[30] The first account of involuntary displacement appeared in 1988. See Pokharel (1988) and Gurung (1989).

[31] For a discussion of the challenges of water project-related dislocation in Nepal, see Dixit (1994)

[32] Aalst and Burton (2002); Blaikie *et al.* (1994).

[33] *Ibid* Chapman (1995) who terms such approaches flexible, which the farmers have done for millennia but with an added institutional extra layer, meaning that the response is local but plugged into the national and regional framework.

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HYDROLOGIC VARIABILITY: IMPLICATIONS FOR LOCAL MANAGEMENT IN NEPAL

AJAYA DIXIT* AND MARCUS MOENCH**

CORE ARGUMENT

This paper argues that variability present inherent challenges to water management throughout South Asia. Conventional water management strategies attempt to reduce the inherent variability in water availability by controlling flows, developing storage facilities (reservoirs) and diversifying water supply sources. The first two strategies are both inadequate and risky in the South Asian context in part because data are generally inadequate to document sufficient hydrologic characteristics at the geographical and temporal scales to make control-based management strategies feasible. Furthermore, though the functioning of facilities essential for large-scale, control-based water management (dams, canals, permanent diversion structures, and the like) is extremely sensitive to sediment loads and extreme stream flow events, erosion and sedimentation processes are poorly understood and difficult, if not impossible, to quantify. The same limitations hold for predicting and measuring is other extreme events such as glacial lake outburst floods (GLOFs), *bishyaris* (landslide-induced floods) and intense rainstorms. Because, in many ways, the hydrology of South Asia is shaped by extreme events, water management strategies need to respond as much to them as to the variability captured in the relatively short-duration data sets generally available.

We argue here that variability, and the characteristics extreme events have embedded uncertainty which has fundamental implications for water management strategies. In most cases, conventional water management structures and institutions are ill-equipped to respond to extreme events. The siltation of major reservoirs occurs far more rapidly than anticipated and fixed diversion or control structures are frequently damaged in high-flow events or rendered ineffectual when stream courses shift. Instead, there is a need for adaptive approaches to water management approaches that are responsive to variability and extreme events and can be adjusted to suit local conditions in order that the strategies cater human as well as needs of the ecosystem.

This paper documents some of the key factors responsible for the variability of hydrologic systems in South Asia as well as the uncertainty that underlies water management. We focus primarily on the Himalayan region, Nepal in particular, but also draw examples from other

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regions where we have undertaken research. The first section focuses on precipitation, river system hydrology, sedimentation and extreme events. We then discuss key issues related to data inadequacy before moving on to analyse the incentives different institutions have to collect data and their implications for coping with variability and uncertainty.

INTRODUCTION

Water is one of the most common substances on earth, and in most locations aggregate water availability is more than sufficient to meet both current and projected needs. Aggregate water availability is irrelevant, however, as access to water for human and environmental needs depend on spatial and temporal variability. We do not care how much water is theoretically available in a region. What do care about is whether or not water is accessible when we want it, in the amounts, we desire or need and of the quality we require for a specific use. Because the natural processes which affect water availability are highly variable, the supply of and demand for water are often substantially different. In most cases, society has responded to variability in water supply through technological interventions, such as dams and reservoirs, tanks, barrages and weirs, designed to reduce the variability of surface water supply sources. Society has also responded by developing access to groundwater—a source of water supply subject to less variability than most surface sources. The groundwater option, however, is growing increasingly limited, particularly in the many areas where extensive development has caused substantial long-term declines in water levels.

Conventional responses to variability generally assume that the natural behaviour of hydrologic systems can be accurately captured by monitoring the location, timing and quantity of rainfall and stream flows in conjunction with collecting data on sediment, evaporation and other relevant factors. It is becoming increasingly clear, however, that there is a growing disjunction between the assumptions we make in designing water management systems and our actual understanding of water in nature. Most conventional water management approaches are predicated on the assumption that we understand the fundamental dynamics of water resource systems—for example, that such systems are stationary (fluctuating about some 'real' long-term mean) constant over time and can be statistically characterised using—i.e. the assumption that fluctuations revolve around a mean value that is constant over time records kept for relatively short periods. Both these assumed dynamics are open to question, however. In locations such as the Himalaya, the nature of hydrologic systems may be characterised more by relatively extreme events than by daily, monthly or annual fluctuations that can be measured during one or two decades of monitoring. While stream flows and precipitation are probabilistic in nature, it is far from clear that we actually have sufficient data to document probability distributions, particularly in their tail areas. In addition, we have little evidence to support the assumption of stationarity. Even leaving current debates over climate change (which explicitly rule out stationarity) aside, there is substantial evidence that in many parts of the world, climate and hydrology are subject to significant changes over time.[1]

Different approaches to water management are more or less vulnerable or adapted to variability, uncertainty and change. Some strategies require solid probabilistic definitions of flows or sediment loads, while others function regardless of whether or not the flows stay within relatively narrowly defined parameters. Many conventional water management structures (like dams and weirs) are inherently vulnerable to the inaccuracy of hydrologic estimates and, as a result, often do not deliver as expected. In fact conventional structures installed in South Asia have failed on many occasions. Rivers have changed and bypassed diversion structures or pump stations and the amount of water captured by reservoirs is, because of sedimentation, often lower than first assumed. Similarly, floods whose magnitudes exceed those predicted during the structural design stage often damage structures by overtopping or washing them out. Not only does water meets immediate human needs, it has pivotal role in mediating ecosystem processes. Water maintains living organism. Productive freshwater ecosystems are crucial to the livelihood of fishers and other littoral communities while providing range of services to people worldwide.[2]

Such events are common place and reflect the substantial uncertainty surrounding hydrologic estimates developed using conventional assumptions and available data sets in environments characterised by high levels of variability. To overcome these shortcomings, uncertainty and variability need to be understood in more detail.

NATURE OF VARIABILITY

No other region in the world better reflects the nature of uncertainty than does the Himalayan region, which is a barrier between the Tibetan plateau and the Gangetic plain. This physical setting contributes broadly to a rich water regime with marked seasonal and spatial variations. In many cases, rainfall and stream flows vary greatly over short distances due to the complex topography and geology of the world's most tectonically active region.

As a result of this variability, approaches to water management that depend on the accurate characterisation of hydrologic conditions require the accurate collection of data at or near the location of interest. The existing network of hydrographic stations established to monitor precipitation, runoff, sediment load, erosion rate, infiltration/percolation and evaporation is inadequate for representing the spatial and temporal variability of the region. As a result, unpredictable hydrology and sedimentation leads to frequent losses both at the micro-scale and larger level of interventions.

Three hydrological issues are important for effective water management: 1) the inherent randomness of the weather systems that produce precipitation and the stream flow, sediment transport and other processes within the complex Himalayan context; 2) how these events are assessed or measured; and 3) how the resulting data are stored, retrieved, analysed and interpreted—i.e. how the institutions that are in control of the data operate and 3) how is generated thus knowledge shared and disseminated. This paper focuses primarily on the first of these issues, i.e. the uncertainty inherent in complex hydrological contexts. The other two issues, data adequacy and data institutions, are briefly addressed at the end of the paper.

Before proceeding into a full discussion of the uncertainties inherent in the Himalayan hydrological context, a few conclusions are important to preview. First, the network of hydrological stations available in the Himalayan region is inadequate for monitoring the temporal and spatial characteristics of key hydrological parameters, specifically precipitation (rainfall and snowfall), stream flow and sedimentation. While the spatial characteristics of the network could be strengthened by establishing more stations, the period of record depends on the length of time a monitoring system has been in place and will only improve with time. Gaps in the temporal record cannot be addressed rapidly. Second, the behaviour of river is inherently unpredictable in mountainous regions where conventional theories of river mechanics and morphology are inapplicable. Third, the Himalayan region has a high inherent level of uncertainty due to the common but unpredictable nature of extreme events such as GLOFs and *bishyari*, and the region's geology and seismicity.

PRECIPITATION: RAINFALL AND SNOWFALL

The Himalayan climate is heavily influenced by elevation and Nepal alone can be classified into the following five climatic regions (Shanker and Shrestha, 1985):

1. A tropical climate in the Tarai, Inner Tarai, and (Chure) Siwalik regions with hot and wet summers and mild and dry winter.
2. A warm temperate monsoon climate in the middle mountains up to a height of about 2,100 metres above sea level (msl).
3. A cool temperate monsoon climate in the middle and high mountains between 2,100 and 3,300 msl.
4. An alpine climate in the high mountain region up to a height of about 4,800 msl.
5. A tundra climate above the snow line, where there is perpetual frost and cold desert conditions.

The extent and magnitude of rainfall and snowfall across this climatic spectrum is influenced by temperature, wind speed, radiation and location. Most rainfall occurs during the south-west monsoon, which occurs from June to September. The extent the monsoon reaches inland determines the volume of water delivered. The temporal and spatial variability of rainfall is strongly determined by the movement of the Inter-tropical Convergence Zone (ITCZ), the earth-encircling region near the equator, where the trade winds of the Northern and Southern hemispheres come together. The general behaviour and exact location of the ITCZ from one year to the next are unknown.[3]

According to the rainfall records collected by the Department of Hydrology and Meteorology (DHM), the average area-weighted annual precipitation in Nepal is about 1,630 mm and half of the country, gets between 1,500 and 2,000 mm of precipitation (Chyurlia, 1984). Over 75 per cent of annual precipitation falls from June to September. The months of October to May, in contrast, are dry, getting only sporadic rainfall. During the winter months, weather systems, known as westerlies, which originate in the Mediterranean region bring rain. The systems reach the central Himalayan region in their dying stages, as its influence tends to be stronger in the west than in the east. As a result, winter precipitation in western Nepal can be significant although in certain years it was not. In the pre-monsoon months, of May and June rainfall is conventional, characterised by thundershowers and squalls caused by the cooling and condensation of rising hot air.

Snow falls regularly in the Himalayan region and feeds glaciers and snow-pack, runoff from which contributes significantly to the flow of major Himalayan rivers and influences their hydrological behaviour. Accumulated snow acts as a reservoir, releasing water as it begins to melt. About eight per cent of Nepal's area is under permanent snow cover. Permanent snow and glaciers is found above 4,000 m. During the winter months, freezing temperature extend downwards to elevation of abot 2500m and with snowfall, accumulation is at its lowest elevation in March and gradually increases as the snow starts to melt with the advent of spring. With the growing impact of global climate change the snowline is known to be gradually receding, though systematic records do not exist. Based on measurements in the catchment of the Kosi River, where 90 per cent of precipitation falls as rain and the rest as snow, it has been estimated that 10 per cent of the country's total precipitation occurs in the form of snow.[4] Chyurlia (1984) has estimated that the total annual accumulation of snow in Nepal is approximately 21.10 million cubic metres of water equivalent.

Rainfall is influenced by both topography and altitude. Even during the monsoon precipitation is highly variable. Precipitation can be categorised into macro, meso and micro types (Domroes, 1977). The macro scale refers to variations in precipitation across the greater Himalaya; the meso scale to variations within a defined geographical region; and the micro to variations within a hill watershed. The characteristics, volume, duration and intensity of precipitation across the hills vary.[5] In fact, pronounced temporal and spatial variations may mean that while a hydrological station on one side of a hill records high rainfall, a station on the other side of the hill records little or no rainfall. Orography strongly effects the spatial variation in precipitation, a fact which precipitation data on either side of the Annapurna range in central Nepal makes evident. Indeed, the highest and lowest amounts of rainfall in Nepal occur on opposite sides of this range: Pokhara receives 5,000 mm of rainfall annually, while Jomsom receives just 400 mm. Striking annual variations are recorded within valleys too. In the Kathmandu Valley, where rainfall data has been collected since 1921, annual rainfall varies from about 875 mm in a dry year (1921) to 1,969 mm in a wet year (1973). In a typical year, the central valley receives 1,400 mm of rainfall while the surrounding hills receive more than 2,000 mm. Preliminary analysis indicates that while the annual rainfall fluctuates around a mean of 1,400 mm, there is a 10-year wet and dry cycle (Alford, 1992).

Although in general regions at high elevation generally receive more rainfall than regions at low elevations, in small watersheds, rainfall and elevation are not directly correlated (Domroes, 1977). Micro climatic variations are pronounced in small watersheds. During the monsoon three strong meteorological phenomena work simultaneously to produce this variability: the monsoon depressions, the cloudbursts and the tropical cyclones. A monsoon cloudburst over a small area can bring as much rainfall as 100 mm per hour; in fact, it is not uncommon for it to rain more than 25 mm in 15 minutes. These sudden short-lived, heavy rainfalls over a small area are usually associated with thunderstorms. Because of cloudburst the Himalayan region and the adjoining plains extending up to 300 km south of the foothills between the longitudes of 78o E and 89o E experience average rainfall that ranges from 50 per cent less to 300 per cent more than normal rainfall.[6]

Cloudbursts are caused by intense vortices that generate strong convective currents. Although the exact mechanism is not understood, these currents lift moisture-laden air with sufficient rapidity for rapid condensation to occur and thereby generating storms of immense strength and ferocity. These storms regularly produce 100 mm and occasionally over 350 mm of rainfall in 24 hours. In Kathmandu, rainfall intensities of 120 mm/hr lasting for 10 minutes have been recorded. Such intense rainfall events have serious impact on flood magnitudes, erosion and drainage problems in urban areas. Because such events are usually localised their exact impacts are difficult to predict not only because of the inherent unpredictability of where cloudbursts will occur but also because of the influence of rainfall-runoff relationships. In areas like the Kathmandu Valley, these relationships are poorly defined, suggesting that other hydrological sub-processes (including, perhaps, water abstraction for irrigation and other uses) have an influence.

