Times of change?
Insights into the Government of India's water policy and management response to climate change

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Abstract

This thesis examines how climate change is being integrated within India's national and state government water policy and management practices. Climate change poses significant challenges to the management of non-stationary hydro-meteorological conditions, whilst meeting rising water demand. The nature and orientation of the Indian government's water institutional approach compounds this challenge, due to their focus on large-scale infrastructure-based supply-side water management. This research takes an interdisciplinary political ecology approach to examine the Indian hydrocracy's response, namely, the Ministry of Water Resources' (MWR) policy response to climate change, and the state level response by the Andhra Pradesh (AP) Irrigation Department. The analysis is based on policy documents and other government reports, interviews with policy makers and water managers, and non-government water experts in India, conducted between 2008 and 2011. The research draws on theoretical groundings of the linear and interactive models to understand public policy processes, water management paradigms including the hydraulic mission, river basin trajectory and institutional reform theory to understand the process and pace of government change. The Indian water policy experience will generate insights into the use of water policy to respond to climate change.

The results indicate that climate change is being integrated within policy and water management practices as a continuation of infrastructure-based supply approaches to water management. This approach is facilitated by the uncertainty of climate change projections and impacts, which provide plasticity for it to be used to strengthen a sanctioned 'water for food' government discourse and hence continue India's hydraulic mission. The MWR and AP Irrigation Department appear resistant to change their strategic approach to water management. However, certain reformist actors within the margins of government are endeavouring to operationalise demand management strategies and institutional reform measures, broadly representing a reflexive modernity stage of water management. Insights into the Indian water policy process highlight numerous challenges to implementation, consistent with an interactive theoretical model of public policy. Implementation challenges of paramount importance include the politically contested nature of water management which serves vested political and financial interests, and the inertia of government, characterised by centralised and hierarchical structures and procedures. The government appears to be operating within the limits of a linear theoretical model of public policy, recommending demand management and institutional reform 'statements of policy intent', but without offering a suitable institutional approach to address implementation challenges. The hydrocracy is largely permitted to continue its approach within the wider political context in India, with other actors implicitly supporting and benefiting from large-scale water infrastructure. In conclusion, this research finds that both continuity and change co-exist within government water management in India. Resistance to change endures, whilst at the same time, certain reformist actors are intent to navigate the complex and uncertain nature of institutional reform.

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AIBP	Accelerated Irrigation Benefit Programme
AP	Andhra Pradesh
APGW	Andhra Pradesh Groundwater department
APHRD	Andhra Pradesh Human Resources Department
APWRRC	Andhra Pradesh Water Resources Regulatory Commission
BCM	Billion Cubic Metres
BWE	Bureau of Water Efficiency
CAD	Command Area Development department (ICAD)
CSE	Centre for Science and the Environment
CCCEA	Centre for Climate Change and Environment Advisory
CWC	Central Water Commission
CW	Construction Wing (ICAD)
DFID	Department for International Development (UK)
ERM	Extension, renovation, modernisation (irrigation)
FYP	Five Year Plan
GCM	General Circulation Model
GIS	Geographic Information Systems
GWP	Global Water Partnership
GDSP	Gross Domestic State Product
ICAD	Irrigation and Command Area Development department (AP Irrigation Department)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITD	Indian Institute of Technology Delhi
IITM	Indian Institute of Tropical Meteorology
INCCA	Indian Network on Climate Change Assessment
INIHG	Indian National Institute of Himalayan Glaciology
IPCC	Intergovernmental Panel on Climate Change
IR	Institutional reform
ISF	Irrigation Service Fee
IWRM	Integrated Water Resources Management
KWDT	Krishna Water Disputes Tribunal
LGRB	Lower Godavari River Basin
LKRB	Lower Krishna River Basin
MA	Ministry of Agriculture
MEF	Ministry of Environment and Forests
M&M	Major and medium irrigation projects
MWR	Ministry of Water Resources
NIDM	National Institute of Disaster Management

NRLP	National River Linking Project
NWC	National Water Commission
NWDA	National Water Development Agency
NWM	National Water Mission
NWP	National Water Policy
NWS	National Water Strategy
PC	Planning Commission
PIM	Participatory Irrigation Management
PMACCC	Prime Minister's Advisory Council on Climate Change
PMNAPCC	Prime Minister's National Action Plan on Climate Change
PMF	Probable Maximum Flood
PMO	Prime Minister's Office
RBB	River Basin Board
RBO	River Basin Organisation
RIA	Right to Information Act
SANDRP	South Asian Network on Dams, Rivers and People
SWP	State Water Policy
WCM	Water Management Committee
WDM	Water Demand Management
WGWR	Working Group on Water Resources (Planning Commission)
WMS	Water Management Strategies
WRIS	Water Resources Information System
WSM	Water Supply Management
WUA	Water Users Association
WWC	World Water Council

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'In rivers, the water that you touch is the last of what has passed and the first of that which comes, so with present time'.

Leonardo da Vinci

1.0 Introduction

1.1 Introduction

This chapter begins by introducing the nature of the water management challenge facing the Government of India (GoI), in terms of developing water policy and management responses to manage increasing demand for water under non-stationarity hydro-meteorological conditions due to anthropogenic climate change. It then outlines the research need and overall objective, research questions and approach taken in this research. The chapter concludes by outlining the structure of the thesis.

1.2 The water challenge: rising water demand and climate change

In recent decades water demand has risen dramatically in India, owing to population growth now standing at 1.21 billion people, and high economic growth over the last decade (GoI, 2011b). This has led to a dramatic decline in per capita water resources, from 4098m^3 in 1967 to 1560m^3 in 2010[1] (FAO, 2012), characterised by rising water scarcity, river basin closure and an increase in competition between sectors (Amarasinghe et al, 2005). Agriculture accounts for the vast majority of water withdrawn in India, currently at 90% (FAO, 2012). The last decade has witnessed rapid urbanisation and industrial growth, with demands from all sectors rising exponentially (Shah et al, 2007). Re-allocation from agriculture to higher value uses, such as for urban drinking water and industrial processes, has become a recent phenomenon in parts of the country with the potential for rising conflicts between users (Jakhalu and Werthmann, 2011; Celio et al, 2010; Molle and Berkoff, 2009). Groundwater has played a crucial role in meeting India's water demands since the early 1970s, particularly to meet rising agricultural needs, with a proliferation of individual pumps and borewells throughout the country. However, groundwater levels have declined rapidly in recent years and are at alarmingly low levels in many parts of the country (Shah, 2009). Furthermore, water demand from all sectors is projected to continue to rise, from 680BCM in 2000 to 900BCM in 2050, as the population continues to grow to an estimated 1.6 billion people under the Business as Usual economic development scenario by the middle of the century (Shah et al, 2007). It is estimated that India will have to double its 2010 food production levels by 2050 to feed its growing population in order to remain food self-sufficient (ibid; Amarasinghe et al, 2008). Per capita water resources are projected to decline to 1140m^3 by 2050, without considering climate change impacts (Gupta and Deshpande, 2004). In Andhra Pradesh (AP) (the case study state for this research), per capita water resources have fallen to 1400m^3 (Gupta, 2010) owing to rapid population growth and economic development within the last decade. The Lower Krishna and Pennar River Basins are closed basins, both characterised by water scarcity and increasing competition between sectors. Future water demand projections in AP indicate a 42% rise in sectoral demand by 2025 to serve growing agricultural, domestic and industrial needs (GoAP, 2012), with per

[1] Water resources per capita per year below 1700m^3 is termed as experiencing 'water stress'; below 1000m^3 is termed 'severely water scarce' (Falkenmark et al, 1989).

capita water resources projected to fall to 1150m^{3}by 2020 (Palanisami et al, 2010). To manage future water demand, water policy and management practices are advocated that include promoting sustainable groundwater management, increasing water use efficiency in all sectors and particularly in canal irrigation systems, improving crop productivity and agricultural diversification, watershed development programmes, increasing water storage at the appropriate scale (large and medium reservoirs, as well as smaller tank and field storage structures) and potentially inter-linking of rivers across India (Amarasinghe et al, 2008; Briscoe and Malik, 2006).

Climate change is considered to be a serious threat through its direct impacts on water resources (IPCC, 2008). Climate change poses a new and uncertain challenge for water managers. Water has historically been managed on the concept of stationarity, based upon observed and measured hydro-meteorological variations, fluctuating within a known and unchanging range. However, climate change fundamentally challenges the concept of stationarity (Milly et al, 2008). Climate change projections for India indicate increasing variability in precipitation levels and monsoon patterns, temperature rise and an increase in the incidence and intensity of extreme weather (GoI, 2012a; Kumar et al, 2011; IPCC, 2007). Such meteorological changes will directly impact levels of surface water runoff, evapotranspiration rates and water availability within river basins in India (Gosain et al, 2011). Indian government water managers now need to operate within the challenge of non-stationarity, managing water under uncertain hydro-meteorological conditions.

The institutional challenge: developing appropriate water policy response and water management practices

Water institutions consist of three components: policy, organisations and law[2] (Saleth, 2004; North, 1990). Integrating climate change into water policy is an emerging field (Pittock, 2011; Dovers and Hezri, 2010; IPCC, 2008). The IPCC (2008) recommends an integrated institutional approach, aligning with the principles of Integrated Water Resource Management (GWP, 2002) to manage water resources under non-stationary conditions in a sustainable manner. More specifically, water policies that promote an adaptive water management approach are advocated to manage variability and increasing water demand (Pahl-Wostl, 2007; Gleick, 2003; Stakhiv, 1988). Such approaches emphasise integration between government ministries and departments, flexibility and learning, participation of all water users, open and transparent government decision making and sharing of information and data, decentralisation, application of efficient technologies, environmental protection, and the development of water management strategies and projects at appropriate scales (Pahl-Wostl, 2007). Gleick (2003) advocates a soft path solution, were demand management and intuitional reform measures complement large-scale infrastructure approaches[3], essentially operationalising

[2] Saleth (2004) refers to government institutions as 'entities defined by a configuration of policy, legal and organisational rules, conventions and practises that are structurally linked and operationally embedded in a specified environment '(ibid:3). The identification of these three components originates from the Institutional Analysis and Development Framework developed by Ostrom (1990), drawing on new institutional economic theory (North, 1990; Williamson, 1975).

[3] Gleick (2003) expands on what constitutes a sort path as 'one that complements centralised physical infrastructure with lower cost community-scale systems, decentralised and open decision-making, water markets and equitable pricing, application of efficient technology, and environmental protection' (ibid:525).

the reflexive modernity stage of water management (Allan, 2002) (See Chapter 2). Regarding water management strategies at the river basin level, a number of planning approaches are advocated, including scenario-based planning (IPCC, 2008), the pursuit of robust strategies in the face of uncertainty (Wilby and Dessai, 2010; UKCIP, 2003; Hashimoto et al, 1982), and strengthening operational responses to extreme weather events such as floods (Wilby and Dessai, 2010; Tanner et al, 2007).