Extreme Rainfall Events

Table 1 is a review of extreme precipitation events in northern South Asia. As the data indicate, these events are common. For example, Dharampur, a hydrological station in south Gujarat, recorded 990 mm of rainfall in 24 hours on July 2, 1941, probably the maximum recorded 24 hours rainfall in India.[7] The earliest recorded extreme rainfall

TABLE 1
SELECTED EXTREME RAINFALL EVENTS

Year	Date	Recorded rainfall (mm)	Region /Stations	Country	
1880	18 September	1,048 (2 days)	Nagina, Uttar Pradesh	Garhwal India	*
1902	26-27 September	770	Dharmapur	India	**
1915	11-13 June	720	Nagibabad	India	**
1924	September	770 (3 days)	India	India	*
1931	24 June-8 July	4,798	Cherrapunji	India	**
1950	12 June	546	Teesta Valley	India	**
1954	24-30 July	500 (heavy			
	22-25 August	rainfall for 4 days)	Affected about 15,000km^2 of Sun Kosi River	Nepal	***
1959	7 September	409	Tansen	Nepal	***
	10 October	473	Anarmanibirta		
1960	29 July	503	Musikot	Nepal	***
1968	3-5 October	1,044	Padamchen (Darjeeling)	India	**
	5-6 October	465			
	25 August	505	Gumthang	Nepal	***
1969	5 August	1,001	Labha-Phaperkheti	India	**
	5 August	742	Aligarh-Gorubathan	India	**
1972	17 May	4,032	Teesta Valley	India	**
1974	28 July	405	Barahakshetra	Nepal	***
1977	10 June	460	Teesta Valley	India	**
1978	20 May	1,800	Teesta Valley	India	**
	15 July	322	Hariharpur Gadhi	Nepal	***
	15 July	301	Tiger Tops	Nepal	***
	16 July	304	Ramauli Bairiya	Nepal	***
	19 July	376	Hetauda	Nepal	***
1979	2-6 October	900 (3-day point fall)	Upper Arun Basin &Num	Nepal	***
1980	12 September	431	Bajura	Nepal	****
1981	28 September	350	Garakot	Nepal	***
	28 September	381	Khanchikot	Nepal	***
	29 September	342	Chapkot	Nepal	***
	29 September	446	Baluwa	Nepal	****
	30 September	420	Mane Banjayang	Nepal	****
1982	13 September	401	Semari	Nepal	****
1984	15 September	344	Hariharpur Gadhi	Nepal	***
	15 September	330	Damak	Nepal	***
	16 September	342	Sinduli Gadhi	Nepal	***
	16 September	381	Chandra Gadhi	Nepal	***
	17 September	355	Bahun Tilpung	Nepal	***
	17 September	403	Triveni	Nepal	***
	16 September	437	Kankai	Nepal	****
1986	August	296	Nibuwatar	Nepal	****
1987	9-13 August	800 (3-day point fall)	Sapta Kosi Basin	Nepal	***
1990	26 August	257	Amlekhganj	Nepal	****
	27 August	453.2	Hetauda (NFI)	Nepal	****
	27 September	438	Hetauda (industrial dis.)	Nepal	****
	27 August	438	Makawanpur Gadhi	Nepal	****
	27 August	230	Beluwa	Nepal	****
1993	20 July	540.0	Tistung	Nepal	****
	20 July	482.5	Hariharpur Garhi	Nepal	****
	21 July	399.0	Amlekhganj	Nepal	****
	20 July	385.0	Markhu	Nepal	****
	20 July	373.0	Daman	Nepal	****
	21 July	437.0	Patharkot	Nepal	****

	6 September	355.0	Parasi	Nepal	#
	6 September	398.0	Dumkibas	Nepal	#
	21 July	403.2	Sindhuligadhi	Nepal	#
1994	10 September	304.3	Beluwa	Nepal	#
	10 September	300.6	Rajaiya	Nepal	#
	15 August	285.0	Dharan British Camp	Nepal	#
	15 August	246.3	Dharan Bazar	Nepal	#
1995	13 Aug	330.0	Karmaiya	Nepal	#
	17 June	270.0	Aizealukhark	Nepal	#
	12 August	234.0	Rangchani	Nepal	#
	24 June	230.3	Rumjakot	Nepal	#
	12 August	286.4	Nijgadh	Nepal	#
1996	13 July	253.3	Tahahara	Nepal	#
	14 July	354.0	Butwal	Nepal	#
	14 July	298.6	Bhairhawa	Nepal	#
	13 July	295.1	Damak	Nepal	#
	11 July	346.7	Shyano Shree (Chepang)	Nepal	#
1997	10 August	319.2	Sitapur	Nepal	#
1998	3 August	362	Bardhaghat	Nepal	##
	3 August	378.0	Farauli	Nepal	##
	3 August	363.0	Pipariya	Nepal	##
	3 August	407.0	Padari	Nepal	##
	3 August	495.0	Parasi	Nepal	##
	9 July	310.0	Basantapur	Nepal	##
1999	6 October	203	Katai	Nepal	#
	11 July	310.0	Dumkibas	Nepal	#
2000	24 April	240.7	Jajarkot	Nepal	#
	8 June	236.2	Koilabas	Nepal	#
	3 August	319.3	Daman	Nepal	#
	3 June	339.5	Janakpur Airport	Nepal	#

*Source: * HPC (1989), ** Kale (1998), *** SMEC (1993), **** ICIMOD (1993), # DHM (Records) and ## NWCF (Records)*

event in South Asia is probably the September 1880 event over northwestern Uttar Pradesh. The centre of the rainfall event was over Nagina, Bijnour District, where 1,048 mm of rainfall was recorded over a two-day period. Earlier events are mentioned in historical texts, including large-scale inundations in Assam Valley in 1769 and 1786. In 1927 high rainfall in Orissa and the flooding of the resultant Baitarni, Brahmini and Mahanadi rivers led the Government of India to appoint the Orissa Flood Committee to study the nature and causes of flooding. The creation of this committee was probably the first attempt to systematically examine the issue of floods in South Asia. At Cherapunji, a total of 4,798 mm of rain fell between June 24 and July 8, 1931. In the Teesta valley, records show that from 1891-1965, rainfall intensities of over 250 mm within 24 hours occurred more than 40 times. During these periods of high rainfall, continuous downpours bringing between 600 and 1,000 mm of rainfall were recorded two to four times. These events transformed hill slopes and valley floors. Similar events occurred in 1968. In mountain areas cloudbursts are a major hazard, and needs to be carefully studied to determine its full range of risks.[8]

An important feature of the above table is that most of the recorded events in Nepal are recent, probably because of the extension of the monitoring network into areas that were without monitoring stations. This observation, as well as oral history suggests that such events have always been common. In Nepal, for example, oral histories recount numerous extreme rainfall events which have occurred in the south-central region since 1915.[9] More recently, data that indicate the impacts of such events have become available. For example, between August 22 and 25, 1954, the axis of the monsoon trough shifted northward over the hills, causing heavy rainfall. In synchrony with this movement the weather system's waves moved eastward across the Nepal Himalaya, for about three weeks.[10] The result was vigorous rainfall over large tracts of hills in central-eastern Nepal and northern Bihar.[11] One gauge in Barahakshetra in eastern Nepal recorded 331.3 mm of rain in four days. The highest 24-hour rainfall recorded, 185.4 mm, was in Dhankuta on August 24. This rainfall event extended into the Kathmandu Valley, where a station in Lainchaur recorded 187.3 mm of rain in three days, from August 24 to 26.

One outcome of the 1954 August rainfall, compounded by earlier storms from 10 to 15 July was an unprecedented rise in the level of the Kosi River. On 23 August, the river flow gauging station in Barahakshetra recorded a peak flood of 24,235 m^3/s, the highest flow recorded at that time.[12] Fourteen years later, on 5 October, 1968, this record was exceeded: flood generated by heavy rainfall over the river's catchment area due to a tropical cyclone system which moved north from the Bay of Bengal peaked in Barahakshetra at 25,880m^3/s. On 29 September a depression started to form over the Bay of Bengal close to the northern coast of Andhra Pradesh. By 2nd October, the depression had intensified into a severe storm whose influence extended over to northeast Nepal and Darjeeling. From 3 to 5 October, rainfall was intense and widespread in these regions. In Nepal, rainfall was particularly high over the catchment of the Tamur River, a major tributary of the Kosi. Harainche, a station in the Tamur catchment area, recorded a 24-hour rainfall of 180.9 mm on 3 October.[13] In Dhulikhel, 221.3 mm of rainfall were recorded in a 24-hour period on 5 October. In the catchment area of the Teesta River, 1,580 mm of rain was recorded in a 36-hour period, with 1,044 mm falling within 24 hours.[14] Massive changes in the landscape of the Teesta Valley resulted.

In 1981 the southern region of the Kathmandu Valley experienced large-scale devastation due to high rainfall. This region did not have its own rain gauge but a station in Godavari recorded 169 mm in 24 hours (Bhusal, 1998) with an intensity estimated at 56.1 mm/hour (Rajabhandari, 1993). The cloudburst badly scared the hills forming the southern rim of Kathmandu: for many years they looked as if a giant cat had mauled them. Again in 1987, Central Tarai and Eastern Nepal received heavy rainfall during the second week of August, as the monsoon trough migrated northward. Within nine days (Table 2), the rainfall recorded in the eastern Tarai was 1,300 per cent of normal levels.

TABLE 2
RAINFALL IN EASTERN TARAI IN AUGUST 1987

Station	Annual rainfall (mm)	Rainfall in August (mm)	24 hr rainfall (mm)	Date (August)
Biratnagar	2,571	749	219	13
Kankai	3,494	1,371	243	13
Karmaiya	1,958	703	140	11
Janakpur	2,389	913	302	11
Lahan	2,172	887	228	11
Tarahara	2,820	1,326	378	11
Rajbiraj	2,415	928	170	11

In 1996, Jhyanku village in Dolakha, east of Kathmandu, suffered a monsoon cloudburst that left hill slopes scarred and many people dead. The survivors describe the rainfall as 'being under an overturned water drum'. In 1993 Central Nepal was struck by a cloudburst measuring 540 mm in 24 hours and with an intensity of 70mm/hour (Dhital *et al.*, 1993); the result was catastrophic flooding. Similarly, in 1998, heavy rainfall in the catchments of the Rohini and other rivers in Nawalparasi and Rupandehi districts caused devastating floods in the Nepal Tarai (Dixit, 2003) and in Eastern Uttar Pradesh,[15] Bihar and Bangaladesh (Mirza, 2003). Diurnal rainfalls exceeding 300 mm, which simultaneously disturb both slopes and channel equilibrium on a regional scale, occur frequently in Nepal (Khanal *et al.*, 1998).

Implications

The great spatial and temporal variability of rainfall in the Himalayan region generates substantial uncertainty regarding the availability of water and the hydrological events that will occur in any given location. Although much of the discussion above has focused on extreme rainfall events, rainfall amount less than the normal are equally common. With only 10 per cent of precipitation occurring as snowfall, the buffer available to sustain stream flows during periods of low rainfall is limited. As a result, water users in any given location must be prepared to face the two extremes of flood and drought. While the broad pattern of the monsoon can be predicted, this knowledge is of limited use to individual farmers and regions since extreme events are often highly localised. Thus, even with the best information possible, uncertainty regarding the availability of water and the resultant extremes in stream flows likely to be experienced will remain high. Variability is high even during monsoon months both within a single wet season across gauges and from year to year at a single gauge. Such variability is typical of the rainfall data recorded at a great many sites around the world and serves as a reminder of the danger of trying to draw climatological inferences from short-term records. It also indicates that rainfall distribution is generally produced by large-scale effects but that local influences cause significant differences (Wu and Thornes, 1995; Boorman, Jenkins *et al.,* 1998).

It is important to recognise that the above issue applies not just to the Himalayan region but to most locations in South Asia. While variability in the Himalayan region may be exacerbated by complex local topography and geology it is high in other areas as well. According to Pisharoty (1993), the average intensity of rainfall in arid regions of India is 1 cm/hr and has a very high coefficient of variation both within and across years. For this reason, runoff is rapid, flood flows are high and erosion intense. The case of Kutch District in Gujarat on the India-Pakistan border illustrates the extremes. As one of the authors of this paper recounted in an earlier publication: The area near Mandvi, which has an average annual rainfall of 350 mm, received 654 mm over a four-day period in July 1992, after having gone through a year of relative drought the preceding year, with a total of only 185 mm for the whole of 1991.[16] Half the annual rainfall in Kutch typically occurs in a period of two to three hours during the monsoon season. There are generally only between eight and ten rainy days in the year during which rain actually falls for an average of only 12 to 15 hours (Pisharoty, 1992). Under these conditions, runoff is brief and intense. Even in high rainfall areas of Gujarat, precipitation is markedly seasonal. In the south, out of an average of 51 rainy days a year, 48.5 (accounting for 94 per cent of the total rainfall) occur from June to September (Phadtare, 1988)".[17]

Brief, intense storms are common throughout India. Rainfall levels as high as 107 mm/hr were recorded during a storm in Kerala (Moench, 1990). Rainfall of this intensity is highly erosive: Kerala storm, for example, produced annual sediment transport in more than 50 per cent of the sample plots. Such effects have major implications for overall river system hydrology.

RIVER SYSTEM AND HYDROLOGY

The complex Himalayan geology in Nepal has created a dense network of stream drainage. There are about 6,000 rivers with a total length of about 45,000 km and a drainage density of 0.3 km/km2 of lateral channels (Shankar, 1976). About 1,000 of these rivers are more than 10 km long and about 100 of them are over 160 km in length. Surface water occupies approximately 2.7 per cent of the country's area, and 97 per cent of that area comprises large rivers that originate in the Himalayan region.

The hydrology of rivers in Nepal generally reflects regional rainfall patterns. From July to September, the rivers experience high flow; then, from October to November flow, levels decrease until they reach their lowest levels between December and April. Pre-monsoon rains, snowmelt and thunder squalls begin to increase flow levels in April, and with the start of the monsoon in early June, flows increase rapidly. Rivers that originate below the snowline have high flows during the monsoon and low flows during the dry season. The Chure rivers exhibit high flow variation: the southern slopes of the Chure receive the heavy rainfall. Peak monsoon flows in these rivers can be a thousand times greater than their lowest levels. Even during the monsoon, however, rivers can remain dry much of the time and only flow following specific rainfall events. Along the foothills, flow may occur below the ground; no systematic methodology is available for estimating this flow, however (WECS and DHM, 1990).

Snow-fed rivers also exhibit marked seasonal variations in flow. The flow of rivers such as the Kosi, one of the largest in Nepal, can fluctuate very rapidly: in the Kosi gorge a rise of six to ten metres in 24 hours is not uncommon. Incessant rain in the Kosi catchment leads to floods; those which occurred in 1954 and in 1968 due to long periods of rainfall were most severe. In smaller streams, the impact of flooding is localised but, depending on the extent and duration of the rainfall and the magnitude of the resulting flood, it can become widespread. At the end of the monsoon, when land is saturated, if rainfall occurs almost 100 per cent of rainfall contributes to overland flow. Similarly, during this period almost all of cloudburst participation results in overland flow, with devastating consequences.

Flow variability at the watershed level is compounded by a variety of local factors that affect hydrologic conditions at any given time. Processes such as infiltration, inter-flow, percolation and groundwater recharge are dependent on site-specific conditions, including topography and geology. In areas of rugged mountains, contributions to groundwater tend to be low and surface runoff, which contributes directly to stream flow, high. As a result, runoff is rapid and the resulting flood flows extreme. In contrast, seepage is high in the *bhabar* (a zone of coarse materials area of estimated 4,014 km^2 (Duba, 1982) at the base of the Chure range north of the less coarse sedimentary deposits). In the *bhabar* the recharge occurs mainly through seepage and percolation during rainfall and contributes to groundwater in the Tarai. Infiltration along riverbeds, particularly in regions where the rivers fan out from the hills, also contributes to recharge.

Because of the complex hydrology and geology of the Himalayan region, flow variability in medium and small basins is high and there is substantial uncertainty regarding their hydrological characteristics. Since most medium and small basins are unmonitored there is not enough data available to estimate mean annual flows, let alone flow distribution or trends. As a result, designs for floods do not conform to real-time events and the water intakes of many irrigation and water supply schemes in the hills and the Tarai, repeatedly washed out. Since prediction is unreliable, system components tend to be incorrectly designed. When a system is over-designed, the cost of the infrastructure soars up. If it is under designed, system performance is sub-optimal and invariably the system fails because it cannot accommodate high flows. The lack of data also constrains low flow analysis. Flow diversions for irrigation are significant: water is diverted from small tributary streams as well as from large rivers such as the Karnali, Sun Kosi, Bagmati, Babai, West Rapti and East Rapti. The volume of water extracted is particularly high during the months of February to May, when river flows are low. The influence of human interference is seen in the flow responses in cultivated catchments. In the mid hills, studies have found that outflow from catchments at the end of the wet season, was higher than a model had estimated. It is unclear, however, whether this level of flow is determined by a natural release of water stored within the soil or is the result of the conservation of water within flooded terraces for crop irrigation (Boorman, Jenkins *et al*., 1998). Because there is no quantitative basis from which to determine and allocate flows, disputes over water rights are common and difficult to resolve. Such disputed are further in the section on data institutions.

SEDIMENTATION

In addition to high and low flows, sediment load is one of the most important factors affecting water management needs and options at both basin and local levels. A major part of the sediment load carried by rivers is of natural origin, from landslides and mass wasting; river erosion both lateral and down cutting; and sheet, rill and gully erosion. Sediment load affects all water management structures, from the useful lifetime of a reservoir to diversion designs and canal maintenance. Unfortunately, sedimentation processes in the Himalayan and Indo-Gangetic basin regions are highly variable and particularly difficult to quantify.

A wide variety of factors affect sediment load. They range from fundamental states such as the ongoing tectonic uplift of the Himalayan range and regional geology to immediate anthropogenic impacts such as those associated with grazing, deforestation and infrastructure development. The quantitative analysis of sediment contributions from different sources is complex: methods range from attempts to directly measure sediment concentrations in streams and deposition in traps to predicting quantities using mathematical models. Most are based on measurements of suspended sediment concentrations. Such estimates are highly unreliable because in most circumstances, it is impossible to directly measure bed load (the portion of sediment that has settled in riverbeds) and because suspended sediment response in the mid mountains is non-liner and episodic (Brasington and Richards, 2000) occurring as it does largely during extreme events. Furthermore, most methods of measurement have been developed in stable, humid regions or in laboratory studies and do not match the hydraulic characteristics of mountain rivers or highly variable flow regimes. Sediment from landslides and other point sources are another major source of uncertainty (Carson, 1985). Since landslides and mass movements are common in the Himalaya, but occur randomly, the prediction and assessment of their contribution to the sediment balance is important but complex. At present, there are no reliable methods for estimating their contribution. In addition, since mass wasting events generally have a major influence on sediment load and often bring about unpredictable changes in transport patterns, analysis based on historical data cannot predict how rivers will behave in the future.

The sediment load carried by Himalayan rivers is high and extremely variable. The highest sediment concentrations are generally associated with high flood discharges and rising river stages.[18] The difficulty in estimating sediment contribution is complicated by the limited amount of data available. For most rivers, there are no continuous records of sediment loads. Nationwide, measurements are currently taken at only 20 stations, and the longest records are only about 10 years. Furthermore, in most cases only the suspended sediment load is measured. In major snow-fed rivers, more than 90 per cent of the suspended sediment load moves during the monsoon months (Shanker, 1989). In rain-fed rivers the figure is between 91 and 97 per cent and while recorded assessment is almost non-existent. <u>The Chure rivers also exhibit similar characteristics</u>. A large amount of sediment is discharged during the short periods single events last. Bed load has never been measured. Many early studies simply assumed that the bed load was about 10 to 20 per cent of the suspended load. Such assumptions have no scientific basis and produce erroneous results.[19] Even where actual field data are used, estimates are subject to variation due to differences in methodology in data collection, and the timing of measurement. Antecedent river conditions, for instance, influence sediment supply and transport, and in turn, measurements. In additional, peak events are usually overlooked during observations.

Though sediment load is not easy to measure, order of magnitude estimates are essential for understanding the influence that sediment loads have on the performance and economics of all development and water management initiatives. In Nepal, the erosion rates of a few catchments in different ecological zones and under different conditions have been estimated and documented (WECS, 1987). These estimates are based on assumptions regarding sediment delivery ratio, trap efficiency, and gully and non-gully erosion contributions. Rates of erosion range from 42,000 tonnes/km^2/year for heavily degraded mountain slopes to 920 tonnes/km^2/year for protected pastures (Laban, 1978).[20] Even for the same river, however, documented sediment yield estimates vary widely (WECS, 1987). In the 1970s the total sediment outflow from Nepal was estimated to be 240 million m^3/year (IBRD, 1974) or 640 million tonnes (Shankar, 1989). To highlight the serious problem facing the Himalaya many academic and journalistic writings quoted this number. More studies have made it clear that sediment discharge is actually much higher, but estimates differ.

The cases of four snow-fed rivers; the Kosi, the Narayani, the Karnali and the Mahakali, demonstrate gap between high rate of sediment discharge and their estimates.

Every year Kosi transfers about 100 million cubic metres of suspended sediment load. HPC (1989) estimated that the annual sediment load of the Karnali was 190 million cubic metres, though earlier estimates varied from 68 to 107 cubic metres per annum.[21] A report by Bangladesh-Nepal Study Team (1989) suggests that the Karnali's sediment discharge is 170 million tonnes (or 238 million cubic metres).[22] The Narayani River transfers about 87.5 million-cubic-metre sediment a year.[23] At Pancheswor, PACO (1991) has estimated that the Mahakali River, which forms the boundary between Nepal and India, has an annual sediment discharge of 47 million-cubic-metres. The combined sediment outflow from these four rivers is about 472 million-cubic-metres, which is almost double the oft-quoted 240-million-cubic-metre total outflow from Nepal. When sediment discharge from the Mahabharat and Chure rivers is included, the figure would be even higher. That the estimate is higher is no surprise given that new data are available and that more elaborate methods are used for assessing sedimentation rates. Macro estimates such as these are necessary for assessing the economic lifetimes of reservoirs.

The above discussion brings to the fore two important points. First, macro-level records offer little utility for addressing local-level water management or for meeting specific design tasks. The Kosi River, one of the few Himalayan rivers for which detailed sediment data has been collected, is a case in point. The Indian government has collected sediment records for this river off and on since 1947 and continuous records exist for a 32-year stretch. While records do include disaggregated figures for the sediment loads of fine, medium and coarse particles (GoI, 1981), the available data still does not cover the complete sediment transport regime of the river needed specific aspects of intake design (Coode and Partner, 1978). In part, this limitation is due to the disproportionate influence of extreme events. Records of the Kosi River show that sediment load was exceptionally high during eight of the last thirty years (Mahmood, 1987). Even in a small river like Khimti the concentration of sediment can range from just 13 ppm in the morning to 8,536 ppm in the afternoon within the same day to 61 ppm the next morning (Norwegian Hydro-technical Laboratory, 1995); the extreme fluctuation reflects the influence of external inputs.[24]

The second key point suggests that numerical estimates of natural events are driven by assumptions and that salience is assigned to data in response to institutional pressures.[25] The low importance accorded to the risk sedimentation poses to the proposed reservoirs is one example of such pressure. While the numbers do provide a basis for studying land surface processes, they should not be treated as absolute; instead, they should be subjected to critical questioning. Thompson *et al.* (1986) suggest that "…we should not place too much faith in the ability of hard science to tell us what the facts in the Himalaya really are." This caution does not mean that there are no facts. It reminds us that our interpretation of the facts is conditioned by prior experience and by the value ascribed to those facts.[26] Hard science facts are determined by the data collected on natural processes, and more particularly, on how it is generated, disseminated, analysed and controlled. In general, information establishes the text on which perspectives are based and solutions negotiated. Information is not, however, neutral and every institutional context is biased toward generating information (or disinformation) that supports its own worldview and presenting it as fact (Moench, Dixit *et al.*, 2003).

The implications of having a poor understanding of the sediment hydrology regimes are crucial for water management. High fluctuations in sediment flow within a short period of time which affect methods can be used for intensive monitoring in order to estimate total sediment yields and draw valid conclusions (Khanal *et al*., 1998). Another implication is on the reservoir sedimentation rates. The sedimentation rates of reservoirs are far greater than anticipated during project design. In the Indian Himalaya the storage loss rates in the majority of reservoirs have been higher than anticipated (Narayana and Shastri, 1985: Tejwani, 1987). The rate of loss for Nepal's only reservoir, the Indra Sarovar with a designed gross storage capacity of 83 million cubic metres on the Kulekhani River is even more extreme. Almost half of its dead storage space of 12 million cubic metres was filled by sediment mass released in a single 15 hours during cloudburst.[27] Heavy siltation chokes conveyance systems, lowers the efficiency of the settling basins and affects the performance of pumps and other hydraulic machinery. These problems are endemic for all hydropower and irrigation schemes in Nepal. The balancing reservoir built at the Trisuli hydropower project to create daily pondage, for example, was filled with so much sediment that power production capacity declined (New Era, 1990).

In another example, debris flowing in the Marysangdi River jammed the intake of the settling tank of the Marsyangdi hydropower project, and the plant had to be shut down to clear the accumulated debris.[28] Although this particular problem was later addressed by using booms, uncertainty in anticipating future behaviour remains. The Surajpura hydropower plant built in the Western Gandak Canal in Nepal has a similar problem: capacity of the 15-MW power plant has significantly declined because of the deposition of silt in the canal and the presence of floating debris in the trash rack of the plant's intake. The production capacity of the Katiya power house in the Kosi Canal has also been grossly reduced due to sedimentation. These experiences indicate the need to be more cautious in planning future water management interventions so that performances match design assumptions and are not sub-optimal.

Sedimentation remains a particular concern for the proposed 29 reservoirs with a storage capacity of about 100,400 million cubic metres (Pradhan and Shrestha, 1992) that Nepal intends to develop. Given the high sediment yields of Himalayan rivers, the proposed reservoirs would experience high rates of sediment accumulation. After the US Federal Inter-Agency on Water Resources published a summary of the rate of sedimentation of reservoirs built in the US, in the 1950s, other agencies and researchers began to study the extent of reservoir sedimentation. Using the rate of sedimentation in reservoirs in the US, Brune developed the concept of trap efficiency, the ratio of the total volume of sediment retained in a reservoir and inflow volume (Brune, 1953). Inflow estimates are based on the assumption that sedimentation rates are steady and that sediment inflows are from a single source.

Not all sediment eroded from the land reaches rivers as the materials may be deposited in intermittent traps on the land's surface. In fact, global literature on sedimentation suggests that for large watersheds less than one-third of the sediment eroded from land gets to rivers (Carson, 1985), or a sediment delivery ratio of about 33 per cent. The delivery ratio in the Himalaya is much higher since there are so few valleys in the mountainous catchments where sediment can be deposited and the entire suspended sediment load is carried out to the plains (Nielson, 1979). In addition, the sediment pulses triggered by extreme events make, delivery ratios, in major Himalayan rivers very high because almost all the sediment mass is fed directly into those rivers.

The available science has its limitation. It offers no method for analysing the pattern of sedimentation when more than one major river or tributary flows into the still water body of a reservoir. The existing methods do not account for the sediment contributed by a lateral tributary stream flowing directly into a reservoir and forming a delta either. This lacuna is especially problematic for Nepal as most of the proposed large reservoirs will have more than one tributary. The proposed Karnali reservoir, for example, will have two major tributaries the Bheri and the Seti rivers. The proposed Sapta Kosi reservoir would receive sediment input from three major tributaries: the Arun, the Tamor and the Sun Kosi. Since the sediment load carried by each river is different, the characteristics of the three inland deltas that would be formed would be different. For many of the proposed reservoirs, the sediment discharge data of the tributaries involved is not available. To overcome this limitation, some studies have assumed that sediment discharge will be proportional to monsoon flows, when the bulk of sediment is transported.[29] The validity of this assumption is open to question.

While sediment-laden rivers are a source of major concern, the lack of sediment in a river creates another set of problems. In the still water created by a reservoir, most incoming sediment (in some cases almost 100 per cent of the inflow) is trapped. Because the water, which flows out of a reservoir is free of silt it erodes the riverbed downstream. Similar process takes place in many irrigation weirs whose upstream reaches show a high rate of sedimentation. Silt-free water can have also detrimental effects on the foundations of dams, bridges and embankments. This change in sediment content also has an impact on the aquatic lives within the river system. Cause-and-effect relationships regarding accretion on and the erosion of bed and banks in the Himalayan rivers have not yet been scientifically studied or established though changes in river morphology and channel response to varying water and sediment discharge have been studied and general relationships between sediment discharge, depth and width of flow, slope and grain size have been established.[30] It is clear that changes in sediment load have major implications for channel morphology, movement and stability of channels and, in consequence, for water management structures and the riverine environment. Predictive capacity, however, is limited.