The nature of the Government's approach and the polarisation of water management in India

The GoI's organisational structure and strategic approach to water management has considerable implications for the way in which climate change may be addressed. The Ministry of Water Resources (MWR) and state Irrigation Departments are highly centralised, hierarchical and bureaucratic in nature (Mollinga, 2005; Saleth, 2004; Iyer, 2003). Since Indian independence in 1947, the primary focus of the MWR and the Irrigation Department has been the expansion of irrigated area and increasing large-scale reservoir storage capacity to consolidate and continue what is widely known as the hydraulic mission (Section 2.5.2 and 4.4). Resistance of the MWR and Irrigation departments to move beyond a primary focus on large-scale infrastructure-based supply approaches to water management has been documented in India (Mollinga, 2005) and AP (Bolding and Mollinga, 2004). The MWR and AP Irrigation Department have been found to be resistant to fundamental change, by deflecting reform measures and appropriating policies, legal acts, projects and initiatives to largely continue their historical approach to water management (Nikku, 2006; Mollinga, 2005; Bolding and Mollinga, 2004). The resistance of government water ministries and irrigation departments to change is also documented internationally (Molle et al, 2009), particularly in Mexico (Wester, 2008; Rap, 2004), the Philippines (Panella, 2004), USA (Reisner, 1993), Thailand (Molle and Floch, 2008) and Indonesia (Suhardiman, 2008).

Water management in India is characterised by a polarity (Shah, 2009; Mollinga, 2005; Saleth, 2004; Iyer, 2003; Kaviraj, 2001; Roy, 1999). On one side, the MWR and state Irrigation Departments are focused on top-down and centralised large-scale infrastructure-based surface water management, including canal irrigation and reservoir constriction and management, and the provision of drinking water to urban and rural areas. And on the other side, non-government actors[4], led by NGOs, civil society and farmer groups, generally pursuing smaller-scale decentralised water management practices, including watershed development approaches, rainwater harvesting, groundwater withdrawal for agriculture and drinking water purposes, and small-scale storage such as check dams, tanks and on-farm storage. There is limited collaboration or effective interaction between the government and non-governmental actors with regards to water management and projects, with both sides entrenched in their opposing approaches to water management[5] (Iyer, 2003).

[4] This group constitutes non-government actors manages water within the 'informal water economy'(Shah, 2006).
[5] The polar nature of water management should be considered within the wider context of the governance gap between government and the local level, or the 'state-village dichotomy' (Mollinga, 2005:16), considered by Kaviraj (1996) to have its roots in India's colonial history and political democracy; with British colonial rule leaving behind a centralised, hierarchical and strong government administration, then staffed by Indians after Independence, ultimately serving the interests of political elites and the higher strata of the Indian caste system.

Towards institutional water reform

In summary, developing appropriate water policy and management practices that integrate climate change whilst managing the increasing demand for water represents a highly complex challenge for the GoI. Moving towards a more integrated, decentralised and adaptive method of managing water, as advocated for dealing with climate change, will challenge the GoI to fundamentally change and reform its institutional water management approaches (Merry et al, 2007; Mollinga et al, 2007).

1.3 Knowledge gaps and the need for research

In 2008 the MWR formally initiated its institutional response to climate change, resulting in the National Water Policy (NWM) that was finalised in April 2011. This policy recommends a number of water management strategies for state governments to consider and implement. Water is an independent issue for state governments to manage under the Constitution of India, with national policy representing guidance and recommendations.

The development of NWM policy coincided with the beginning of this PhD research, allowing an opportunity to examine the GoI's response to climate change through its water policy and water management practice. No such research had previously been carried out in India. Furthermore, the development of the NWM policy represented the most comprehensive review of water resources and management in India to date, facilitating insights into government institutional[6] approaches and strategic direction beyond climate change.

Research on the GoI's water institution approach, particularly the workings and strategic direction of the MWR and state Irrigation Departments, is a relatively under examined topic in India (Molle et al, 2009; Mollinga, 2005) and AP state (Bolding and Mollinga, 2004; Mooji, 2003). The first serious piece of research on this topic in India dates back to the early 1980s, focusing on the political and administrative corruption of government canal irrigation systems (Wade, 1985, 1982), followed by research examining practical aspects of canal irrigation management in South Asia (Chambers, 1988), two irrigation-focused PhD theses (Nikku, 2006; Ramamurthy, 1995) and an analysis of institutional water management structures and procedures of the GoI (Saleth, 2004). The most recent research on institutional water management and policy processes in India was seven years ago (Mollinga, 2005), which this research updates and expands upon. Furthermore, to the best of the author's knowledge, AP state government's water management practices at the river basin level have not been examined within the context of climate change.

[6] The organisational response of the GoI is examined by virtue of its policy response. Legal aspects of water are not examined in this thesis, as the GoI's institutional response to climate change principally focuses on the water policy and organisational response, without recommending any change to current legislative arrangements and procedures. Sections 2.7.1, 2.5.1 and 4.2 for further information on policy, organisational and legal institutional components.

1.4 Overall objective, research questions and approach

The overall objective of this research is to understand how climate change is being integrated into national government policy and water management practice in India. Five research questions are identified to achieve this overall objective. Insights generated are then used to reflect upon the title of this thesis, whether there is a time of change within the Indian Government, in moving beyond its primary focus on the hydraulic mission.

Research Question 1: What is the GoI's national water policy response to climate change?

Research Question 2: What water management strategies does the national water policy response to climate change (the NWM) advocate, and why?

Research Question 3: What is AP state government's adoption of the NWM Goals through water management strategies, and is climate change linked to the choice of particular water management strategy?

Research Question 4: What are the challenges to implementing the supply and demand strategies and institutional reform measures adopted by the AP Irrigation Department?

Research Question 5: What does the Indian water policy experience tell us about the use of water policy to respond to climate change?

This research takes an interdisciplinary approach. It uses political ecological theory to structure the design and to understand the hydro-social[7] dimensions of the national and AP state government's response to climate change, aligning the research questions with key theoretical insights in presenting the conceptual framework of the thesis. The first and second research questions focus on national government, particularly the MWR. The first research question examines the policy formation process of the NWM. The second research question examines the water management strategies advocated through the NWM to provide an insight into the strategic outlook of the MWR, and relates these with other water policy priorities and the historic orientation of the MWR. The third research question focuses on AP state government, particularly the Irrigation Department, and examines the water management strategies adopted from the NWM policy and whether climate change has influenced the choices. Selection of water strategies is contextualised at the river basin level in AP, encompassing hydrological, political, technical, economic and social dimensions. The fourth research question addresses the multitude of factors that determine policy implementation in AP. The fifth research question provides reflections and discussion on the overall findings of this research.

[7] As noted by Swyngedouw (2009), a hydro-social approach with theoretical roots in political ecology allows an interdisciplinary understanding of the relationship between how changes in river basin hydrology through water management practices are related to social and political power of formal water institutions (government).

1.5 Thesis structure

Chapter 2 describes the theory which underpins this research. Public policy processes, including linear and interactive models, are introduced to gain a theoretical understanding of government policy formation processes, along with key concepts such as water control, policy discourse and the political nature of water management. The role of government is then discussed in the context of the hydraulic mission, leading to an examination of the process of institutional reform. Climate change projections and impacts on water resources in India and AP are detailed, leading to an overview of water resource management strategies at the river basin level, and then discussion of these strategies as potential adaptations to climate change. The chapter concludes by presenting the conceptual framework of this thesis.

Chapter 3 presents the research design including epistemological considerations, methods of data collection and analysis, and ethical considerations.

Chapter 4 sets the scene by introducing the institutional water management structure (policy, organisation and legal components) of national and state government, with particular focus on the MWR and AP Irrigation Department. It then details the status of water resources and historical review of the hydraulic mission in India and AP.

Chapter 5 presents an analysis of the MWR's policy response to climate change. Firstly, it focuses on the NWM policy formation process, including the role of the MWR and non-government actors to address the first research question. Secondly, it analyses the strategic direction of the policy by exploring the supply and demand strategies along with institutional reform measures recommended. In order to understand why certain strategies are being recommended by the MWR, the research draws on related water policy documents and the historic approach of the MWR.

Chapter 6 analyses the AP state government's adoption of the NWM Goals through water management strategies, and considers is climate change linked to the choice of a particular water management strategy. The chapter contextualises the choice of water management strategy at the river basin level in AP, by examining the hydro-social dimensions that influence government decisions. It also discusses the robustness of water management strategies as potential adaptations to climate change projections in AP.

Chapter 7 examines the challenges of implementing the demand and supply strategies and institutional reform measures in AP. The work draws on insights from state government officials and non-government water experts in AP, to understand how political dimensions, government organisational inertia and other issues influence the effectiveness of policy implementation, particularly demand strategies and institutional reform measures. It also discusses the hydrocracy within the wider political context in India.

Chapter 8 integrates the principal findings of Chapters 5, 6 and 7 to make reflections and conclusions in relation to the fifth research question and the research objective of this thesis. It is structured around six themes, including the MWR's and AP Irrigation Departments policy and water management strategy response to climate change, whether the response is directly in relation to climate change, insights into the Indian water policy process, the hydrocracy within the wider political context, if the institutional response is an adaptive and integrated in its approach, and the reform agenda at the margins of government.

2.0 Theoretical foundation and conceptual framework

2.1 Introduction

This chapter outlines the theoretical foundations of the overall research objective of this thesis: how is climate change being integrated into national government policy and water management practices? A political ecology theoretical framework is employed to conceptualise the interdisciplinary nature of this research, to examine both the GoI's water policy response to climate change, and the resulting choice of water resource management (WRM) strategies set within hydrological context of India and the case study state of AP.

The political ecological theoretical framework is introduced in Section 2.2. This leads to an examination of climate change projections in India, and the impacts on water resources globally and more specifically within India and AP state (Section 2.3). The water management and institutional responses to climate change are discussed in Section 2.4, detailing the variety of water management strategies, planning and institutional approaches advocated in adapting to climate change impacts. This section also introduces the concept of river basin development to understand the choice of water management strategies at different phases of river basins trajectory, discussing different supply and demand strategies and interventions under the direct management of the government. The role of government in water management is discussed within the context of the hydraulic mission (Section 2.5). Institutional reform is then introduced (Section 2.6), beginning with an overview of triggers that can promote reform, the process of reform and the resistance of government to change, then drawing on existing literature on the public policy process in India. It also examines the results of reform initiatives over the last thirty years in the water sector, particularly relating to agricultural water management (irrigation), highlighting the inherently political nature of the reform process, and finally, concluding with some factors that can enable lasting reform. The public policy development process is then introduced in order to understand the GoI's policy response to climate change (Section 2.7). Linear and interactive models of public policy development are discussed, leading to concepts of the political nature of water management, water control and policy discourses underlying expressions and exertions of power. The chapter ends with presenting the conceptual framework, aligning the research questions with key theoretical insights (Section 2.8).

2.2 Political ecological theoretical framework

This study uses a political ecology theoretical framework. Political ecology offers an appropriate theoretical approach to examine hydro-social processes. Political ecology is an established field of human-environmental research in geography (Walker, 2005), with its roots in ecological and social science (Paulson et al, 2003; Peet and Watts, 1996). Political ecology studies 'how power structures and politics that underlie environmental change determine environmental policies and their outcomes' (Budds 2009:418). Political ecology theory is based on the assumption that environmental issues are inherently influenced by the nature of interactions of socio-economic and political dimensions with biophysical (environmental) factors (Sullivan and Scott, 2005; Budds 2004; Robbins, 2004; Forsyth 2003; Bryant 1998; Blaikie et al 1994). A central component of political ecology in environment and development discourses are power relations between actors (Budds 2004; Bryant 1998; Bryant and Bailey 1997). Political ecologists have attempted to analyse how power relations are inscribed in environment and development processes by asserting that certain actors are able to become economically and politically better off than others following changes in these processes (Bryant, 1998). Budds (2004) states that 'much political ecology work has focused on the politics to the neglect of the ecology, often to the extent that it has become the study of the politics of environmental change rather than a more balanced account of 'nature-society interactions' (ibid:418-419). This has led some to observe that political ecology studies do not include an explicit discussion of the ecology, considering the environment as 'simply a stage or arena in which struggles over resource access and control take place' (Zimmerer and Bassett, 2003:3). This has led to the predominance of political and economic explanations for environmental change, failing to consider the dynamics of nature in that process (Walker, 2005; Forsyth 2003; Zimmerer and Bassett, 2003). As noted by Walker (2005), such examinations 'become primarily questions of power, struggle and representation, while the connections of these struggles to the biophysical environment remain unexamined' (ibid:78).

In adopting a balanced political ecology approach to examine hydro-social interactions, and not merely considering political ecology as a subset of social science policy analysis or social science development studies, the ecology should be central in conceptualisation (Mollinga, 2010; Budds, 2009). In doing so, the ontological assumption that the material aspect of ecology is part of the explanation for socio-nature interactions is central. Such an approach acknowledges the complexity and emergent properties of socio-ecological systems (Trosper, 2005), explicitly considering nature's agency (e.g. physical properties) in environment change (Walker, 2005). Such an explicit acknowledgement moves beyond simply considering the environment as a 'stage or arena' in which conflicts over natural resources take place (Zimmerer and Bassett, 2003). Recognising the material aspect of the environment for socio-natural interactions does not in any way diminish from the recognition of the inherent political aspect of environment change and policy, rather, it complements a dual and balanced approach in understanding nature and human interactions.

Furthermore, based on positivist epistemological approach, authors have examined how science conceptualises nature as material, rational and universal, based on social values of western scientists, and the corresponding research cultures and institutions (Robbins, 2004; Castree, 2001; Blaikie, 1995; Escobar, 1996). Forsyth argues that much work on political ecology has failed to examine the validity of environmental science in explaining the natural environment (the ecology), particularly in terms of either questioning how it is shaped by socio-political factors, or considering the politics with which those explanations have been selected and accepted (Forsyth, 2003). The key argument is that environment science should be understood as being inherently politicised, rather than producers of purely technical and neutral assessments and knowledge (Demeritt, 2001).

Political ecology of water

Political ecological approaches have traditionally focused on environmental degradation including soil erosion and deforestation, along with changes in land use practices (Escobar, 2010, 2006; Robbins 2004; Forsyth, 2003[8]; Blaikie, 1995). Water resources have historically received relatively less attention and can be considered as an emerging field of enquiry in recent years (Linton, 2010; Mollinga, 2010; Budds, 2009). However, there is a growing body of thought that political ecology offers an appropriate conceptual framework to understand the inter-relationships between water resources within both the physical and socio-political domains, that of hydro-social. As noted by Swyngedouw (2009): 'political ecological perspectives on water suggest a close correlation between the transformations of, and in, the hydrological cycle at local, regional and global levels on the one hand; and relations of social, political, economic, and cultural power on the other' (ibid:56).

Existing political ecological studies on water have predominantly focused on the politics that underpin social relations of control over and access to water resources, advancing both political economy and policy-orientated analyses by focusing on the ways that modes of water management are politically-driven and controlled, both materially and discursively (Budds, 2009; Loftus, 2006; Swyngedouw 2004; Bakker 2003; Kaika, 2003; Mehta, 2001; Swyngedouw 1999). The mobilisation of water for different uses in different locations is a conflictual political process, and techno-social system for controlling water flows through reservoirs and canals manifests how social power is distributed and used in a given society (Swyngedouw 1999). Essentially, this work has conceptualised water management as hydro-social process within a political ecology framework, considering water as a resource that is embedded in social and hence political relations (Budds, 2009; Rudy, 2007; Crifasi, 2005; Debbane, 2007; Kaika, 2003; Swyngedouw, 1999). Swyngedouw (2004) states that 'water is a hybrid thing that captures and embodies processes that are simultaneously material, discursive and symbolic' (ibid:28). Swyngedouw's (2004) consideration of hybrid water builds on

[8] Forsyth (2003) does have water resources and watershed management in his index, although he refers to water mostly in the context of forests, soils and biodiversity, which are the main focus of his discussion.

Forsyth (2003) argument that a critical realist and poststructuralist political ecological approach can contribute to a more socially relevant environment science, for example, through hybrid science (Batterbury et al, 1997), that does not retreat from social theory but places biophysical ecology and environmental science at the centre of analysis (Forsyth, 2003).

Drawing on the idea that 'human-environment interactions constitute a dynamic and dialectical process through which society and nature continue to make and remake each other' (Worster 1985:22), this notion has been further developed in considering the 'waterscape' as constituted by material and discursive socio-nature processes, rather than interactions between people and nature as distinct entities (Perreault, 2006; Bakker, 2003). Social and political relations are manifested by water laws, policy discourses and resulting water management strategies that have led to hydraulic infrastructure construction, directly altering river basin hydrology; yet they (socio-political relations) themselves are also influenced by water flows and hydrology, for instance, in terms of physical water availability in a river basin (Harvey, 1996; Norgaard, 1994; Worster, 1985). Hydraulic environments are socio-physical constructions that are actively and historically produced, both in terms of social content and physical-environmental qualities (Harvey, 1996). Such an approach encompassing the inseparability of the social and the physical in the production of what is termed particular hydro-social configurations (Swyngedouw, 2009; Budds, 2009; Bakker 2003).

Swyngedouw (2004) defines a hydro-social approach, within a broad political ecology framework, as one that 'envisions the circulation of water as a combined physical and social process, as a hybridised socio-natural flow that fuses together nature and society in inseparable manners (ibid:110). In other words, hydraulic environments are socio-physical constructions that are actively and historically produced, both in terms of social content and physical-environmental qualities (ibid). The inseparability of the physical and social within water management is also stressed by Molle (2003), who states that 'the particular blend of water resource management responses - selected by a society at a particular point in time - to address water-resources problems must be understood within a framework that spans not only hydrological, physical or economic constraints, but also the distribution of agency and power among actors, and their respective interests and strategies' (ibid:28). The recognition of the inseparability and inter-connectedness of social and physical does not in any way subtract from the recognition of the inherently political nature of water management, as identified by (Mollinga, 2005; Bolding and Mollinga, 2004; Mosse, 2003; Mehta, 2001). Swyngedouw (2004) stresses the need to understand social power relations (economic, political or cultural) through which hydro-social transformations take place. This includes the analysis of the discourses and arguments by actors (including the government) that are employed to defend or legitimise particular water management strategies.

2.3 Climate change and its impacts on water resources

This begins by introducing climate change, drawing heavily on recent IPCC reports (IPCC, 2008; 2007). It then details historic patterns in temperature and precipitation in India, leading onto examining climate change projections for India and AP state. Climate change impacts on water resources are discussed at a global level, and then specially for India and AP state.

2.3.1 Climate change

The IPCC (2007) defines climate change as 'a change in the state of the climate that can be identified by changes in the mean and/or variability of its properties, and that that persists for an extended period, typically decades or longer' (ibid:30). This refers to any change in climate over time, whether due to natural variability or the result of anthropogenic activity. This differs from the definition by the UNFCCC, which defines climate change as 'a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (ibid:30). Climate variability refers to variations in the mean state of the climate on spatial and temporal scales beyond that of individual weather events. It may be due to natural internal processes within the climate system, or to variations in natural or anthropogenic external forcing (ibid). The definition offered by the UNFCCC is narrower in scope focusing on anthropogenic human activity as the cause of climate change; in contrast to the broader definition of the IPCC that frames climate change in terms of longer term trends in mean climate variables of period of decades and longer, with (natural) climate variability as variation on climate system over short timescales (months, years and decades) (Pielke, 2005). A climate model is a numerical representation of a climate system[9] based on the physical, chemical and biological properties of its components, their interactions and feedback[10] processes. Climate models or Coupled Atmosphere-Ocean General Circulation Models (AOGCMs or GCMs) provide a representation of the climate system that is near the most comprehensive end of the spectrum currently available (IPCC, 2008). Climate models are applied as a research tool simulate the climate[11], over varying times scales including decades, years, intra-annual including monthly and seasonal times scales (ibid). A climate change projection of the response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models (IPCC, 2008:224). A climate scenario is a plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate

[9] The climate system is the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere, and the interactions between them (IPCC, 2007).

[10] An interaction mechanism between processes in the climate system is called a climate feedback when the result of an initial process triggers changes in a second process that in turn influences the initial one. A positive feedback intensifies the original process, and a negative feedback reduces it (IPCC, 2008:224).

[11] Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organisation (IPCC, 2008:223).

projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as about the observed current climate. A climate change scenario is the difference between a climate scenario and the current climate (IPCC, 2008:224). The IPCC's Special Report on Emissions Scenarios[12] (SRES) details projections for future greenhouse gas emissions (IPCC, 2007), developed by Nakicenovic and Swart (2000). The starting point for each projection is a storyline, describing how world population, economies, political structure and lifestyles may develop in future decades (Appendix 1). However, it must be stressed that the IPCC acknowledge that there is a low level of consensus (e.g. high uncertainty) amongst climate models regarding the sign of the change, especially in precipitation but also with temperature rise, in different regions of the globe for future decades (IPCC, 2007).

2.3.1.1 Climate change in India

Historical climate trends in India

Temperature

The annual mean temperature over India has shown a warming trend of 0.5°C per 100 years during the period 1901–2007 (Kothawale et al, 2010). Accelerated warming has been observed in the recent period 1971–2007, mainly due to intense warming from 1998–2007. This warming is mainly contributed by the winter and post-monsoon seasons, which have increased by 0.80°C and 0.82°C in the last hundred years respectively (ibid). The pre-monsoon and monsoon temperatures also indicate a warming trend. Mean temperatures have increased by on average 0.2°C per decade for the period 1971–2007, with a steeper increase in minimum temperature than maximum temperature. In the most recent decade, maximum temperature was significantly higher compared to the long-term (1901–2007) mean (ibid).