In the mountains, the rivers have restricted scope for the lateral movement. This is not the case in the Tarai where the high sediment loads deposited often cause river channels to bifurcate, shift or oscillate. In some stretches of Tarai rivers, almost two metres of sediment have been deposited over the last 45 years. The Kosi, for example, has moved 110 km westward over the last 150 years as a result of deposition, today it continues to show a westward-moving tendency.[31] The Kamala, Bagmati and Narayani rivers also show tendencies of changing course and the Chure rivers are particularly unpredictable. The latter rivers have small catchments but fan out into many sub-channels as they descend from the hills into the Tarai plains and often disappear underground as they cross the *bhabar* zone. Flashy rivers show a high deposition rate resulting in the change of river course and eroding portions of highways. Such rivers also outflank bridge necessitating massive rehabilitation efforts.[32] As they move downstream, these rivers then begin to flow in incised channels further onto the Indo-Gangetic plains. Subsequently, as the rivers flow over the deposited fan they erode the bed and also devour banks elsewhere displacing lives and properties. These rivers thus erode banks, and agricultural land, homes and, in many places, threaten highways and bridges, necessitating elaborate river training measures for mitigation.

The core point is that sediment loads play an important role in shaping the characteristics of rivers in Nepal, as do the uncertainties inherent in monitoring or predicting specific impacts in specific locations. Sediment loads have tremendous implications for the effective functioning of water management structures and because there is a high degree of uncertainty in determining what sediment loads will be in any given location, projections concerning the lifespan and functioning of many water management structures are equally uncertain.

GLACIAL LAKE OUTBURST FLOODS AND *BISHAYARI*

Beyond the ‘ordinary’ uncertainties associated with flows and sediment loads, hydrology in the Himalayan region is shaped by two types of extreme events that are far less common in other regions: glacial lake outburst floods (GLOFs) and floods caused when landslides which dam rivers are breached (locally known as *bishyari*). *Bishyari* remains a poorly investigated phenomenon though a mid-1980 land resource mapping project suggested that occurrence of landslide dam should be investigated more fully. According to Chyurlia (1984), “It must be mentioned that another ‘sort’ of lake occurs in Nepal. This is the temporary lake which may form along a stream channel that has been blocked by landslide debris. Such lakes may alter the hydrological characteristics of the river basin wherein they are located until such a time as the debris is removed by fluvial erosion. Occurrence of such phenomenon should be investigated more fully. At the moment very little is known about such phenomenon in Nepal." Landslides and the advance and retreat of glaciers are other common processes in the Himalaya.

A large number of glacier lakes are located in the northern Himalayan region generally at elevations higher than 3,500 m (Bajracharya and Mool, 2004). These lakes generally form behind glacial moraines, large piles of unconsolidated debris that accumulate at the toe of glaciers and act as artificial dams when the glaciers retreat. Altogether 2,323 glacial lakes have been identified in Nepal. The Kosi basin contains the largest number, 1,062; the Gandaki basin has 338 lakes; the Karnali basin has 907 lakes, and the Mahakali 16.[33] Of them, 411 are larger than 0.02 km^2 and have more than 600,000 m^3 of water (*ibid*, 2004). Moraine dams are frequently breached when melt waters either pipe through them or flow over their tops. Based on their review of past events, Bajracharya and Mool (2004) suggest that floods occur once every three to ten years. The sudden discharge of water and debris has a catastrophic and long-term impact on downstream river reaches, some of which have been documented.[34] The incredible mass of sediment transferred is generally deposited in wider reaches of river channels where flow is attenuated. Sediment deposited as alluvial fans is transferred to downstream reaches in subsequent floods. Unless the condition of glacial lakes is monitored regularly, GLOFs are unpredictable. Both GLOF and *bishyari* are sources of sediment which is transferred to downstream reaches causing landslides along river channels.

The first reported GLOF event occurred on 25 August, 1964, when Longda burst in the headwaters of the Trisuli River in Chinese territory. The most recent GLOF was the bursting of Tam Pokhari (Sabai-Tsho) on 3 September, 1998, at the headwaters of the Inkhu Khola, one of the tributaries of the Dudh Koshi River. Most of the known cases of GLOF have occurred in the major rivers of the Kosi Basin in Nepal and the Pumqu Basin in China. Some other well-documented events are the GLOFs in the Bhote Koshi-Sunkoshi (Zhangzangbo) in 1964 and 1981; and the GLOFs in the Arun River 1964 and the Tamur River 1980 (Mool, 1995). On August 4, 1985, the Dig Tsho moraine-dammed lake in front of the Langmoche Glacier overtopped and burst its dam. It destroyed the nearly completed Namche Small Hydel Project and numerous footbridges and trails; many lives were also lost (Ives, 1986; Mool. 1995).

Bishyari are even more unpredictable than GLOFs. Landslides a common phenomenon in the Himalaya, frequently block river channels. Most are triggered by rainfall in catchment areas and along steep, unstable slopes (Dikshit; 1990). When large-scale landslides occur, rivers are often blocked and their water impounded behind an unstable mass of debris. When the temporary debris dam breaches, a huge surge of sediment mass and water flows into the valley below. This kind of surge often reshapes river channels and the balance between sediment load and river flow. In the heavy monsoon of 1987 there was a *bishyari* the Sun Kosi River: debris flow from the Sunkosi catchment entered the Bhote Kosi River and blocked it. The subsequent partial breaching of the sediment dam caused a high peak flow down the main river which destabilised the river banks by scouring them and undermined structural components of the Sunkosi Hydropower Plant with its impact. About one kilometer stretch of the Arniko highway was also washed away.[35]

The serious implications of GLOFs and *bishyaris* are well illustrated by the frequency of such floods. One occurred on the Trisuli River in 1962 with a magnitude about 2.5 times the recorded maximum instantaneous flow of the river at Betravati (CIWEC, 1991). Another event in 1964 on the Gyirong River, a tributary of the Trisuli, caused high sedimentation along its banks. In 1980, three days of rainfall brought a hillside down in the Tamor River. The breaching of the temporary dam created caused a massive flood surge and then a mudflow as the massive sediment deposit was mobilised. Over about 14 hours the mudflow transported between 55 and 65 million tonnes of sediment,[36] an amount equivalent to 36 per cent of the annual load or five times the average monthly load for the month of June. Recapitulating his experience while designing the Chatara canal intake, Mahmood (1987) wrote, 'The design was at a fairly advanced stage when the mudflow of June 1980 occurred. The mudflow caused a major change in the alignment of the bed level of the river channel. As a result, a substantial revision of designs became necessary and was carried out. The mud flow in the Kosi had not been anticipated and the previous ten years of sediment data had no record of similar events.'

Even without GLOFs and *bishyari*, floods cause widespread damage to local economics and infrastructure. In 1984, the Malekhu Bridge on the Kathmandu-Pokhara Highway (the main road link to the capital) snapped as a result of a flood. The event prevented basic necessities from being trucked into the capital and paralysed life for almost a week. In September 1981, a heavy downpour in southern Kathmandu led to the collapse of several sections of Lele Mountain, which in turn caused the transfer of huge sediment loads that surpassed averages by several orders of magnitude (Carson, 1985). The flood created by the cloudburst of 1993 over south central Nepal wiped out major bridges in the highway that connects Kathmandu with the Tarai. This cloudburst also triggered massive mass movements and debris flows that deposited almost five million cubic metres of sediment into Indra Sarovar. When the 1993 event was incorporated, the average sedimentation rate was calculated at 4,273 m^3/km^2, six times higher than the rate assumed in the design.[37] Extreme events have major implications for the development and management of water in any region. Most of the water resource infrastructure in mountain regions around the world was designed for conditions observed in the past and will be inadequate for handling extremes outside the expected range.[38]

DATA ADEQUACY ISSUES

Given the high variability inherent in Himalayan hydrology, intensive monitoring is essential if the distribution of 'normal' flow and sediment load variations, as well as extreme events such as GLOFs and *bishyaris* are to be characterised. At present, however, even the basic networks for monitoring precipitation are inadequate and data on stream flows and sediment transport are patchy at best. As a result, the temporal and spatial variability of hydrologic events cannot be explained and decisions, particularly at the micro level, are made under conditions of uncertainty. The situation of the Nepal Himalaya is typical of mountainous regions, where hydrological networks tend to be less dense than they are elsewhere.[39]

The state of Nepal's precipitation network is typical of hydrological monitoring in Nepal. The average rain gauge density in Nepal, about 330 km^2/gauge, (there are 445 gauges in Nepal's total 147,181 km^2 area)[40] is considerably less than the 100 km^2/gauge density recommended for mountainous regions by the World Meteorological Organisation (WMO, 1974).[41] To meet WMO's recommendation for accurately assessing monthly, seasonal, and annual rainfall, Nepal, suggests Chyurlia (1984) needs a minimum of 1,400 raingauges. In a more recent paper, Chalise *et al*. (1996) suggest that a minimum of between 600 and 1,500 stations would be needed. If the number of station is increased, the quality of representation would improve. But whether the stations will capture the variability is open to interpretation. The criterion by WMO is based on the relationship between population density and number of gauges. According to WMO (1974), 'It is almost impossible to install and operate in a systematic way a number of good stations, regardless of the need, when population is sparse. For example, to set up more than two gauges on a catchment of 1,000 km^2 when the population of the area is only 100 is almost impossible, especially if this population is not permanent.' The distribution of Nepal's existing stations reflects, to a degree, population distribution.[42] While useful, the criterion entails a certain amount of subjectivity and may not be sufficient to adequately capture precipitation variability in the Himalayan region.

According to Chyurlia (1984), an ideal network should comprise a number of stations that are distributed throughout the landscape so that climatologial zones are covered. Since climatological zones vary according to elevation, a certain altitude-number criteria can be used. An attempt to develop a primary relationship is presented in Table 3. It shows the rain measuring gauges in the Tarai, hills and the Himalaya and the number of stations necessary according to the criteria of WMO. In the Tarai, there is one gauge for every 202 km^2 area, which is much better coverage than the 600 km^2/gauge recommended by the WMO for lowland regions. Still the micro level characteristics of the rainfall in Nepal's low lands are not captured. This limitation was observed during the wet monsoon of 1998, when Nepal's Nawalparasi Tarai, Eastern Uttar Pradesh, Bihar and Bangladesh faced massive flooding caused by an exceptionally wet monsoon. The formal rainfall stations in the region did not record the high rainfall though those installed in the catchment of the Rohini River recorded a 24 hour rainfall of 459 mm (Dixit, 2003). In the hills, one gauge covers 328 km^2, and the higher mountains, one gauge covers 1,380 km2 both these figures are lower than the densities recommended by the WMO. When hydro-ecological regions are considered, Table 3 shows that a total of 1,129 stations are needed.

TABLE 3
THE NUMBER OF RAINFALL STATIONS NEEDED IN NEPAL AS PER WMO RECOMMENDATIONS (1974)

Region	Area* km^2	WMO criteria per station (km^2)	Existing gauges	Existing density per station (km^2)	Number of station according to WMO
Himalaya	22,077	250	16	1,380	88
Hills	100,083	100	305	328	1,000
Tarai	25,021	600	124	202	41
Total	**1,47,181**		**445**	**330**	**1,129**

* *The division of Nepal's area into hydro-ecological regions is indicative.*

The point is not whether the number should be 1,400, 600 or 1,129. The attempt is to show that with different assumption the use of the same criteria can result in different outcomes. It is clear that, the subjective foundation of WMO's criteria notwithstanding, the present number of gauges in Nepal is not sufficient and that more stations need to be established. Though desirable, rapid expansion appears unfeasible because it is expensive and because of trained human resources for monitoring is not available. In addition, accessibility to many places is still difficult. Nepal needs to explore innovative and inexpensive ideas like using schools as sites for monitoring rainfall.[43] Another innovative approach would be to relocate some of the stations to capture the spatial and temporal in identified pockets.

Monitoring of river flow is also inadequate. Even though critical sites on major rivers are gauged, they do not help in assessing the hydrology of small rivers or in capturing extreme events (Karmacharya, 1989). Most stations are located at lower altitudes; very few stations are located between the altitudes of 1,000 and 1,500 m (Gyawali, 1989). Only 40 hydrological stations in Nepal contain automatic water-level recording devices and they are all located along major rivers (Khanal *et al.*, 1998). The inadequate number of gauging stations on rivers is due in part to now remote and difficult to access many river reaches are. In many cases, floods, landslides and high sediment deposition disturb the gauge installations and result in poor quality operation and high maintenance requirements. Overall, the status of monitoring sites creates uncertainty in understanding the specific process-responses of specific river systems. Several pockets in the Himalaya, mountains and hills remain 'grey': there is no rain or stream gauge in the area. Because data is inadequate, only gross variations in local hydrology, such as the fact that elevation and rainfall have a complex relationship (Higouche *et al*., 1982) can be documented. The available data do not enable scientists to characterise variability, even within a single catchment.

Some key portions of the hydrologic cycle remain essentially unmonitored. Snowmelt, for example, is known to be significant in high altitude catchments and has a major influence on the overall hydrological processes of the Himalaya. Snow falls between 3,000 m and 5,000 m, a significant range, but is rare below 3,000 m. High mountain hydrology, which deals with the processes of snow and ice, has received some attention during occasional glacial studies by Japanese researchers. The government of Nepal has initiated a Snow and Glacier Hydrology Project within the Department of Hydrology and Meteorology. Four high-altitude stations above 4,000 m were established in the Makalu, Khumbu, Langtang and Modi Khola valleys. Another was established in the rain shadow zone of Khanjiroba Himal in Humla and a sixth was established in Simikot in West Nepal.[44] These six stations are all there are to monitor the approximately 10 per cent of Nepal's precipitation that occurs in the form of snow.

This weak monitoring of the mountainous region creates substantial uncertainty regarding water made available through snowmelt. Generally, snow begins to fall in October and continues to fall until March, when the snowline is at its lowest. With the advent of spring, the snow-pack starts to melt and contribute to stream flow. Scientists' understanding of the physics of their snowmelt and runoff is rudimentary. Although it has been established that the volume of runoff during pre-monsoon months and the area covered by snow are positively correlated (Thapa, 1991), basin models which relate snow to regional runoff have yet to be developed. As mentioned earlier, snow is estimated to constitute 10 per cent of Nepal's precipitation, but research in the headwaters of the Dudh Kosi also suggests snowmelt in that basin may constitute as much as 30 per cent of the annual stream flow (Alford, 1992). Understanding how much water snowfall actually contributes to basin availability is of critical importance since snow makes a substantial contribution in stabilising stream flows, particularly during the dry season. As a result, projections of water availability for used in agriculture, domestic supply or hydropower generation depend considerably on the condition of the snow-pack.

It can be concluded that in Nepal, the network of hydrographic and climate stations needed to monitor all the components of the water cycle is weak. This weakness is, in itself, a significant source of uncertainty. Strengthening the network is no simple task. In the first place, even assuming that climatic condition are stable, extended periods of recording are essential in order to accurately quantify both the range and the long-term variation. At present, many data sets are discontinuous; they are collected for the purposes of one-time, short-term projects and allowed to lapse. Such gaps raise a key institutional issue. While the need to expand the monitoring network is clear, the financial resources needed for successfully managing additional gauges are currently unavailable. Furthermore, even if resources could be made available, the maintenance of data collection systems requires a social commitment, which will not develop unless the data are used and demanded by those involved in their use. At present, the demand for data is generally high when major water development projects are under consideration and comes from the governmental and development organisations which finance or are otherwise involved in the design of such projects. Data and the capacity to analyse it are generally absent at the local level. Local water management institutions may require data, but the demand for it has yet to emerge. Even where a demand is present, data are unavailable or unsuited to the questions local water managers ask. Before expanding monitoring networks, questions regarding the type of data required, who would use it and how it would be collected need to be resolved. At present, these institutional questions remain unanswered and lie at the heart of the fragmented information about and understanding of the hydrologic processes that characterises Nepal.

DATA INSTITUTIONS

Who collects data now and why? Answering these questions is central to understanding the social dimensions of hydrological uncertainty in the Nepal Himalaya and throughout much of South Asia. As we have argued in other papers, data collection is highly politicized (Moench, 1994). Control over data is often used as a tool for executing political power. Beyond political control lie equally fundamental questions of incentive.

At present, a fundamental mismatch exists between the physical variability of the hydrological system and centralisation of the institutions developed to monitor that variability. Variability is, by and large, a phenomenon that affects people at a local level most strongly. Farmers care if stream flows are too low for their irrigation systems to function, they care if sediment clogs their canals and they care if floods damage diversion structures. Local people care if a *bishayari* wipes out their homes, destroys trails or kills people. Such local concerns are, in many ways, disconnected from more abstract, national-level objectives such as agricultural and hydropower development. While populations living in major cities are concerned about the impact of floods or droughts, their concern is generally indirect and theoretical since such events don't usually affect their lives or livelihoods directly. The only situation in which there is strong and direct national concern over conditions at the local level emerges is when large infrastructure projects are being considered. When the government or major investors are planning or constructing major water management facilities, then local conditions—the frequency of floods, the magnitude of sediment loads and the likelihood of extreme events—directly affect the viability of and return from their investment.

This mismatch has shaped national institutions involved in hydrological data collection. Most data collection takes place through government branches such as the

Department of Irrigation and the Water Resources Ministry. These institutions are involved in the design and implementation of large-scale water development projects. As a result, they are neither detached nor objective players attempting to understand hydrologic variability for its own sake. They have a specific agenda and collect information related to that agenda. Data are collected in locations where they are required for projects or where prospective projects are likely to take place and not collected where major projects are unlikely. National institutions have little incentive to collect data in such locations and local populations have yet to recognise the role such information could play in their own development and have yet to develop the capacity to collect and analyse it. Furthermore, information (such as sediment load) that could undermine the viability of a project tends not to be collected or is downplayed.

This situation may change as water development at the local level increases and as competition over available resources forces local populations to recognise and address their inherent variability. In recent times, competition over water both among and within sectors has emerged as a critical issue in many areas. In Kathmandu, for example, municipal water supplies are increasingly unreliable and major debates exist over the advantages and viability of alternatives. Our own analysis suggests that much of the water scarcity in the capital is artificial, a product of poor maintenance of existing municipal systems, which lose a very high percentage of water to leakage, combined with poor systems of allocation and with pollution. Other people sees the scarcity as absolute and emphasise the need to develop of new supply channels, such as the Melamchi Project (a major project proposed to transfer water from the Melamchi River outside of the Kathmandu Valley into the city) as a viable solution. Differences between these perspectives cannot be resolved without data on water use and on the variability of supply sources. Tension between the two perspectives has generated new demands for data. In addition, demands are emerging from local populations as tensions grow over the different ways to address the competition in specific areas.

The case of the East Rapti Irrigation Project in Chitwan is one example where local-level competition has increased the demand for data. It has been proposed to divert water from the Rapti River, which forms the northern boundary of Royal Chitwan National Park, to provide irrigation water for eastern Chitwan (Mishra and Hemchuri, 2000). This proposal has raised concerns that the park ecosystem will be adversely affected by decreased flow in the downstream reaches of the river. Although much debate over the proposed diversion has taken place, the issue remains unresolved. An environmental impact assessment of the project identified the lack of data on flow and water quality as a serious factor limiting an evaluation of the cause-and-effect relationships between the project and the park ecosystem (Dixit, 1990). In addition, the data gap was identified as a constraint in the future management of the park regardless of whether or not the project was carried out (*ibid*).[45]

While the East Rapti River is, as is usual, part of a project context, competing viewpoints are generating a greater need for data. As documented in earlier studies along the Tinau River (Gyawali and Dixit, 1999), conflicts are increasing where local institutions affecting water management intersect. There are many points along a river where upstream activities—sand mining in the riverbed, diversion schemes or pollution point sources, for example—have direct impacts on downstream users. These impacts are felt but cannot be quantified and are heavily influenced by the natural variability of hydrologic systems. To understand such impacts and to reduce uncertainty requires having basic data on the dynamics of the hydrological system available. Incentives to collect data for furthering such understanding are increasing at local levels but are distinctly absent within the national institutions conventionally responsible for data collection.

CONCLUSIONS

If data collection systems are to be improved and the uncertainty inherent in high variability environments reduced, innovative approaches that recognise and build off the incentives institutions currently have to collect data need to be developed. The demand for data at local levels is nascent—theoretically present but yet to be catalysed. Since variability is primarily a local level phenomenon, understanding and quantifying that variability could bring very practical benefits to local populations, including the resolution of disputes over low-flow allocation and the identification of the impact of water management activities such as diversions or channel modification. Acquiring data on floods and extreme events could also enable local populations to respond by reducing their overall vulnerability or at least enabling them to move to safer places when floods or extreme events are imminent.

National-level institutions, at least those involved in the direct implementation of projects, have little inherent incentive to collect or provide data in non-project locales and present, local institutions lack the capacity to collect or even analyse data. Resolving this contradiction requires a combination of innovative local approaches, which involve the direct participation of communities in data collection and the establishment of new national institutions that have the capacity to analyse data but are independent and separate from the politics and incentives of national implementation departments. In the US independent specialist scientific organisations (such as the USGS) plays the role of a neutral arbiter.[46] Recent development in Nepal has introduced similar organizational restructuring. The Department of Hydrology and Meteorology (DHM) remained a poor cousin within the Ministry of Water Resources since its inception in the 1960s. In the late 1990s DHM came under the Ministry of Science and Technology. Theoretically, this shift introduces separation of direct project interest of the MOWR from scientific needs. How successful DHM has played the role of a neutral arbiter is yet to be reviewed.

It is important to appreciate that any approaches, which build off core incentive will not reduce uncertainties rapidly. In virtually all areas, the data now available are too limited to be of much use for local-level analysis in mountainous regions. Kundzewicz and Kraemer (1998) have argued this point as follows: "The scientific information on water resources of mountainous areas is very fragmentary. Incomplete and fragmentary information mean that knowledge of the different components and processes in the hydrological system of mountain regions are incomplete. In most cases information collected at valley stations are used, but such generalisation is rarely applicable because topography has complex influence on the air mass circulation, which varies from large to small spatial scales, and vertical gradients. The few high altitude precipitation gauges available in some mountainous regions are, in addition, affected by the systematic wind-induced error, and in most cases there is no database for applying reliable corrections." These conditions imply that the assessment of precipitation will remain uncertain for a long time to come (Lang, 1998).

Kundzewicz and Kraemer's statement recognises the complexity inherent in the Himalayan hydrological sub-system. When the whole region is considered, the complexity increases manifold. According to Ives (2004), "The common denominator of mountain slope agriculture geomorphology is extreme variability/variability is space and time, in bed rock type and structure, altitude, slope angle, and in aspect, vegetation cover, inter-annual and intra-annual precipitation patterns, farming practices and ethnic groups, an degree of access to a road network. To this must be added the environmental contrasts and the many differences cross the international borders of the region." This is the larger context within which local water management takes place.

Spatial variability, which includes altitudinal gradients of terrain, vegetation and rock surfaces, soil, underground water, snow and ice conditions, and all meteorological variables, poses numerous problems to be understood by the hydrological analysis of mountain river basins. Many other hydrological processes, such as the role of soils and non-vegetated areas, the effect of the various vegetation belts, and the role of surface and subsurface flow in the generation of floods, are also not sufficiently understood.[47]

This means that the basis for estimating the atmospheric water input into the mountain hydrologic systems is often not very reliable. As discussed earlier, climatic and living condition, accessibility, natural hazards, and remoteness are other reasons for the lack of sufficient observation networks and data.

The above discussions also suggest that the hydrological system has embedded uncertainty which implies that we don't know what the future is. This is so despite the fact that the climate system has some element of regularity to it; the monsoon has a set period of occurrence when certain amount of water input would occur in normal conditions. Yet, we face an increasingly uncertain system. So, what should be done? The contours of the future challenge are encapsulated by Ives (2004) thus: "Although Thomson *et al.* (1986)

expressed doubts that the 'uncertainty' could be dispelled, and thus should be accepted as part of the Himalayan scene, it is believed that an attempt must be made to reduce the level of uncertainty as far as possible."

The key to reducing uncertainty lies in understanding the risks and the incentives that various levels of society have to absorb or mitigate. We need approaches that recognise the dominance of extreme events and way to better adapt to them. We also need to develop approaches that take cognisance of the inherent problems in data collection. Instead of stating "we need to know sediment loads to design our structures" we should ask: 'how can we design structures or approaches that aren't affected by sediment loads?' An approach that recognises natural variability, considers the incentives that different levels institutions have to quantify or understand variability, and adapts to inherent uncertainties is, essential.

NOTES

1 This paper does not touch upon the uncertainty introduced into the Himalayan hydrological system by climate change. For a general discussion of the impact of climate change on water in Nepal, see Mirza and Dixit (1997). For further analysis of the implications of climate change for the Himalayan region, see Shrestha, *et al.* (1999), Shrestha *et al.* (2000) and Shrestha *et al.* (2003).
2 See Unesco (2003)
3 For details, see Das (1987).
4 The Snow and Glacier Hydrology Project under the Department of Hydrology and Meteorology (DHM) began measuring snow processes in 1995 (Grabs *et al.,* 1998). The proportion of annual river flow contributed by snow and ice melt has not yet been accurately established. About 10 per cent of the area in the Kosi Basin, for example, is under snow and glaciers (Neilsen, 1979).
5 The recorded average annual precipitation ranges from 163 mm in Lomangtang (Mustang Bhot) to 5,244 mm in Lumle (near Pokhara) (Khanal *et al.,* 1998). Pockets of high precipitation include Khudi Bazaar (Lamjung), Pansayakhola (Nuwakot), Sermathang (Sindhupalchok) and Kanyam Tea Estate (Illam), where more than 3000 mm of annual rainfall occurs (Khanal *et al*., 1998).
6 Dhar *et al.* (1985).
7 *Ibid.*
8 Kattelmann (1994).
9 This aspect is discussed by Dhital *et al.* (1993)
10 According to Das (1987), such an extended event is rare.
11 During these four days, one station in Kathmandu recorded 172.8 mm of rainfall. Though this 24-hour rainfall level was not high, the phenomenon, which lasted for three weeks, spawned large-scale loss of life and property.
12 Regular stream gauging of the Kosi River was started in 1947 at Barahakshetra. See GoI (1981) for details on peak floods in the Kosi River.
13 Climatological records of Nepal, 1967 and 1968.
14 According to Starkel (1972), mass movement transformed the cultivated area of Darjeeling by 20-25 per cent, but only two per cent of the forested area was affected.
15 For details see the People's Commission on the 1998 Flood in Eastern Uttar Pradesh.
16 Personal communication with K C. B. Raju, Director, Central Ground Water Board (Retired).
17 Calculated from data in Phadtare (1988). Also see Burke and Moench (2000).
18 See Neilsen (1979).
19 These issues are also dealt with by WECS (1987), Carson (1985), Bruinzeel and Bremmer (1989),

Dixit (1995) and Gyawali and Dixit (1999).

[20] See Gyawali and Dixit (2001) and Thapa (2001) for discussions on sediment dynamics in the region.

[21] Bangladesh Nepal Joint Study Team (1989).

[22] HPC (1989) that Karnali's sediment load is 260 million tonnes per year. The report assumed that specific gravity is 1.4, an assumption on the low side. According to Garde and Raju (1977) "The specific gravity of the sedimentary particle depends on the mineral composition of the particles. Incidentally water borne sands contain a very large percentage of quartz and hence their specific gravity varises between 2.60 and 2.70. Therefore, for all practical purposes, the specific gravity of river material is assumed to be 2.65." In this paper we assume that the specific gravity is about 2.

[23] This estimate is based on 175 million tonnes/year (Sharma and Kansakar, 1992) and by using 2 as the specific gravity of sediment.

[24] In the October 1981, flood, a one time record of the sediment concentration in the Bagmati River at Puret Ghat, Kathmandu, was 11,000 ppm. This high concentration reflects the impact of the extreme rainfall event (Dixit, 1981, unpublished *mimeo*, Institute of Engineering).

[25] For discussion on institutional pressure also see Thompson *et al*. (1986).

[26] Similar arguments are used by management scientists in analysing human behaviour. For details see Covey (1997).

[27] The details are found in Staphit (1993), Galay, *et al*. (1995), Dhital, *et al*. (1993), Gyawali and Dixit (2001) and Thapa, (2001).

[28] Kayastha (1996).