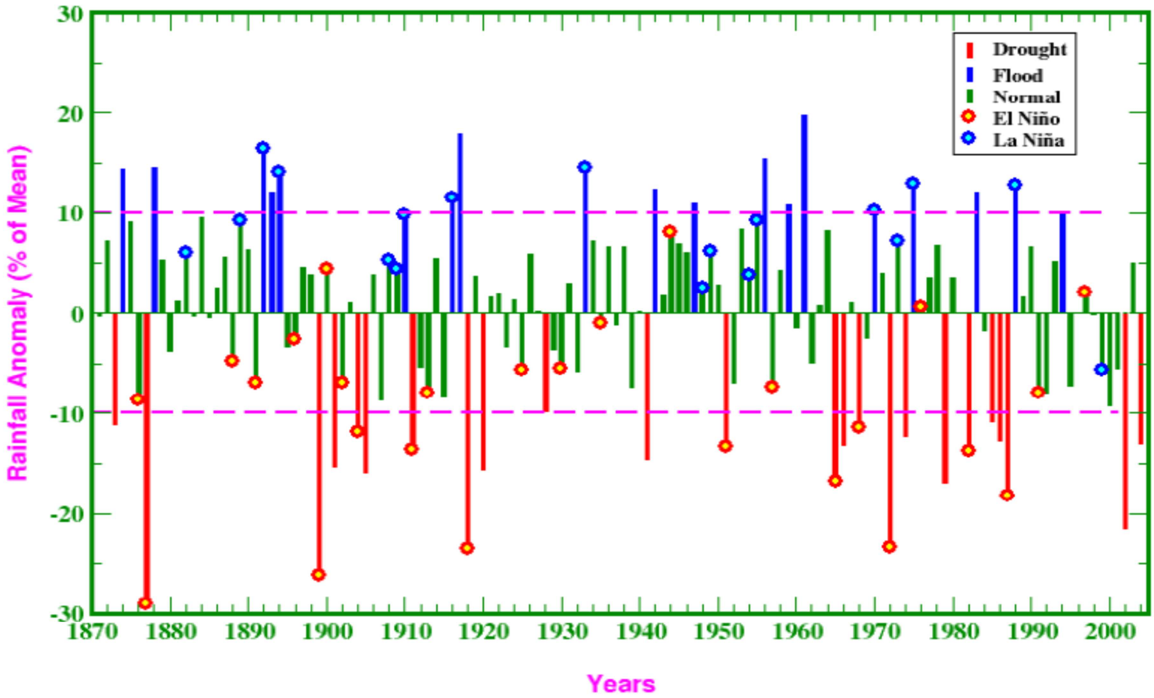
Precipitation

A study of trends of precipitation patterns reveals that while there is no overall trend in precipitation in India, there are statistically significant trends at the regional level, with some areas showing an increase in precipitation while other regions exhibiting a drying trend (Guhathakurta and Rajeevan, 2008). The patterns differ for different months and for the monsoon season, with predominantly dry or wet monsoons. Such is a manifestation of climate variability at the decadal time scale (ibid). In a comprehensive study of historic precipitation intensity from 1951-2000, Goswami et al (2006) finds a marked increase in heavy (above 100mm a day) and very heavy (150mm a day) extreme precipitation events. In spite of year to year variability, there are significant rising trends in the frequency and magnitude of extreme rainfall events and a significant

[12] An emissions scenario is a plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g., greenhouse gases, aerosols), based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change) and their key relationships (IPCC, 2008:234).

decreasing trend in the frequency of moderate events over central India during the monsoon seasons during the period of analysis (ibid). The findings of Goswami et al (2006) were confirmed by Krishnamurty et al (2009) who found a similar precipitation intensity pattern during the period 1951-2003; and documented by the MEF's INCCA report which found an increasing trend in the frequency and intensity of extreme events during the period 1971 to 2000 (INCCA, 2010). Summer monsoon precipitation[13] series from 1871 to 2001 shows mean precipitation of 848mm, with a standard deviation of 83mm, a 9.8% mean variation (Figure 2.1). Kripalani et al (2003) analysed the 130 years of summer monsoon precipitation variability from 1897-2001, and concluded that there is no clear evidence to suggest that the strength and variability of neither summer monsoon precipitation nor the epochal changes are affected by global warming and anthropogenic climate change.

Figure 2.1: Variations in summer monsoon precipitation, 1871-2001 (Kripalani et al, 2003)



Webster et al (1998) finds that some of the most pronounced year-to-year variability in climate patterns and extreme weather events can been linked to El Niño weather events. It is claimed that half of the severe failures of the Indian summer monsoon since 1871 have occurred in El Niño years (Figure 2.1). Furthermore, the Indian monsoon has a direct link with the Southern Oscillation Index[14] (SOI) (ibid), with weak monsoons associated with a large negative SOI and occurrence of El Niño. Whereas strong monsoons have been linked to large positive SOIs and absence of El Niño events (ibid).

[13] The summer monsoon period is from June to September.

[14] The Southern Oscillation Index (SOI) provides an indication of the development and intensity of El Niño or La Niña events in the Pacific Ocean. The SOI is calculated using the pressure differences between Tahiti and Darwin in the Pacific Ocean. Negative values of the SOI greater than −8 often indicate El Niño episodes. These negative values are usually accompanied by sustained warming of the central and eastern tropical Pacific Ocean, and a decrease in the strength of the Pacific Trade Winds. Positive values of the SOI greater than +8 are typical of a La Niña episode. They are associated with stronger Pacific trade winds and cooler ocean waters in central and eastern tropical Pacific Ocean regions (Trenberth, 1975).

Climate change projections for India

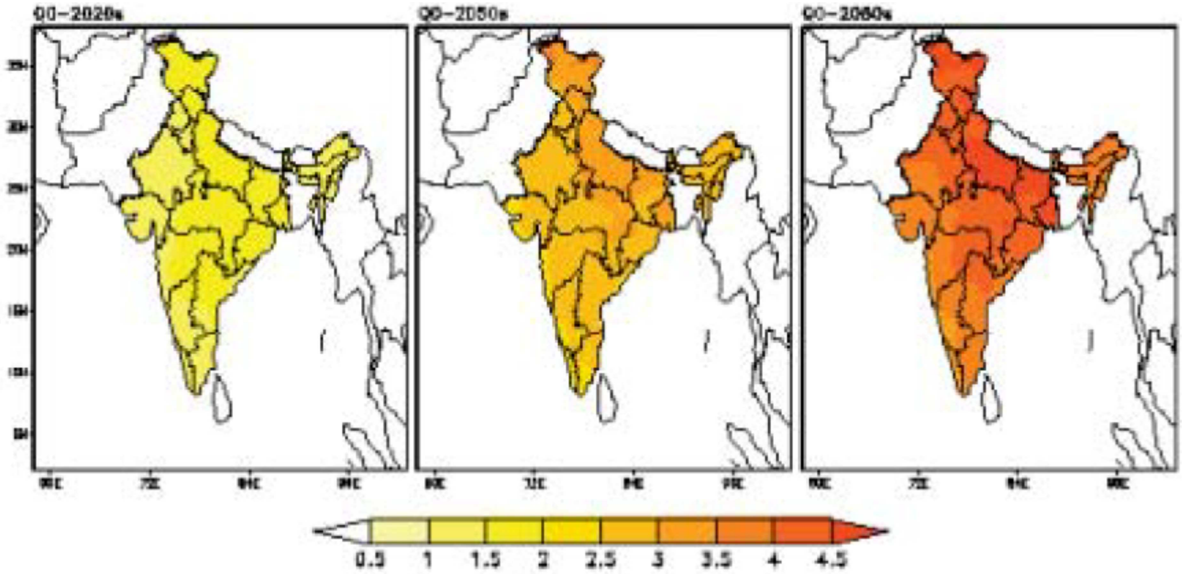
From the onset, it must be stressed that the IPCC acknowledge that there is a low level of consensus (e.g. high uncertainty) amongst climate models regarding the sign of the change in precipitation over large parts of Asia, as well as other regions of the globe (IPCC, 2007). Numerous studies on climate change projections in India confirm the high uncertainty of climate models for both precipitation and temperature change in future decades (Kumar et al, 2011; Rajendran and Kitoch, 2008; Kripalani et al, 2003; Lal et al, 2001, 2000). The most recent overview of climate change projections in India is provided in the second NATCOM[15] report published by the Ministry of Environment and Forests (GoI, 2012a), drawing on earlier work presented in the Indian Network for Climate Change Assessment report (GoI, 2010a). The second NATCOM report details the latest modelling simulations, primarily conducted by IITM. Climate change scenarios were analysed using the PRECIS model[16], with model simulation carried out for the A1B emissions scenario for the period 1961-1990 (baseline simulation), for three time periods: the 2020s (2011-2040); the 2050s (2041-2070); and the 2080s (2071-2098)[17] (GoI, 2012a).

Temperature

PRECIS model simulation indicates that there will be a gradual increase in mean annual air temperature over India for the period 2020 to 2080, with a temperature rise of 3.5°C to 4.3°C by 2098 (Figure 2.2). For the 2030s, temperature is projected to increase by 1.7°C to 2°C (ibid). Spatial variation of temperature rise across India is significant, with north and central regions showing a greater increase in temperature relative to other regions of the country.

[15] The second NATCOM report (2012) represents India's national communication in fulfilments of its commitment under the United Nations Framework Convention on Climate Change.
[16] PRECIS – Providing Regional Climate for Impact Studies – is an atmospheric and land surface regional model developed by the Hadley Centre in the UK. It has a 50km x 50km horizontal resolution over South Asia, run by the Indian Institute of Tropical Meteorology
[17] The model simulations were carried out for three Quantifying Uncertainties in Model Projections for A1B scenario for the period 1961-1990 (baseline simulation) and for three time periods: 2020s (2011-2040), 2050s (2041-2070) and 2080s (2071-2098). Three PRECIS runs: Q0, Q1 and Q14 were carried out for the period 1961-2098 and were utilised to generate an ensemble of future climate change scenarios for the Indian region (GoI, 2012a).

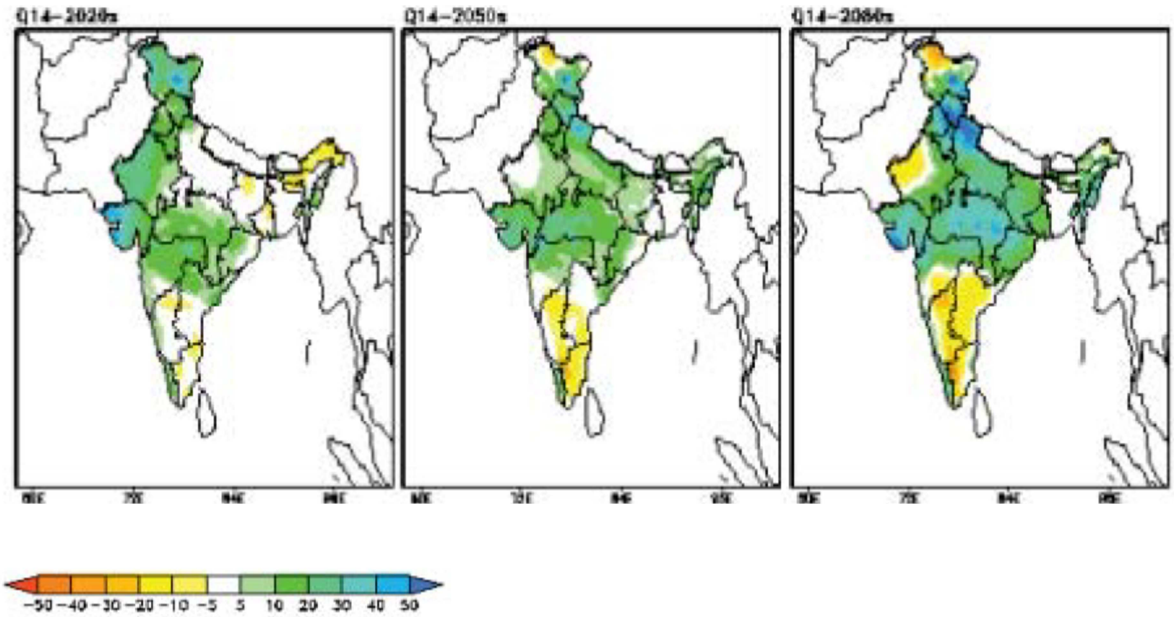
Figure 2.2: Simulated change in annual mean air temperature for the period 2020s, 2050s and 2080s with respect to the baseline (1961-1980) using the PRECIS model (GoI, 2012a).