[29] While assessing the sedimentation rate of the Karnali Chisapani reservoir, HPC (1989) assumed that discharge would be proportional to monsoon flow. While such assumptions provide an order of magnitude, they are fraught with serious limitation.

[30] Dixit (1995).

[31] See Gole and Chitale (1966).

[32] One such river is the Manahari, which originates in the Mahabharat range and joins the East Rapti.

[33] Bajracharya and Mool (2004) provide details about the growth of hazardous lakes in Nepal.

[34] The details of past GLOFs are also found in Vuichard and Zimmerman (1987) Watanabe, *et al.* (1994) Mool (1993), Kattlemann (1998).

[35] Dixit (2002) provides a summary of *bishyari*. One landslide in Alakhananda River of the Garhwal Hills created a 350-m dam of debris across the river. When this dam broke, a 50-m-high flood was created. About hundred years later, in 1970, a 60-m high debris dam blocked the same river. When the dam broke, the flood washed down about 10 million m^3 of sediment. Nepal's Kali Gandaki River was blocked for 26 days by a landslide dam in 1856 AD. In September 1998, monsoon rains triggered a landslide of 400,000 m^3 in the same river. In the Tinau River of Nepal a landslide in 1978 caused by 125 mm of rain in 24 hours blocked the river. The subsequent over topping of the landslide dam washed away Dauretole of Butwal, causing heavy damage to property and killing many people.

[36] Mahmood (1987) estimated the yield.

[37] For discussions on the initial monitoring of the sedimentation of the Kulekhani Reservoir, see Staphit (1995) and Galay, *et al.* (1995). Gyawali and Dixit (2001) discuss the uncertainties demonstrated by the event.

[38] Bandhyopadhya *et al.* (1997).

[39] *Ibid.* Additional discussions on the poor quality of monitoring in Nepal are found in Chalise and Khanal (2001).

[40] The increase in density is due to the establishment of additional stations. The number of stations reached about 445 in early 2001 compared to 350 in the late 1980s.

[41] The 1974 guide of the WMO recommends that in flat regions one station should cover an area 600 to 900 km^2 while in the mountainous regions of temperate, Mediterranean and tropical zones one gauge should cover an area between 100 to 250 km^2.

[42] Chyurlia (1984).

[43] This concept of raingauges in school was proposed by Dixit and Gyawali (1997).
[44] Grab *et al*. (1998) discuss the snow hydrology project in Nepal.
[45] In the 1990s the Asian Development Bank (ADB) financed a study to collect hydrological data in the East Rapti River with the objective of improving understanding of the river's hydrology and ecosystem. The monitoring project began in 1994 and continued till 1998. The study concluded that "East Rapti River at Sauraha would be more than 6 m^3/s even during driest day of the dry season. Hence, the environmental impact of ERIP on RNCP in terms of water availability for wild habitats would be insignificant." See GEOCE (1999). It is not clear if the data thus collected is being used for management of the waters of the East Rapti River.
[46] See Moench, Dixit *et al.* (2003)
[47] See Lang (1998) for a discussion.

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DROUGHTS AND STATE FAILURE: UNWILLING TO LEARN AND UNWILLING TO DISTRIBUTE

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INTRODUCTION

A preliminary review of literature on droughts and famine suggests that the interaction between drought shocks and the economy are complex, rather than direct and straightforward. Droughts, however defined, are frequent and severe condition which results from the extreme variability of rainfall in the arid and semi-arid areas. This conventional notion that drought is a phenomenon of arid and semi-arid areas, is changing because of the fact that even areas with high average rainfall are facing acute water scarcity today. Cheerapunji, the world's highest rainfall area, is facing severe drinking water shortage. Drought in the state of Orissa with an average rainfall of 1100 mm surprised many. Water scarcity condition in the Himalayan region is also not uncommon. It shows that drought is just not the scarcity or absence of rainfall but more related to water resource management and utilisation. It is the state and people's perception and response to water resources, which has led to an increase in, if not intensity, the severity of drought. Also, 'groundwater drought' is emerging as a serious threat in most parts of India, and other parts of the globe.[1] It is debated that the present water scenario is more a consequence of mismanagement of water resources and droughts are man-made than only natural.

Water shortages are common to rural and urban areas. The state, which has sovereign right on water, always had centralised of water resource planning and management. The state response to water problems has been largely supply side management. Drought was considered to be a transient phenomenon and approached more in an *ad hoc* way than a systematic long-term strategy. The impact of drought on agriculture and livelihood was taken for granted and relief measures were considered to be a solution. The State has showever, failed to even distribute the huge food stocks in the country. The other actors, that is the market and the individuals, particularly, the moneylenders, hoarders, black marketeers, acted more like absorbers or grabbers of opportunity and more involved in accumulation. The civil society having limited role in the past is now emerging as a strong force to question state on some of their misdeeds. They did play some role in experimenting new approaches to drought management. The fatalist's, that is, ultimate sufferer or takers of drought, are the vulnerable population in the rural areas who continue to suffer. Unorganised, driven by present then long-term sustainable approach and response to drought, more interested in survival aggravated the situation by overexploitation of water resource. Consequently, intensity and impact of drought increased, particularly in the last decade, despite all round economic development. The main problem lies not only in our understanding the droughts, their intensity and coverage, but lack of understanding the impact and dynamics of responses to drought by various actors.

This paper examines the broad drought management policies of the State and coping strategies adopted by various actors since independence and identifies gaps to suggest appropriate measures to mitigate or reduce the impact of drought. More specifically the objectives are:

- To examine the nature and intensity of drought
- To document the perceptions and impacts of droughts
- To analyse the responses and management strategies of various actors such as State, market, NGOs and people.

DROUGHT MANAGEMENT

Famine and drought are an inter-woven global endemic natural phenomenon occurring in different parts of the world at different times of varied intensity. In examining the phenomenon of natural calamity a distinction need to be made between trigger event like 'too little rain' which may be natural and the associated disaster which may be largely man-made. One must also examine how famines/droughts differ from each other. The basic difference lies in the degree of mortality, geographic scope, chronological duration, intensity or severity. But more important than these quantifiable indicators is the different moral environments within which they take place and through which they are described and recorded (Zook, 2001). The depictions of famine or drought casualty or suffering perhaps can be fabricated to serve different purposes and fulfilling different moral and political agendas. In other words the attempt to create a coherent, seamless narrative ultimately can be an awkward, imperfect process. It is also debated that there is no clear cultural or historical pattern in relation to environmental degradation or famine/drought relief and prevention, and from among the myriad environmental or charitable values that different cultures and society profess, none is absolute and none is universal (*Ibid*). Consequently, the impact and response to famine and drought vary across geographical regions and cultures.

Drought and famine are often synonymously used but they have different connotations. A drought is not a famine. Drought is a meteorological phenomenon that does not always have a direct relationship with famine, while famine is not a mere deficiency of food but an absolute lack of food. Taking into account social and economic disorganisation in defining famine, Mariam (1984) states that famine is the most negative state food consumption under which people, unable to replace even the energy they lose in basal metabolism, consume whatever is stored in their bodies, that means they literally consume themselves to death. Famine is a general widespread, augment and persistent, extraordinary and insufferable hunger lasting for several months and affecting the majority of the rural population over a more or less extensive area, resulting in total social and economic disorganisation and mass death by starvation.

Emphasising the effects of both physical and mental caliber, Dumont (1970) defines famine as a "chronic state of food deficiency which erodes the physical and mental capacities of its victims, ultimately causing premature deaths." defind famine as 'extreme scarcity of food' and drought as 'continuous dry weather' characterised by lack of rainfall. Droughts and scarcities are generally confined to limited localities and for shorter periods of time. While deficiency of food is the main focus in the definitions of famine, it is lack of rainfall in defining droughts. The definition that the term 'drought' is of meteorological origin is more comprehensive. Drought results from long continued dry weather and/or insufficiency of rain, which causes exhaustion of soil moisture, suffering of plants from lack of water, depletion of underground water supply and reduction and eventual cessation of stream flow. Agronomists define drought as an interval of time, generally of the order of months or years in duration, during which the natural moisture supply at a given place consistently falls short of the climatically expected moisture supply. But it is important to state the critical limit, below which drought may be considered severe, to classify drought intensity. Bandhopadhyaya (1988) lists four types of droughts, namely (1) meteorological drought, (ii) surface water drought, (iii) ground water drought and (iv) soil-water drought and argues that the various forms of droughts get generated independently but inseparable and are linked to each other through the water cycle that describes the dynamics of the continuously moving water resources.

The National Commission on agriculture in India (1976) defines three types of droughts, namely, meteorological, agricultural and hydrological droughts. Meteorological drought is defined as a situation when there is significant decrease from normal precipitation over an area (i.e. more than 25 per cent). Agricultural drought occurs when soil moisture and rainfall are inadequate during the growing season to support healthy crop growth to maturity and causes crop stress and wilting. Hydrological drought may be a result of long term meteorological droughts which result in the drying up of reservoirs, lakes, streams and rivers, and fall in groundwater level.

The concept of drought varies from place to place depending upon normal climatic conditions, available water resources, agricultural practices and the various socio-economic activities of a region. It is difficult to define drought in terms of natural conditions of rainfall, temperature and soil, because drought is a human conception that is inseparably tied to the mode of making a living and to the cultural level of societies. Any comprehensive definition of drought must take into account the complexity of socio-cultural, economic and political organisations of societies and the consequent variations in the effects of lack of adequate rainfall in the local settling. Also, a drought is necessarily to be perceived in terms of the needs of a given community.

Drought is frequently defined according to disciplinary perspective. Subrahmanyam (1967) has identified six types of droughts: meteorological, climatological, atmospheric, agricultural, hydrologic and water management. Many others have also included economic or socio-economic factors as essential factors in the determination of drought occurrence. The most commonly discussed definitions are; meteorological, agricultural, hydrologic, social, and economic droughts. The definition of different kinds of drought used in drought literature is follows: Meteorological drought – "a reduction in rainfall supply compared with a specified average condition over some specified period"; Hydrological drought – pertains to the impact of a reduction in precipitation on natural and artificial surface and subsurface water storage system, thus, possibly lagging behind periods of agricultural or meteorological drought"; Agricultural drought – a reduction in moisture availability below the optimum level required by a crop(s) during different stages of its growth cycle, resulting in impaired growth and reduced yields; Social drought – related to the impact of drought on human activities, including indirect as well as direct impacts: and Economic drought – "a meteorological anomaly or extreme event of intensity, duration(or both), outside the normal range of events that enterprises and public regulatory bodies have normally taken into account in their economic decisions and that, therefore, results in unanticipated(usually negative), impacts on production and the economy in general" (Benson and Clay, 1998).

There is no generally accepted definition for drought. The meteorologist defines drought in terms of negative departure of normal annual precipitation. Agronomist on the otherhand defines drought in terms of water deficit to the crop growth. For hydrologists drought is depletion of underground water table and lowering reservoir water's level. Economists perceive drought as a situation of water shortage, which creates economic hardship. Anthropologists or sociologists are more interested in understanding the impact of rainfall deficiency on people and their institutions. Each of these definitions has own limitations.

Drought definitions might be categorised as either conceptual or operational, with conceptual referring to those definitions formulated in general terms to identify the boundaries of the concept of drought. Operational definitions attempt to identify the onset, severity and termination of drought episodes. Estimate of potential impacts is included in some operational definitions, which can also be used to analyse drought frequency, severity, and duration for a given historical period. These definitions can be used to calculate the probabilities of drought of varying intensity, duration and spatial characteristics.

The various approaches taken by scientists and non-scientists to define drought demonstrate its complex and interdisciplinary nature. At the same time, although most definitions emphasise the physical aspects of drought, the social aspects are closely related. Only a few definitions adequately address the impact of drought. As a result, the primary, secondary and tertiary impacts of droughts are poorly understood.

However, from policy point of view, the need to identify drought-prone areas is important. And rainfall becomes the commonly used basis to delineate drought-prone areas. The Indian Irrigation Commission in its report of 1972, attempted identification of the drought-prone areas in the country. Drought year is the one when the total rainfall is less than 75 per cent of the normal rainfall for that year. The Commission classified drought-prone areas as those where in a period of 25 years if one fifth of the years are drought years the area is classified as drought-prone. The Indian Meteorological Department (IMD) also defines 'drought' in any area as a situation when the annual rainfall is less than 75 per cent of the normal. According to IMD a situation of rainfall deficit between 25 and 50 per cent is 'moderate drought.' The situation is 'severe drought' if the deficiency is more than 50 per cent.

Almost all areas in the country which get a normal rainfall of less than 750 mm (30 inches) can be classified as drought-prone. This is about 35 per cent of the country's area. Another 18.5 per cent of the country that gets a normal rainfall of 750 to 1000 mm can be described as the transitional zone. Thus, without irrigation, over half the country would be drought-prone. Though drought-prone areas are identified on the basis of meteorological phenomena, variation exist from one drought-prone area to the other in terms of cultural, economic and geographical setting and resources, and this is not taken into consideration while identifying drought-prone areas. Hence, drought is not unique and its description is totally dependent on specificity of the location. Therefore, determination of what exactly is counted, as drought is a complex issue. This looseness in defining drought gives scope for political manipulations. The lack of a precise (and objective) definition of drought in a specific situation is an obstacle to its understanding, which leads to indecision and/or inaction on the part of policy makers, and others.

PERCEPTION OF DROUGHT

In the last century, large investments were made on agricultural research, irrigation, food security, poverty eradication and general economic development at national and global-level. These initiatives have resulted in huge stocks of foodgrain. In India alone the food stocks (in 2001) are around 62 million tonnes. However, it is also true that even in India, deaths related to drought are reported from drought-prone areas. Also large number of livestock perish every drought year. Why is hunger pervasive despite the huge foodstocks? It is also true that areas affected by drought increase every time it occurs and its intensity in producing misery also tends to deepen. The social and economic impacts of droughts are much pervasive. The disjunction between starvation death and foodstocks emerges due to poor understanding of drought and formulation of drought mitigation policies. At a philosophical level the questions are related with the paradigm of economic development.

One of the main problems is due to perception of drought and understanding of drought-prone areas. Commonly, it is perceived that droughts are result from the vagaries of nature, i.e. erratic behaviour of the monsoon. It is also perceived that there is no control and little can be done to avert the impact. The response is post facto: provide succor to the vulnerable ones. The second perception sees drought-prone region to be geographically isolated and hence backward. Furthermore, because of the geographic location nothing can be done except provide assistance to cope with the situation. However, both viewpoints are incorrect. Emphasis on drought as a 'natural hazard' is valid up to a point but is insufficient. Viewing drought as a vitiation of nature diverts attention from a whole range of social and human activities that intensify or reduce the impact of drought. Only focus on drought as a hazard leads to a blurred understanding of its social and economic effects. In public policies the hazard of drought is seen as a situation of crisis. The responses show limited concerns to the myriad of issues that lead to drought. The goal is simply to save human lives if and when the next monsoon fails.

People do not view drought in a simple, unified way. Their perception of drought is complex and responses often unpredictable. Farmers do not have one overriding scientific model of cause, effect and response; they have multiple perceptions and so multiple responses (Soones *et al.*, 1996). The farmers' expectation of drought is related to differing definitions of drought and farming locations. The relationship between experience and drought perception is of critical importance. The expected impact of drought and responses are significantly related to both age and experience of a farmer. In order to understand the diversity of coping strategies, it is necessary to explore the social, political and institutional factors that provide contexts for these individual perceptions. Perceptions, however, are not static and may shift over time or are expressed differently under altering circumstances.

Individuals—farmers, research scientists, extension workers, development aid personnel, and politicians—see the hazards of the everyday world through different lenses. The way that such risks are perceived and responded to is based on educational background, gender, age, historical and personal experience, attitude and behaviour derived from peers, friends, family and so on. What people perceive as undesirable and the way people react to a hazardous environment are not solely based on a positivist assessment of outcome probabilities. Instead, responses to all types of risks and uncertainty are based on values and preferences. The realisation that risk perceptions are socially constructed has important implications for public policy.

Thus perceptions of drought and the associated risks are crucial if mitigation policies are to successfully minimise the risks due to drought.

APPROACH TO DROUGHT

Approach to any problem is largely shaped by its perception. We discussed about different perceptions of drought and these cause major difficulties in dealing with the hazard. Some of the difficulties are as follows:

(i) Drought is perceived as a creeping phenomenon because its onset and end are often difficult to identify. Sharp distinction from non-drought day to drought spells is absent;

(ii) Drought is generally viewed as a transient phenomenon. As a result, it is usually not taken seriously once the rains have returned;

(iii) Drought impacts are pervasive on human activities at different levels and scales. Direct impacts like withering crops, dry watering points and reduced forage for livestock are obvious. Second and third order effects, such as, price rise, increased food imports, surges in rural-urban migration rates, are not recognised. As a result, much of the impacts attributable to drought are difficult to identify;

Successful approach to drought mitigation cannot afford to ignore the socio-economic dimensions of droughts for at least two reasons. First, its social and economic aspects, which incidentally are not always amenable to quantification, express the severity of the drought; secondly, human activities could also induce drought.

The problem is further compounded by the fact that government perceives drought as a 'crisis situation' and a short run problem. At the household-level, individual perceive drought as a natural hazard, beyond human control. Both lead to different kinds of approaches and solutions. They also lead to many undesirable consequences. In the long run defining drought only as a crisis situation or natural phenomenon beyond human control undermine the confidence and capabilities of the people to respond to drought using available resources in a productive manner. They become more and more dependent on the government and expect relief on a larger-scale and for longer time. The social resilience is undermined leading to *maibap* notions. They tend to believe that nothing else is possible, that there is really no remedy that will promote self-dependence. In turn, the government becomes complacent in a believe that its actions are in the best interest of the people and that it is doing what all that is expected of a welfare state. Scientists, administrators and politicians also perceive droughts differently but these are not taken in when states make responses to droughts.

IMPACT OF DROUGHT

The impact of a drought on the overall economy of the country or a state is evident at macro (state, regional and national level) and micro-levels (village and household level). The impact varies in its nature, intensity and outcomes. The macro or primary impact directly affects the physical, social, economic and environmental factors. While the second round indirect secondary impact affects several other aspects of an economy. However, the overall (macro) economic performance of a country or state will largely depend on the range of externally determined and domestic factors that can interact with rainfall variability. The extent and intensity of drought shock will be determined by the factors, such as, prevailing economic conditions, national international price movements, the structure of agricultural sector, stage of environmental degradation, management of water resources, cereal reserves, migration pattern and remittances, internal and external conflict. (Benson and Clay, 1998). The micro-level impact is largely on the entitlements to produce and procure food. The impact varies depending upon the social structure (class and caste), and village and household resource endowments.

The direct impacts of drought can be classified under four broad categories, viz. physical, social, economic and environmental. The initial direct physical effects of drought on the production sectors are similar regardless of the type of economy, although the relative and absolute magnitudes of each shock will depend on specific country characteristics. Others directly and affected first are agriculture, livestock, and other water-intensive activities. The canvass of these activities is the common people households, private enterprises and public agencies. They have a larger coverage and hence cause far reaching consequences throughout the economy. Moreover, drought entails loss of assets in the form of crop, livestock and productive capital damages as a direct consequence of water shortages or related power cuts. In the industrial sector agro-based industries are the one directly affected, as the lower domestic production of agro-processing inputs reduces nonagricultural production. Domestic availability of water is also restricted. This latter aspect has implications for health and household activities, including the time required for collecting water. As water becomes scarce, competition among and between sectors may increase. Decline in rainfall adversely affects surface and groundwater resources, flora and fauna. They lead to short and long term impacts on bio-diversity.

Droughts have potentially important implications for government policies, first and foremost, via their impact on the budgetary balance. A drought shock is likely to reduce tax revenue via a decline in income, employment and exports. On the expenditure side, increased expenditure on relief, social welfare, health and water supplies, consumption-related subsidies on food distribution, and the logistical costs of drought-related imports may confront government. Law and order services could also be put under greater pressure by a rise in crime, in turn associated with temporary unemployment, migration and increased destitution. In addition, these are likely to be pressures for the increased provisions of subsidies and credit to affected productive sectors, including public utilities. Government policies can exacerbate the impacts of drought. Government can also use policy action to influence the nature and scale of impact of drought events in a more deliberate fashion.

Increased budgetary pressures, resulting from lower revenues and higher expenditure, can be met by both external and internal borrowings, higher taxes or imposing new taxes. Also reallocation of planned government expenditure may occur within or between sectors and between capital and recurrent spending with varying opportunity costs.

Drought shocks have a range of indirect secondary effects too, whose nature and magnitude depend on particular country's socio-economic and political circumstances. Generally, the secondary impact is on regional inequality, employment, trade deficits, external debt, and inflation. The size of agricultural and non-agricultural multipliers plays an important role in determining the second round and subsequent effects of drought shocks.

Drought shocks can have differing impacts for various socio-economic and geographically located groups, with potentially significant implications for the pattern of income distribution.

The micro-level impacts, village and household level, are equally important. Drought can result in a considerable intensification of household food insecurity, water related health risks, and loss of livelihoods in agricultural sector. As discussed above that agriculture sector is first to be affected by drought. Within the agricultural sector, marginal and small farmers are more vulnerable to drought because of their predominant dependence on rainfed agriculture and related activities. As a consequence they face much greater relative loss of assets, thus, widening disparities between small and large size of producers. Also as the purchasing power declines, unemployment increases reduced availability and higher cost of credit consequently the vulnerable group is either forced to migrate, work at lower wages or live in near hunger conditions. The drought impact is also felt on the village level institutions. Breakdown in the kinship ties, patron-client relationship is common. Drought can have differing impact for various social groups and the intensity varies according to their economic strength, that is ability of households to cope with drought and other adverse conditions.

RESPONSES TO DROUGHT

The response to drought is generally at two levels; first, household and community level; the ultimate sufferer of drought, and second, the state, who is responsible for the welfare of the population. The responses and strategies adopted are quite different, however, in terms of duration, i.e. short-term and long-term, and nature, i.e. physical, social or economic.

Households: Poor rural people in marginal environments have a remarkable capacity to cope with food shortages. Households adopt various coping strategies in response to drought conditions. A growing body of literature on these coping mechanisms, both from Africa and Asia, focuses on the difference between seasonal and crisis coping strategies, the sequence and timing of these strategies, and the objectives (and constraints) which influence the choice of strategies (Chen, 1991, Prasad, 1998, Scoones, 1996, Jodha, 1978). The coping strategies reported from various parts of semi-arid rural India are: growing a mix of crops and/or rearing a variety of livestock, entering the labour and tenancy markets as needed, drawing down stored goods or fixed assets, adjusting consumption, borrowing and drawing upon traditional social security arrangements, and seasonal and long-term migration.

Households responses to drought can be grouped in three stages: (i) risk-minimisation, involving crop and herd dispersal, non-farm income diversification, and asset and other saving accumulation; (ii) risk absorption, involving the sale of livestock and non-production assets, a search for new sources of income, and collection of debts; and (iii) *risk taking to survive*, involving reduced consumption, the save of productive assets, and reduced socialisation. Since wealthier households have more assets, better access to credit and other social support, and more non-farm income than do the poor, they are better able to maintain their level of consumption during drought related food crises. They also have better access to credit and other social support, and more non-farm income than do the poor.

While analysing the people's livelihood strategies one should have wider context of rural livelihoods as rural people are not just farmers**.** They are factory workers, miners, and farm labourers, crafts people and traders. Different people at different stages of their lives adopt different livelihood strategies. Men, women, older and younger people, rich and poor, take different approaches to manage risk and uncertainty in their lives. The social and economic worlds that influence decison making at local-level go well beyond the farm gate, and include networks of social relations. They also include links between national economic policies, which in turn is affected by international economic trends, and price levels, market functioning and levels of infrastructure and service support. The influence of external actors, whether government extension workers, development projects or religious leaders, on the options and possibilities of local level action also become important.

A vast body of literature discusses the concept of livelihood diversification.[3] Ellis (1998) has defined livelihood diversification as "the process by which rural families construct a diverse portfolio of activities and social support capabilities in their struggle for survival and in order to improve their standards of living." Researchers have made distinction between risk strategies and coping as determinants of diversification (Davies 1996, Carter, 1997). This distinction is resolved by distinguishing *ex-ante* risk management from *ex-post* coping with crisis. Risk management is interpreted as a deliberate household strategy to anticipate failures in individual income streams by maintaining a spread of activities (Walker & Jodha, 1986), while coping is the involuntary response to disaster or unanticipated failure in major sources of survival.

A complementary of distinguishing risk and coping is to interpret risk as *ex-ante* income management and coping as an *ex-post* consumption management in the wake of crisis (Carter, 1997). Following this distinction, coping includes tactics for maintaining consumption, such as drawing down on savings, using up food stocks, gifts from relatives, community transfers, sale of livestock, other asset sales, and so on. A literature pertinent to the concept of coping is that concerned with the vulnerability of rural families to livelihood collapse in the face of disaster, such as drought, floods, and cyclones. The focus is especially on human interactions with natural resource systems, and on ways of describing the robustness of livelihoods confronted by erosion of the natural resource base or sudden shocks. Vulnerability is defined in this context as a high degree of exposure to risk, shocks and stress, and proneness to food insecurity (Chambers, 1989; Davies, 1996).

Another concept that arises in the context of coping behaviour is that of adaptation. Livelihood adaptation has been defined as the continuous process of changes to livelihoods which either enhance existing security and wealth or try to reduce vulnerability and poverty (Davies and Hossain, 1997). Adaptation may be positive or negative: positive if it is by choice reversible, and increases security; negative if it is on necessity, irreversible and fails to reduce vulnerability. Negative adaptation occurs when the poor can no longer cope with adverse shocks. Adaptation is evidently closely related to diversification but the two are not synonymous. Diversification explicitly draws attention to a variety of dissimilar income sources (farm, non-farm, remittances, etc.) as its chief characteristics. This is one potential outcome of adaptation but not the only one. Adaptation may result in the adoption of successively more vulnerable livelihood systems over time (Davies, 1996). By contrast, the prime motive of successful diversification by the poor is to reduce vulnerability.

All this discussion is to emphasise that vast body of literature is available on the subject and researchers recognise that the study of these aspects is to have extended understanding of the household and the coping strategies than the conventional knowledge. This extended understanding can be used to formulate appropriate intervention policies and programmes.

State Response to Drought: The state response to drought has largely guided by government's perception of drought. During the twentieth century, governments have typically responded to drought by providing emergency relief, short-term and long-term assistance to distress areas. Emergency and short-term assistance programmes are often reactive, a kind of 'band-aid' approach to more serious land and water management problems (Withite and Glantz, 1987). Actions of this type have long been criticised as inefficient and ineffective by the scientific community (need to differentiate perspective) and government officials, as well as by recipients of relief. Long-term assistance programmes are far fewer in number, but they are proactive. They attempt to lessen a region's vulnerability to drought through improved management and planning.

In the general area of policy studies, considerable scholarly interest has focused on examining the success and failures of public drought mitigation policies. Critical evaluation of various policies and programmes has sought to identify factors responsible for policy failures and suggest what the government should have done to improve their chances of success. Debating on success and failure of policy it was argued that success or failures are slippery concepts, often highly subjective or reflective of an individual's goals, perception of need and perhaps even psychological disposition towards life. Another dimension to it is that making a judgement of a policy's failure or success is a political act because different dimensions and standards are used when assessing a policy's or programme's worth or goodness.

STATE RESPONSE TO DROUGHT MANAGEMENT—INDIAN CASE

National policies for responding to drought management can be classified into two first. The first lasted from 1951 to 1987, when India experienced its first post independence severe drought and nationwide concern resulted in a review of rural development policies. The second period began in 1988 and has continued to date. The approach the first period was to increase food availability and stabilise climatic variability by making major investments in large-scale irrigation projects. Though these projects might have boosted agricultural production, they, in fact, failed to deliver the desired results, and did not improve the situation in drought-prone areas. Since 1985 there has been a distinct shift from a sectoral short-term approach to an integrated holistic long-term approach focusing on environmental and ecological issues. Various programmes in the field like Rural Landless Employment Guarantee Programme (RLEGP), National Rural Employment Programme (NREP), Drought-prone Area Programme (DPAP), Desert Development Programme (DDP) and Accelerated Rural Water Supply Programme (ARWSP), along with various programmes related to minor irrigation, the environment, forestry, and agriculture, were integrated to tackle the problems of rural unemployment and drought-proofing. To deal with the drinking water crisis, a specific time-bound, target-oriented drinking water supply programme was started.The administration also changed its strategy in the field. Drought relief works were undertaken to create more water-harvesting structures, soil conservation and terrain development works. More target-oriented programmes were started. All these efforts, however, have secured only marginal improvements in the intensity, severity and condition of the drought vulnerable sections of the population in drought-prone areas.