Precipitation

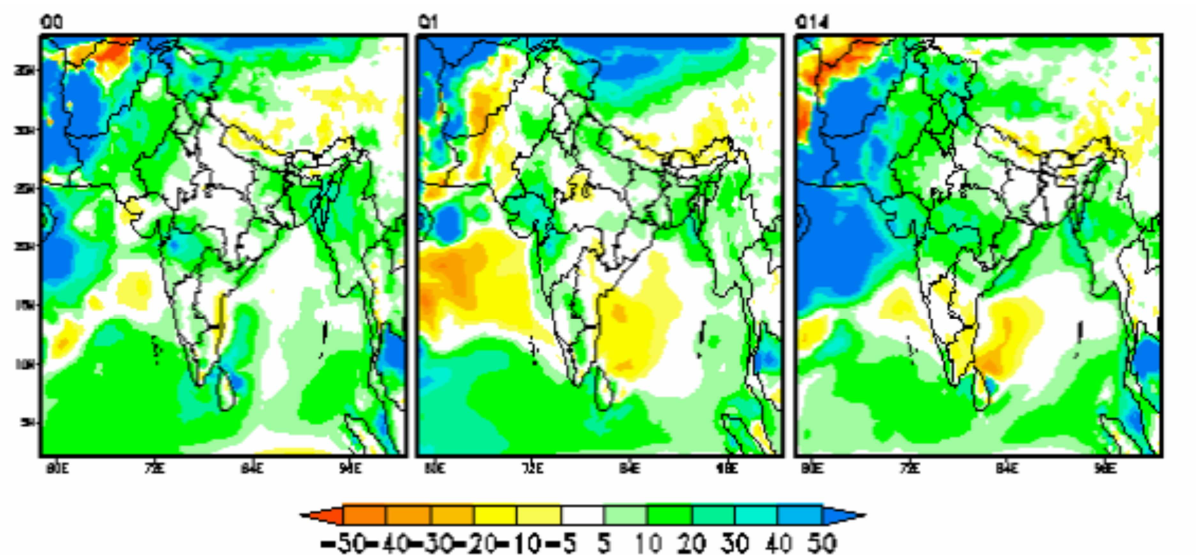
PRECIS model simulations presented in the second NATCOM report indicate that annual precipitation levels show a large degree of spatial variability across the country. Although simulations project a significant increase in precipitation in northern and central regions, the southern peninsular shows a decrease in precipitation (Figure 2.3). However, at the country level, simulations indicate a 16%, 15% and 9% increase in annual precipitation for the corresponding 2020, 2050 and 2080 time periods, respectively (GoI, 2012a). Such is in line with earlier simulation conducted by Lal et al (2001) using the Hadley Centre Regional Model (Had RM2), who found an increase of 7-10 % in mean annual precipitation by 2080. However, the NATCOM report makes an explicit acknowledge of the high uncertainty of climate model projections (GoI, 2012a:79).

Figure 2.3: Simulated percentage change in mean precipitation in 2020s, 2050s and 2080s with respect to the baseline (1961-1990) (GoI, 2012a)



Intra-annual precipitation variation is projected to increase in all seasons throughout India (GoI, 2012a; Kumar et al, 2011; IPCC 2007; Lal et al, 2001). Precipitation levels are projected to decrease in the winter months (November to January) by 5-25% by 2080 (from the baseline of 1961-1990); and to increase in the summer monsoon months (June to September) by 10-15% by 2080 (Lal et al, 2001). This is confirmed by more recent model simulations, predicting that by 2030, summer monsoon precipitation will increase by 3-7% from 1961-1990 levels (GoI, 2010a). Recent PRECIS modelling suggests significant spatial variation in increasing summer monsoon rainfall across India, with a general increase in precipitation levels from June to September (Figure 2.4). Furthermore, the date of summer monsoon precipitation onset in early July could become more variable in the future (Lal et al, 2001). Approximately 70% of the annual precipitation in India is delivered during the summer monsoon months (June to September), crucial to agricultural practices (Kumar, 2006).

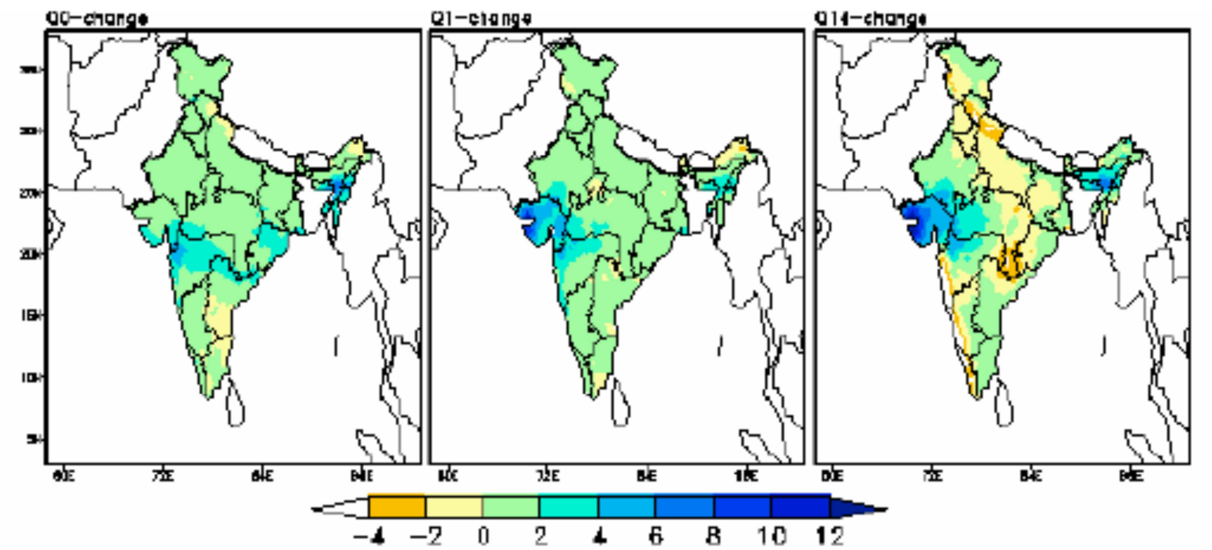
Figure 2.4: percentage change in summer monsoon rainfall (June-September) by 2030 with three PRECIS model runs from 1970 baseline (GoI, 2012a)



Precipitation intensity

The second NATCOM report concludes it is likely that the incidence and intensity of extreme weather events, particularly periods of intensive precipitation events and extreme precipitation within one day[18] along with extended periods of lower precipitation, below the seasonal mean, will increase in future decades (GoI, 2012a, a; Kumar et al, 2011; Krishnamurthy et al, 2009; Rajeevan et al, 2008; Rajendran and Kitoh, 2008), especially during the summer monsoon season (Pattanaik and Rajeevan, 2010; Sen Roy, 2009) . These recent prediction is in line with earlier predictions by Lal et al (2001) and the IPCC (2007) (Figure 2.5).

Figure 2.5: Change in intensity of high precipitation days by 2030 from 1970 baseline (GoI, 2012a)



[18] Above 8cm of precipitation within a single day (24 hours) is classified as an extreme precipitation day (Kumar et al, 2011).

Table 2.1: Summary of key climate change studies examining historic and future projected changes in precipitation and temperature in India

Study focus	Author	Key findings
Precipitation – historic		
Incidence of heavy precipitation events, 1961-2007	GoI, 2010a	Number of heavy precipitation events (exceeding 99th percentile) are increasing almost over the entire landmass of India. Frequency and intensity of extreme events defined as 1-day maximum precipitation shows increasing trend everywhere except some northern parts of India.
Historical analysis of extreme precipitation events form 1951-2003	Krishnamurty, 2009	Increase in incidence of extreme precipitation events during period of study
Analysis of extreme precipitation events during summer monsoon from 1901-2005	Rajeevan et al 2008	Increase in extreme precipitation events between 1901 and 2005, with the trend much stronger after 1950
Analysis of extreme hourly precipitation events in India from 1980 to 2005	Sen Roy, 2009	Increased incidence of hourly extreme precipitation events, particularly in high elevation areas of the Himalaya
Historical precipitation intensity 1951-2000	Goswami et al, 2006	Increase in heavy (above 100mm/day) and very heavy (150mm/day) precipitation events during period of study.
Inter/intra season precipitation patterns over India in last century	Goswami et al, 2006	Increased levels of summer monsoon precipitation by 10-12% over northern AP.
Indian summer monsoon precipitation variability, from 1871–2001	Kripalani et al, 2003	Summer monsoon mean precipitation variability of 9.8% for 130 years, 1871-2001.
Precipitation – future		
Simulation of mean annual precipitation using PRECIS model for periods 2020s (2011-2040); the 2050s (2041-2070); and the 2080s (2071-2098); using 1961-1990 as baseline	GoI, 2010a	16%, 15% and 9% increase in annual precipitation for the corresponding 2020, 2050 and 2080 time periods respectively. summer monsoon precipitation increase from 3-7% from 1961-1990 levels. Increase inter-annual precipitation variation, with winter months receiving less precipitation (Nov-Feb) and summer months receiving more (June-Sept).
Long term (decadal) changes in mean annual precipitation levels. Hadley Centre Regional Model (Had RM2), 2000-2080	Lal et al, 2001	7-10 % increase in annual mean precipitation projected by 2080. Winters projected to become drier, decline between 5-25% in average winter precipitation Summer monsoon precipitation projected to become wetter, estimated increase of 10-15% of precipitation by 2080. Decline in winter precipitation may lead to droughts during the dry summer months, especially before monsoon onset. date of onset of summer monsoon over India could become more variable
Summer monsoon rainfall variation and precipitation extreme events for period 2071-2100 from baseline 1961-1990 utilising PRECIS model under A2 SRES scenario	Kumar et al, 2011	Modest (mean 10%) increase in seasonal mean summer monsoon rainfall with increase in frequency and intensity of extreme precipitation events. Monsoon precipitation (onset and intensity) will become increasingly more difficult to predict.
Summer monsoon variations with future climate change projections simulated by a super high resolution global model	Rajendran and Kitoch, 2008	Summer monsoon more variable with increase intensity and frequency of extreme rainfall events
Simulation of Indian summer monsoon precipitation and inter-seasonal variability, NCAR model to 2050	Lal et al, 2000	More intense precipitation spells are expected in future Grater variability with regards to the onset date of the summer monsoon.