Surveying the variety of perceptions about criteria for judging policy success or failure, Smith (1989) has grouped the diversity under three major categories. First, criterion of policy designs, which views the policy from the perspective of its appropriateness and agreement with its objectives and means. Second criterion deals with policy process in terms of how the policy is formulated and implemented within the context of the policy arena. Third criterion relates to policy achievement and concerns of effectiveness and adequacy of the policy in achieving its goals. Kerr (1976) has described three types of policy failures, namely, implementation failure, instrumental failure and failure in the normative justification. These criterion of policy of failure are completely unrelated to achievement or efficiency, these refer to the normative justification dimension wherein the 'policy' goal or purpose must be justifiable by appeal to some norm, principle or value which the relevant public shares and sees applicable in a particular case. The question is, therefore, not of taking objectives for granted by asking whether these objectives are appropriate for society. It is here that disagreement over failure or success can be very intensive. It makes no difference whether a particular policy is achieving its stated objectives and is efficient or not. What is more important is to judge whether it is right or wrong. This leads us to even more difficult terrain. How does one decide whether a policy is right or wrong particularly in the context of short-term and long-term interest of a society?

How people are made aware of problems and the way demands are articulated in a democracy usually serve sectarian interests (Gupta, 1990). Policies, therefore, also have political uses. They may help in bolstering the image of a regime or in answering the return of a political leader in the next election. Traditionally, however, evaluations of public policies have primarily focused attention on the dimensions of efficiency and effectiveness. These assessments are important but they make one very important assumption. They accept the officially stated goals or objectives of the policy and do not question their validity. It is important because the masses are frequently unaware of their objective interests who are quite different from their expressed wants and preferences—the product of a system that works against their real interests.

For formulating an 'appropriate' policy, needs and concerns have to be articulated that they become part of the policy-making agenda. This is a two-step process. Step one is that of aggregating needs and concerns. The second step is to articulate these needs so that they become part of the agenda for policy making. Both are political processes and are greatly influenced by the nature of society and the political system.

AGGREGATE FOOD AVAILABILITY AND DISTRIBUTION POLICES

The aggregate food availability or promoting domestic food production as a part of long term strategy for mitigation of drought is debated. Also the role of commercialisation of agriculture and promotion of cash/export crops (both food and non-food) has been much debated. It is some time argued that this will divert resource away from the domestic production of food and expose poor farmers to even greater risk of food entitlement failure. The market risks have already increased after the adoption of new economic and trade liberalisation policies adopted in India. The Rajasthan farmers realised the impact of these macro-policies in 2001 when the price of pearl millet crashed: it did not even meet the production costs involved.

Increasing aggregate food availability during drought is the best form of state intervention from the point of view of minimising hunger and hunger-led mortality. Public buffer stock have been a popular stabilisation policy in India and elsewhere. Stocks are raised when aggregate food availability is high. This policy and the related issues, such as the size of stock needed, costs of the scheme, agency to handle and control over funds and release of stocks, are very much debated. Even private storage and village level storage is seen as an alternative to state managed large stocks. The food procurement and distribution in India is being questioned from many quarters. Despite the huge food stocks and large network of Public Distribution System (PDS) there are heavy storage losses, stocks are not able to replenished, less off take both at state and village level, food do not reach the target population Sagar, 2003. Administrative hassles in getting quota allotted, released, payments are the reasons why food is not available to the affected population. It is also argued that private traders can deliver the food more efficiently than the government or aid agencies and at a lower cost. The concept of village level food banks is also proposed. These issues need to further analysis and clarification.

NGOs can be other alternative to reach the vulnerable section. The experience of Rajasthan during the drought year 1999-2000 was quite encouraging, as they could reach the most affected in far-flung areas, with least administrative costs. They better addressed equity, access, and corruption issues than the state agencies.

STATE FAILURES

Even with well-informed and well-intentioned policies, governments and other agencies in developing countries can face severe infrastructure, administrative and logistical constraints on their capacity for action. Inadequate rural infrastructure and communications have often been identified as a contributing factor to droughts and famines, and a severe constraint on their relief (Dreze, 1990). In fact this may well reflect past failures of public planning and action.

There have also been serious short-term public action failures. First, there are policy failures resulting from faulty theories and misinformation. The British Government's faith during the nineteenth century in non-intervention in food markets during famines almost certainly made matter worse (Dreeze, 1990). At the other extreme, the forced collectivisation of agriculture and associated food procurement policies implemented under the Soviet Union's first Five Year Plan resulted in a severe famine in rural Ukraine in 1930's. Similar policies occurred in Ethiopia from the mid-1970s are believed to have contributed to the famine of the mid-1980s. The collapse of food entitlements in China during 1959-61 is believed to have been instigated by the destructive effects on food production of the rapid industrialisation policies implemented as part of the 'Great Leap Forward', compounded by an urban bias in food distribution. Similarly, wartime policies enforcing rice export quotas and the production of non-food crops contributed to the famine in Vietnam in 1943-45. There have been a number of descriptions of how governmental interventions in agricultural markets enhanced vulnerability to famines in Africa.

Secondly, there are public action failures that arise when those in power may not share the objective of avoiding or relieving famines. In some drought and famine prone economies, the government's survival appears to have little to do with its ability to secure the basic consumption needs of these governed. Indeed, higher poverty during famines or droughts may often come side by side with absolute, as well as relative, gains to more powerful sub-groups of the non-poor. Thus the incentive facing political leaders can work against effective drought or famine avoidance or response. An extreme, but not uncommon, form of this type of public action failure is when a government knowingly uses famines/ droughts as a weapon against its (external and internal) enemies. Within this category of deliberate public action failures are also examples in which the drought or famine is used to attract donor sympathy to get more aid, or instrument of foreign policy etc.

The resolutions to public action failures are numerous varying across countries. Some examples are (i) better governance, (ii) early warning and rapid response, (iii) open formal political institutions and independent press, (iv) food stocks and distribution policies and (v) creating institutional structure for coordinating governmental actions.

DROUGHT AS A HAZARD AND OPPORTUNITY

Drought result form combination of various factors linked in a complex way and responses are often unpredictable. People do not view drought in a simple, unified way. Also the perceptions are not static, they may shift over time or be expressed under altering circumstances (Scoones *et al*., 1996). The perception and response are also based on based on the socio-cultural, economic background of politicians, administrators, researchers, and extension workers, farmers and development aid personal. This realisation that risk perceptions are socially framed has important implications for public policy.

The dominant perception sees drought as a hazard and it is overplayed. This is more framed by the past researches and writings on drought and famine narrating the miseries and sufferings of the population in different parts of the world. This was also felt necessary to, in the given socio-political milieu, to attract attentions and support the affected population. However, this tendency has underplayed an important positive aspect of drought, that drought is also an opportunity. The immediate question is, opportunity for what? It has been established that drought is not only a meteorological phenomenon but also an socio-economic dimension to it. The impact of drought varies across different section of the population. The most vulnerable section is the population in lowest income profile. It is also established that drought coping strategies largely depend on the socio-economic background and the existence of socio-economic institutions in the system. The institutional and market failure is common outcome of severe drought. It must be recognised though there are no miraculous solutions and no shortcuts to the resolution of droughts. However, such crisis is a time of opportunity as well as danger. With this comprehensive perspective of drought we look for the opportunities.

First, drought provides us environment and chance to review our past and present policies to take steps, which are impossible in normal circumstances. It can be supported by the fact that 1987 drought did help create an intellectual climate in the country for rethinking. A critical appraisal of 'development' efforts began. Drought provides an opportunity for fresh appraisal and reform than can rescue from the recurring disaster and set hope for the future. Even some innovative bold steps favouring vulnerable sections, areas and regions can be initiated/taken. With an overall environment of sympathy large resources can be mobilised for investments in drought-prone areas. Second, drought provides opportunity to settle political differences and mobilise partly worker, strengthen political-base and also attain the goal of serving the affected population. It is the best time to attain the political agenda of eradicating poverty by launching poverty reduction programmes that too without much political opposition.

Third, drought provides environment and commitment to remove/reduce the urban bias in policies and planning. Throughout the policies made for urban people by urban people have pushed aside the needs of rural majority. Food prices have been kept artificially low to benefit urban consumers rather than rural producers. Investments in basic quality of life, such as, health and education and welfare have gone to the towns first. This crisis is not just of neglect but also policy errors. When policies have touched on the countryside they have often demonstrated doubtful priorities. The consequence is that far from the dramatic spotlight of drought, the quality of rural life as a whole is deteriorating dangerously increasing vulnerability to drought. In most cases, the declining government revenue is taken up in paying salaries, debt clearance and other recurrent costs. There is virtually nothing left for investment in development of any kind. Without external assistance government do not have the means to bring about a major shift of resources from city to countryside. The resources are just not there and national stability will not allow for further cuts in urban living standards. Therefore, the resources for a new rural initiative can either be from outside aid donors or by leaving fresh taxes. Drought provides us a good opportunity to initiate new taxes on urban population.

Fourth, it provides an opportunity to correct the generally prevailing perception that 'drought is solely a natural phenomenon' and emphasise that 'drought is also a man-made disaster.' Instinctually, one wants to believe that it is not true that the nature and not the man who is responsible. It is far more comfortable for us all if we can continue to think of drought as being the result of nature or climatic variability. The uncomfortable truth is that the facts point unerringly to man, contributing as well to drought conditions and the nature alone cannot be held responsible. As forests retreat and deserts advance, as threats to essential life-support system increase and ecological fragility grows, so will the vulnerability of the human race. It is all because the human kind continues proliferate use of natural resources and struggling against nature instead of cooperating with it. Therefore, there exists an opportunity for creating this realisation among masses.

Fifth, drought provides voice to the most neglected, unorganised, and marginalised section of the population. As during distress they suddenly pose a threat to governmental structures and are at least able to impose themselves on the conscience of others. In that latter aspect the power of the media, especially television, has been crucial. In normal times it will be a difficult task to organise the group.

Sixth, perceiving drought as a hazard of nature and as a crisis serves diverse purpose, such as political planning and development policies. Relief measures tend to provide an opportunity to global, natural and state governments to project themselves as the guardian of public welfare, champion of the cause of the poor and under-developed and uses relief measures to gain political mileage. Among political parties and political leaders, drought-as-relief continues to dominate their thinking rather than questioning the state failure in drought proofing. Rather the concern is more to procure a large volume of relief funds of which there is hardly any transparency and accountability. Even in the British period famine works had a political, administrative and humanitarian value. A new transparent and accountable system can be introduced to check corruption on relief work and drought related issues.

Seventh, drought provides an opportunity to reach inaccessible areas and population where it is ordinarily hard to get. Drought strikes at and exposes the vulnerability of the poorest. Custom and hierarchy, often barriers between outside helpers and the most vulnerable, may be forced aside for the duration of a drought. Vast number of people, mostly illiterate, who have often lived outside the reach of government and modern services, are thrown into contact with, and dependence on, the outside world. Drought forces them to move, for sake of old homes, meet new people, and confront new choices. It is obviously one of the opportunities and risks.

Some of the risks are well known, for example, the experience of food aid, however, is that it creates a dependence on outside sources of food, both by changing tastes and by undermining the price of local food, thereby discouraging production. There is no doubt that it is a double-edged weapon and that it can very quickly contribute to the problem of hunger that it seeks to ameliorate.

Eighth, drought relief works provides an opportunity to improve the entitlements of the vulnerable sections. Droughts have a profound effect on societies, disrupting the social capital and local institutions, the main instrument to cope with drought, causing lasting changes. Well targetted relief can channel some of this change towards progressive improvements.

This list of opportunities can be extended depending upon the socio-economic, political and cultural context. Some other issues are: drought as an opportunity for common property asset building, strengthening cooperation among various actors, scope and opportunity for capacity building, to build non-water economic structures and investments in alternatives, strengthening and revival of natural resources, building drought resilience through institutional mechanisms, mainstreaming women, destitute and poor sections and other vulnerable. The objective is to highlight that it is right time now to emphasise on the positive aspects of drought. However, it will require a comprehensive understanding of drought, its impact and the coping strategies adopted.

State machinery such as the whole bureaucratic set-up and State policies represent this group. The State in the present context has been feckless, inefficient and irresponsible in responding to recurring occurrence of droughts. The hitherto State policies in responding to drought have been not only *ad-hoc* but also myopic. And, the State views the suffering mass of people as mere takers and never bothered to think about what they are entitled for. What is inherent is also the corrupt governance. Most of all, the State is unwilling to learn from the past experience.

Drought also sees individualistic response Basic elements in this group are agents involving in the market. They are traders; black marketers, hoarders, moneylenders and the whole lot of profit making agents whom would like to make use of the prevailing drought conditions. These are absorbers of profit who turn drought into their favour. This is a classic case of scarcity leading to prosperity for a few.

NGOs and academics make egalitarian response. This is the group, which do make noises about the suffering mass due to drought. But what is lacking for instance among NGOs is the lack of coordination among them. Some of them feel that they are running a parallel government and therefore avoid connections with the government. Some others survive by taking grants from the Government in order to undertake relief measures and in the process make close friendship / nexus with the hierarchists. Such NGOs will eventually turn out to be individualists. Academics on the other hand, feel so good writing about droughts and make papers and books and present them in the international conferences and are content with that. These academics and NGOs refuse to attack the problem politically. Most of all, NGOs and academics often do not show interest in coming together and do not exchange their respective expertise.

The suffering masses represent the fatalist group. The people who are hit by the drought are basically 'takers' or considered to be the shock absorbers of society. These people have no voice of whatsoever; Literacy is very low among this group; and this group provides the major vote bank. This group makes attempts to cope with the droughts by seeking non-farm employment and so forth; If that is not possible, other options open to them are selling their belongings, get into a debt trap, stay and suffer or flee.

NOTES

1 For detail review on livelihood diversification, see Ellis (1998), Walker and Jodha, 1986, Carter, 1997, Davis, 1996.

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