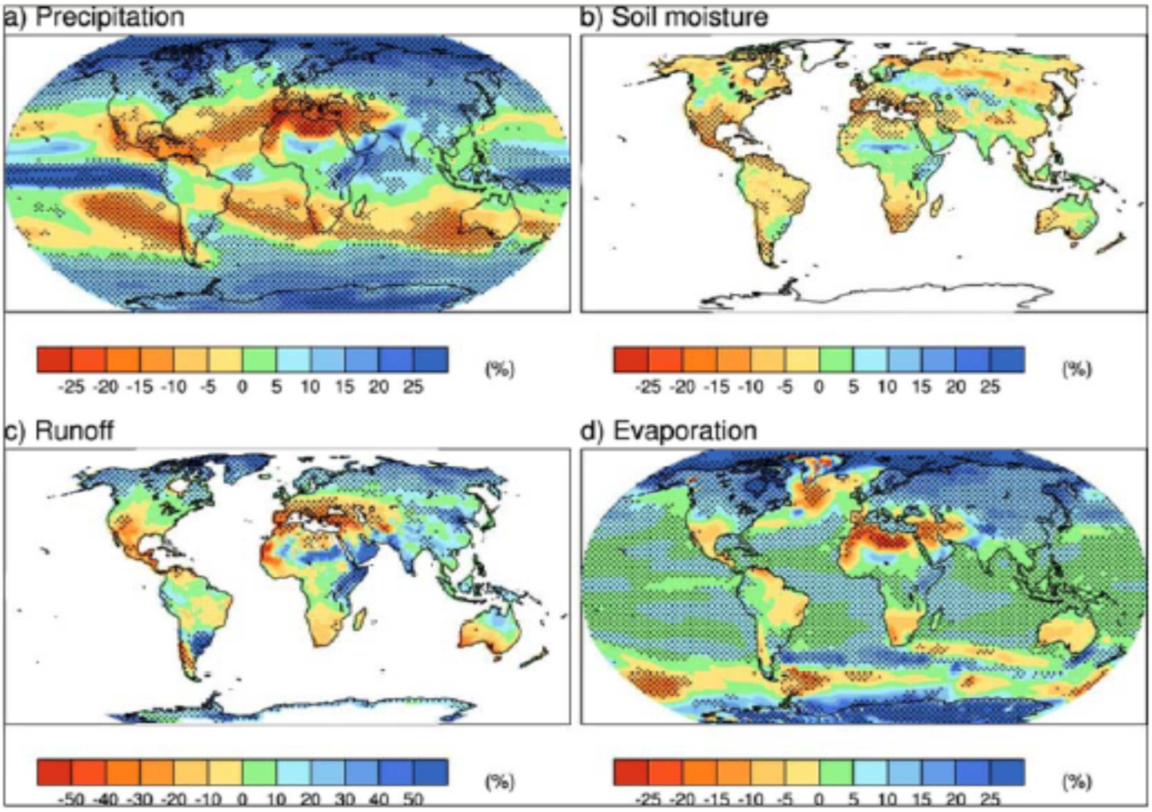
Temperature – historic		
Historical analysis of warming trends from 1901 to 2010 across India.	Kothawale et al, 2010	Indian annual mean air temperature increased of 0.51oC in the period 1901 to 2010. warming is mainly contributed by the winter and post-monsoon seasons, which have increased by 0.80°C and 0.82°C in the last hundred years respectively. The pre-monsoon and monsoon temperatures also indicate a warming trend.
Air temperature over India over last 100 years	Pant and Kumar, 1997	Overall increase of 0.57°C throughout India
Mean atmospheric surface temperature over India	Dash et al., 2007	Overall increase 1 to 1.1 °C
Temperature – future		
Simulation mean annual air temperature using PRECIS model for periods 2020s (2011-2040); the 2050s (2041-2070); and the 2080s (2071-2098); using 1961-1990 as baseline	GoI, 2010a	Annual mean surface air temperature rise from 1.7°C to 2°C by 2040. Gradual mean surface air temperature rise over all of India, reaching3.5°C to 4.3°C by 2098.
Hadley Centre Regional Model (Had RM2), 2000-2080	Lal et al, 2001	Temperature increase of 3.5-5.5 °C by 2080, for the B1 and A2 scenario Projected surface warming more pronounced during the winter than the summer season.
El Niño		
Correlation between annual variability & El Niño events, from 1871-2001.	Webster et al, 1998	Roughly half severe failures in summer monsoon have occurred in El Niño years.

2.3.2 Climate change impacts on water resources

2.3.2.1 Global impacts of climate change on water resources

The IPCC technical report on water and climate finds that globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits (IPCC, 2008). By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress (ibid). The IPCC predicts increasing precipitation variability and seasonal runoff shifts in water supply at a global level (Figure 2.6). However, the IPCC acknowledge that there still exits a large degree of uncertainty with regards to the exact nature and extent of impacts of climate change on water resources owing to climate model uncertainty (IPCC, 2007, 2008). Furthermore, it is important to note that climatic phenomenon such as the El Niño-Southern Oscillation, the North Atlantic Oscillation, and the Pacific North American Oscillation also play an important role in global climate patterns (IPCC, 2007; Webster et al, 1998).

Figure 2.6: Fifteen global climate model mean averages in: a) precipitation (%); b) soil moisture context (%); c) runoff (%); and d) evaporation (%). Changes are annual means for the scenario SRES A1B for the period 2080-2099 relative to 1980-1999 (IPCC, 2008)



Global estimates of the number of people living in areas of water stress differ significantly among studies (Alcamo et al, 2007; Arnell et al, 2004; Vörösmarty et al., 2000). Arnell et al (2004) estimates that the numbers of people living in water stressed basins by 2050 will be 4.4 to 5.7 and 2.8 to 4.0 billion respectively, under A2 and B2 emission scenarios; whereas Alacamo et al (2007) estimates the number to be 6.4 to 6.9 and 4.9-5.2 under A2 and B2 scenario respectively. Climate change and variability is one of a number of factors that will influence future water availability and stress. Other important factors include demographic change, economic development, socio-political and technological changes. Such factors have an important influence on water availability and stress, under most time horizons and regions (IPCC, 2008).

The IPCC (2008) concludes that at a global level increased precipitation intensity and variability, at an inter and intra annual level, is projected to increase the risks of flooding and droughts in many areas in the future. Climate model simulations for the 21st century are consistent in projecting precipitation increases in high latitudes and parts of the tropics, and decreases in some subtropical and lower mid-latitude regions (ibid). With regards to runoff, the IPCC finds that by the middle of the 21st century, annual average river runoff and water availability are projected to increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics. The report also finds that it is very likely that heavy precipitation events will become more frequent, particularly in tropical and high latitude areas that experience increases in mean precipitation (ibid).

Contextualising climate change hydrological impacts with water demand drivers

A number of global studies have compared long-term changes in precipitation levels under climate change projections with water demand drivers[19] (e.g. meeting population growth, economic development and urbanisation) for the hydrological balance. Vorosmarty et al (2000) compared the global water demands of a growing population and economic development to that of a changing climate up to 2025. They found that population and economic development over the next 25 years has a far greater influence on the supply-demand balance, when compared against the projected impacts of global mean climate change to that of water demand drivers (ibid). Arnell et al (2004) finds that differences in the population projections detailed in the four IPCC Special Report on Emission Scenarios (SRES) would have a greater impact on the number of people living in water-stressed river basins, when compared against differences in the climate impact scenarios. Alcamo et al (2007) modelled the global effects of water use in relation to water stress up to 2050, as well as population growth and climate change. He examined water use in the context of income, water efficiency use, water productivity and industrial production. He concluded that the growth of the domestic sector (urbanisation), stimulated by income growth, was the most dominant factor in increasing water use and stress in future decades (ibid). Grafton et al (2012) examined the threat of climate change and trade-offs between extractions and flows in the Colorado, Murray, Orange and Yellow River basins. In all of the basins, although climate change has aggravated impacts on river systems, current high levels of water extractions remain the principal contributor to reduced system flows. Conway et al (1996) examined the impacts on future water availability in Egypt due to driving forces operating to three levels at the Nile basin: global (climate change), regional (land use) change, and river basin (water resource management). Through a modelling approach, climate change was found to have relatively less impact on future water resource availability by 2050, when compared against regional and river basin impacts.

Within the context of water demand drivers in India, Shah et al (2007) provides a detailed examination of the main water demand drivers represented as scenarios for the years 2025 and 2050. Shah et al, (2007) finds that rising population and economic development with associated changes in lifestyle and diet of the middle class in India will lead to a substantial increase in water demands, especially in large urban centres. They find that scenario projections indicate a 22% and 32% increase in water demand by 2025 and 2050 respectively across India (ibid). It is estimated that India will have to double its 2010 food production levels by 2050 to feed its growing population in order to remain food self-sufficient (ibid). Per capita water resources are projected to decline to 1140m^3 by the year 2050 in meeting future water demands, without considering climate change impacts (Gupta and Deshpande, 2004) (Section 4.3 for overview of India's water resources).

[19] The Millennium Ecosystem Assessment terms these water demand drivers as 'non-climate drivers' (MEA, 2005:74).

2.3.2.2 Climate change impacts on water resources in India

The impact of climate change on the water resources in South Asia is predicted to be significant (IPCC, 2008). However, it must be stressed from the onset that there still exists a large degree of uncertainty with regards to the downscaled climate model data used to input into the hydrological models to predict future changes in water resources (e.g. surface runoff) under climate change scenarios for India (GoI, 2012a; Gosain et al, 2011; IPCC, 2008).

Recent research conducted by the IITD (Gosain et al, 2011) utilising the latest GCMs represents the most up-to-date and authoritative assessment of climate change impacts on water resources in India. The results have been adopted and validated by the recent second NATCOM report (GoI, 2012a). Numerous studies have examined the rate of retreat of Himalayan glaciers based on historical data and observations (Bali et al, 2011; Dyurgerov, 2010; Immerzee et al, 2009; Singh and Bengtsson, 2003; Singh et al, 1995). Although glacial retreat is observed in some Himalayan glaciers including the large glaciers of Gangotri (Kumar et al, 2008) and Satopanth (Nainwal et al, 2008); other glaciers show no historic signs of retreat and loss of ice mass (GoI, 2010a). However, a general trend of glacial retreat is observed in the western Himalayan region (ibid). The recent Indian Network on Climate Change Assessment report (2010) tentative links the observed rise in mean surface air temperature to the reduction in glacier mass balance in the Himalaya (GoI, 2010a:119). Limited historic data and lack of comprehensive field measurements restricts definitive findings and conclusions. The Indian National Institute of Himalayan Glaciology established in 2009 by the MEF is currently pioneering studies on this issue. Increased Himalayan glacial melting is predicted to increase the risk of seasonal flooding in the immediate downstream areas of the Ganges river basin in the short to medium term (Eriksson et al, 2009; IPCC, 2008). However, in future decades the reduction in glacial and snow mass and hence the volume of melt-water is projected to reduce future downstream water flows from the Himalaya (Hannah et al, 2005; Singh and Bengtsson, 2003; Singh and Jain, 2003) with implications for livelihoods (Eriksson et al, 2009), particularly in the summer months (Barnett et al, 2005) with glacial melt contributing an estimated 10-20% of summer flows of major rivers in the Ganges basin at present (Singh and Bengtsson, 2004).

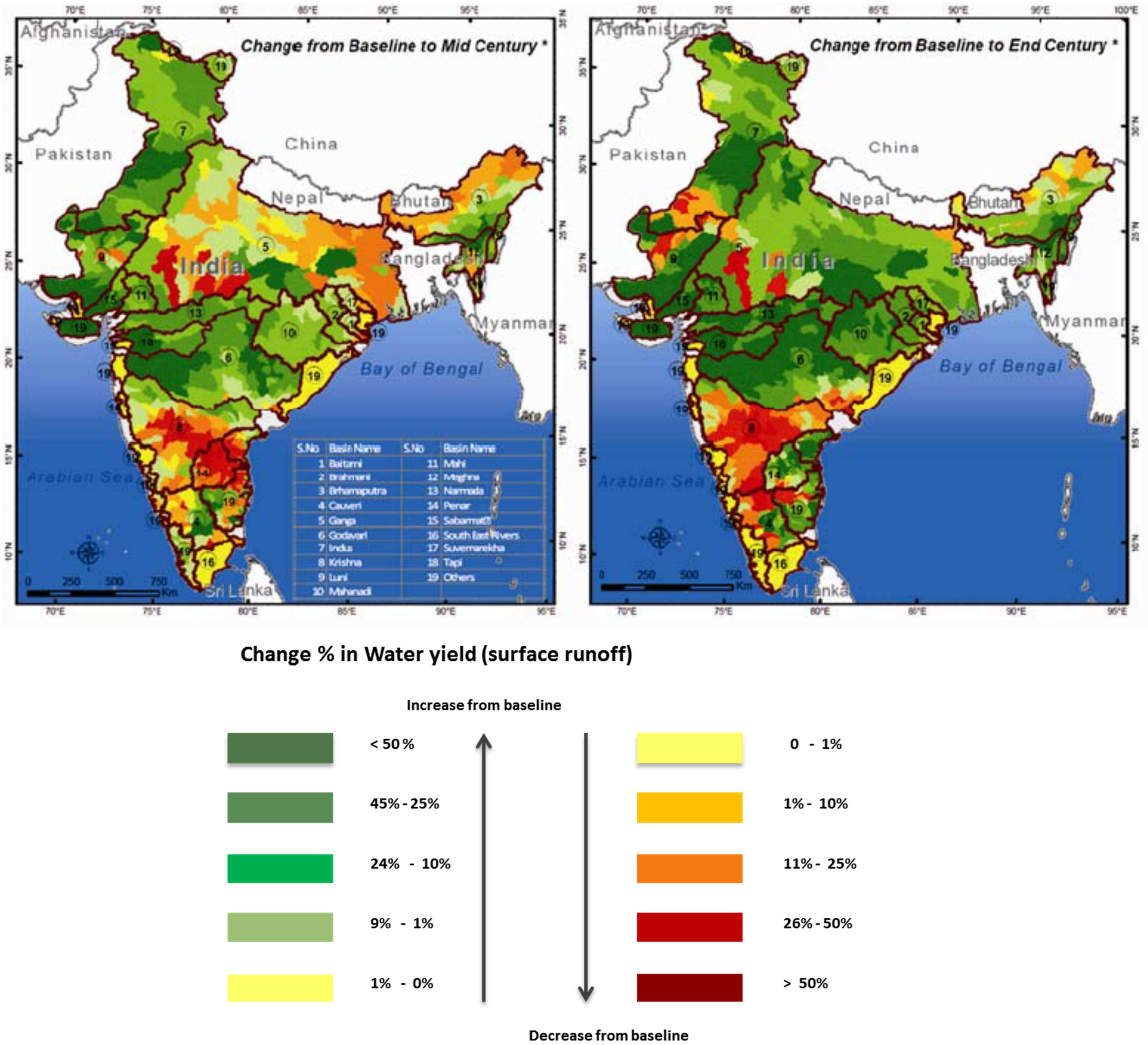
Gosain et al (2006) quantified the impact of projected changes in precipitation under climate change scenarios on runoff and water resources for twelve major river basins in India, using HadRM2 and SWAT[20] models. In the first study of its kind, results indicates that surface runoff under climate change would vary considerably in different river basins across India, although a general trend of a reduction in the quantity of runoff was observed (ibid). Although some basins were projected to experience an increase in the level of precipitation in future decades under climate change, the levels of runoff decreased owing to higher levels of

[20]The Soil and Water Assessment Tool (SWAT) model is a distributed parameter and continuous time simulation model. The SWAT model has been developed to predict the response to natural inputs as well as to man-made interventions on water and sediment yields in un-gauged catchments. The model: a) is physically based; b) uses readily available inputs; c) is computationally efficient to operate and; d) is 'continuous time' and capable of simulating long periods for computing the effects of management changes. The major advantage of the SWAT model is that unlike the other conventional conceptual simulation models, it does not require much calibration and therefore can be used on un-gauged watersheds (which are the usual situation) (Gosain et al, 2011).

evapotranspiration with mean air temperature rises (ibid). Overall, the study concluded that the levels of runoff would decrease by 2060 throughout the majority of river basins in India, leading to future water scarcity with the likelihood of increase incidence of droughts. Such is confirmed by the IPCC report which concluded that climate change is likely to further exacerbate future water scarcity in India (IPCC, 2008). Increased likelihood of flooding in the summer monsoon months is predicted owing to the projected increase in precipitation levels and extreme rainfall events from June to October (Kumar et al, 2011; Gosain et al, 2006). Gosain et al (2011) utilised the latest PRECIS Regional Climate Model outputs for the baseline (1961-1990) for the mid-century (2021-2050) and end of century (2071-2100) under A1B IPCC SRES scenario[21]. PRECIS outputs were analysed with the SWAT model for each of the major river basins in India, including water yield (surface runoff as a function of river basin terrain, land use, soil type and precipitation), sediment yield and actual evapotranspiration. Results indicate that variations in water runoff show a large degree of spatial variation across India, both between and within river basins for the mid and end of century projections (Figure 2.7). A general trend is observed of increasing annual runoff in central and northern river basins, with southern basins experiencing a reduction in runoff.

[21] For the Q14 QUMP ensemble.

Figure 2.7: Percentage change in annual water yield (surface runoff) at the river basin level for mid-century (2021-2050) and end of century (2071-2100), from the baseline (1961-1990)[22] (adapted from Gosain et al, 2011)



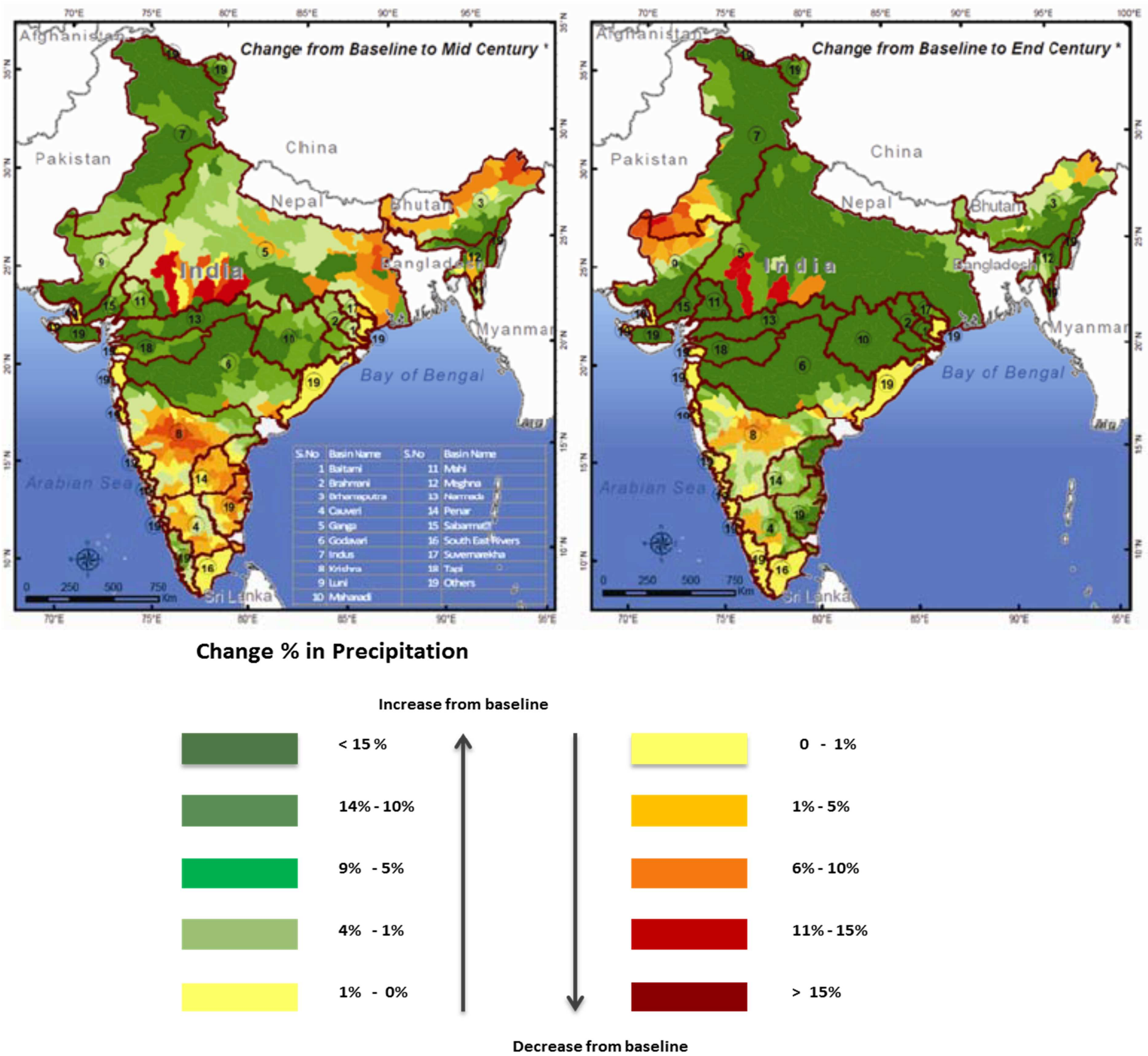
Projections for India at the river basin level suggest a general trend[23] of increasing annual precipitation in northern and central basins, and a reduction in southern basins by the mid and end of century (Figure 2.8). The corresponding increase in surface runoff in northern and central basins and reduction in southern basins is attributed to annual precipitation projections (Gosain et al, 2011)[24]. Intra-annual and intra-seasonal precipitation variability is projected to increase with climate change, with wetter summer monsoon and drier winter months, along with more intense precipitation periods within seasons (Kumar et al, 2011; GoI, 2010a; Lal et al, 2001). This will have a significant effect on hydrology at the intra and seasonal annual scale throughout India (GoI, 2010a).

[22] The percentage change in annual water yield (surface runoff) displayed in the legend are based the percentage change from baseline using the equation: 100 x (MC-BL)/BL (Gosain et al, 2011).

[23] There are exceptions to the observed general trend across and within individual river basins, with a degree of spatial variation. However, for the point of general observations at the river basin and country level, a fairly strong relationship between precipitation projections and surface runoff can be considered.

[24] High levels of evapotranspiration with increasing temperatures result in some areas of basins (sub-basins) having a reduced surface water runoff with projected increase in mid and end of century precipitation.

Figure 2.8: Percentage change in annual precipitation across river basins by mid and end of century[25] (adapted from Gosain et al, 2011)

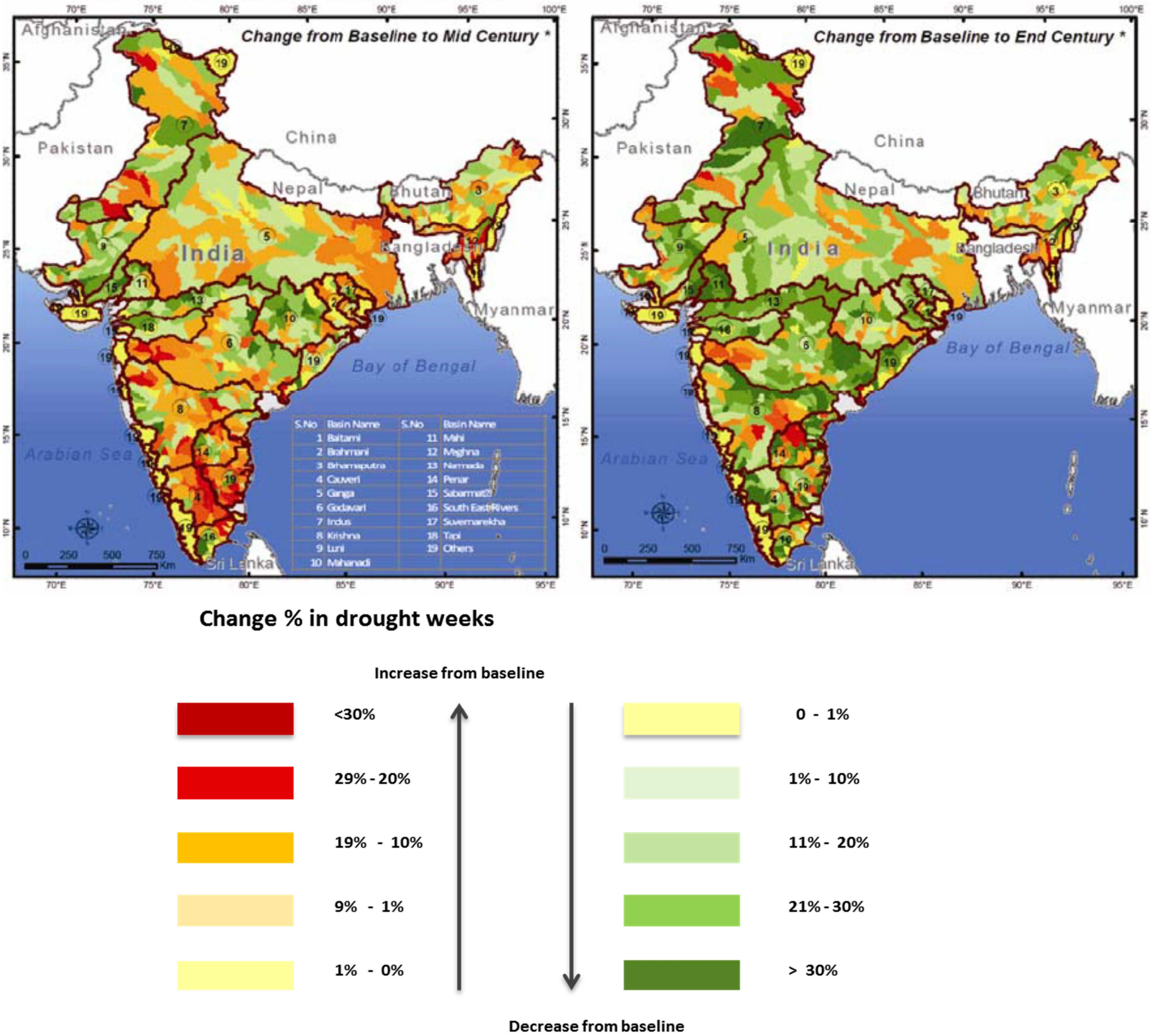


Drought analysis from the SWAT model projects an increase in drought conditions throughout many river basins, linked to projected future changes in precipitation and evapotranspiration (as a function of increasing temperature) (Figure 2.9)[26]. A rise in the number of drought weeks (from the baseline 1961-1990) is witnessed both within many river basins and across India as a whole, although there is a large degree of spatial variation across the country, with some basins and sub-basins projected to have a decrease in drought weeks (ibid).

[25] The percentage change in annual precipitation displayed in the legend are based the percentage change from baseline using the equation: 100 x (MC-BL)/BL (Gosain et al, 2011).

[26] Gosain et al (2011) utilises the Palmer Drought Severity Index (PDSI) incorporating data on rainfall, land use and soil properties. PDSI value below 0.0 indicates the beginning of drought situation and a value below –3.0 as severe drought condition. The SWAT model utilised the soil moisture index developed by Narasimhan and Srinivasan (2005) with a focus on agricultural drought.

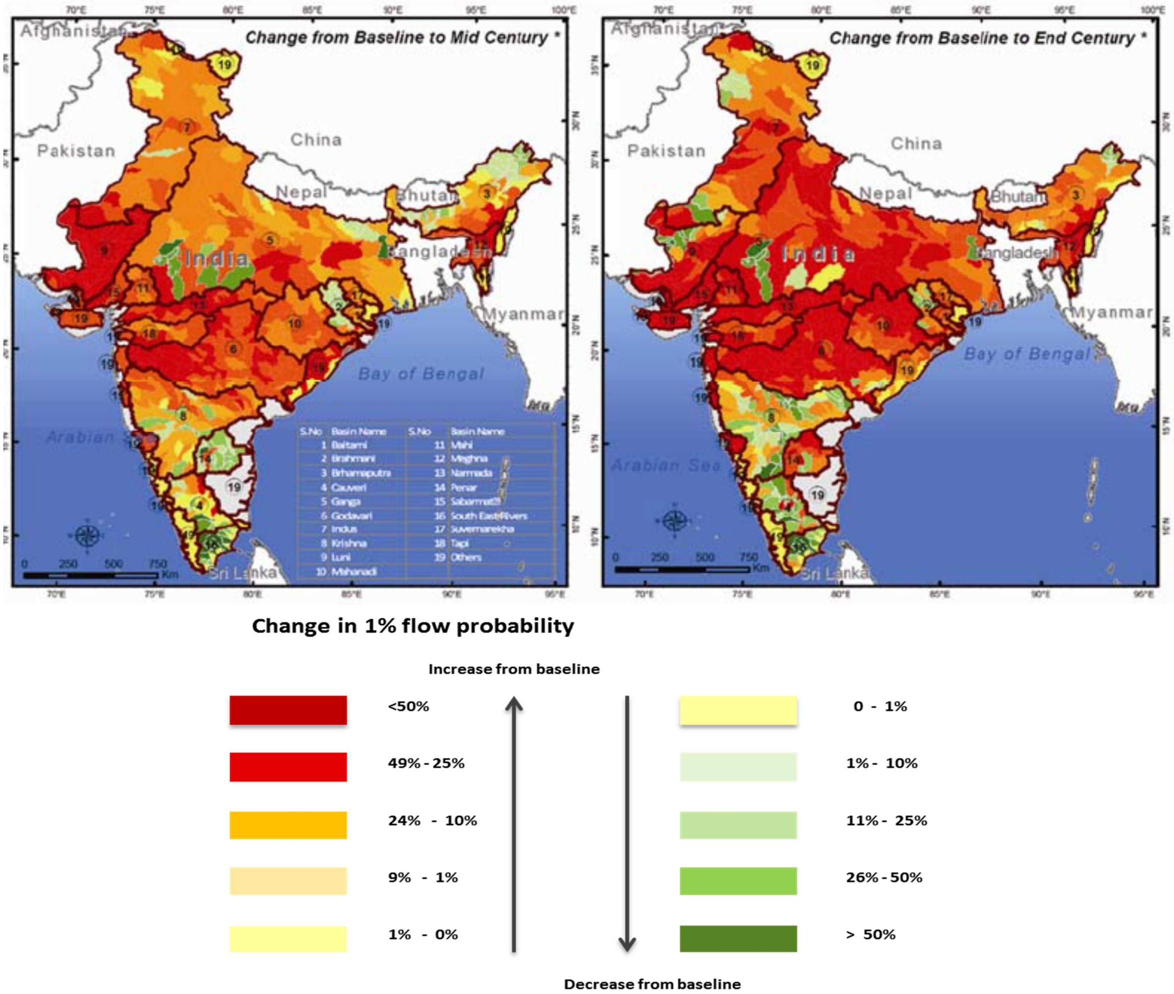
Figure 2.9: Percentage change in drought weeks in India for mid and end of century, from baseline (1961-1990)[27] (adapted from Gosain et al, 2011)



Analysis of future flooding under climate change utilised projected daily river flows and maximum annual peaks for each river basin and sub-basin, based on outputs from the SWAT model. Analysis concentrated on the future change in magnitude of flood peaks above the 99th percentile[28]. Results suggest an increase likelihood of flooding in northern and central basins from 10-50%, with a relatively less flooding in southern basins (Gosain et al, 2011). However, there is large spatial variability both across and within river basins (Figure 2.10). Intense precipitation is expected to occur over fewer days than historically observed, increasing the likelihood of flash floods during the summer monsoon months (Kumar et al, 2011; Lal et al, 2001).

[27] The percentage change in drought weeks displayed in the legend are based the percentage change from baseline using the equation: 100 x (MC-BL)/BL (Gosain et al, 2011).
[28] As an indicator of exceptionally high river flow, equalling or exceeding 1% frequency peak discharge with regards to baseline historic river flows (1961-1990) (Gosain et al, 2011).

Figure 2.10: Percentage change in stream discharge at 99 percentile (extreme river flow) for mid and end of century, from baseline (1961-1990)[29] (adapted from Gosain et al, 2011)



Climate change impacts on water resources in AP state

Table 2.2 provides a summary of key impact indicators in Andhra Pradesh (AP), including the three major river basins in the state: the Lower Krishna River Basin (LKRB), Lower Godavari River Basins (LGRB) and Pennar basin (Section 4.3.2 for overview of AP's water resources). For the entire Krishna River Basin (KRB) and LKRB by mid and end of century, climate change projections indicate an overall reduction in annual precipitation, characterised by an increase in intra-annual precipitation during summer monsoon months and a reduction in winter months; leading to an overall reduction in annual surface runoff with corresponding increase incidence of droughts. Flooding is projected to increase throughout the basin, as is evapotranspiration (as temperature rises) and river sediment yield. By contrast, the Godavari River Basin (GRB) and LGRB are projected to receive an increase in annual precipitation and surface water runoff, with increased likelihood of flooding throughout the basin. The Pennar basin is predicted to experience a reduction in annual precipitation and surface runoff

[29] The percentage change in 1% flow probability displayed in the legend are based the percentage change from baseline using the equation: 100 x (MC-BL)/BL (Gosain et al, 2011).

by the mid-century, leading to further reduction in both variables by the end of the century with associated increase in the likelihood of flooding.

Table 2.2: Summary climate change impacts on runoff, evapotranspiration, sediment yield with flood and drought implications for the KRB, GRB and Pennar basins (GoI, 2012a; Gosain et al, 2011; GoI, 2010a)

	KRB (including LKRB)	GRB (including LGRB)	Pennar basin	Reference
Temperature	Rise of 1.7-2°C by 2030s; 2.5-3.2 by 2060; up to 3.4 by 2080s. Some spatial variation across basin, but generally hotter in eastern area of LKRB.	Rise of 1.7-2°C by 2030s; 2.5-3.2 by 2060; up to 3.4 by 2080s. Hotter in eastern half of basin	Rise of 1.7-2°C by 2030s; 2.5-3.2 by 2060; up to 3.4 by 2080s.	GoI, 2010a; Kumar et al, 2011
Precipitation	General trend of reduced annual precipitation by 10% maximum by mid and end of century for entire basin. Spatial variation across entire river basin, with north-east area 5% including the LKRB increase in precipitation by end of century. Intra-annual precipitation variability throughout basin, drier winter months and wetter summer monsoon months, in line with country average of 3-7% increase of summer monsoon rainfall by the 2030s.	Significant increase in annual precipitation over entire basin by mid and end of century, up to 15% on baseline (1961-1990). South eastern area of basin including LGRB exhibits lower rise of 5%. Intra-annual precipitation variability throughout basin, drier winter months and wetter summer monsoon months, in line with country average of 3-7% increase of summer monsoon rainfall by the 2030s.	Reduction in annual precipitation by 10% by mid-century, but by end of century, a rise of 5%. Intra-annual precipitation variability throughout basin, drier winter months and wetter summer monsoon months, in line with country average of 3-7% increase of summer monsoon rainfall by the 2030s.	GoI, 2010a
Runoff (surface water)	Overall trend of reduction in runoff in the basin as a whole, of up 10% by end of century. However, large degree of spatial variability within basin, with largest runoff reduction in central areas, with north west area showing increase in runoff. LKRB trend of average 10% reduced runoff by end century.	Significant rise in runoff from 1-40% throughout the basin, large degree of spatial variability. LGRB lower relatively lower runoff (+9%) by mid-century, and reduced runoff by up to 25% by end of century.	Reduced runoff by up to 25% by mid-century, however, increased runoff by up to 25% by end of century (correlating with increase and then decrease in annual precipitation by mid and end of century respectively).	Gosain et al, 2011
Droughts	Significant variability with increasing incidence of drought weeks, with general trend of decreasing drought in western area of KRB, and increasing droughts in eastern basin including the LKRB by mid-century. Frequency and intensity if droughts increase by the end of century, particularly in central and eastern areas including LKRB.	Large degree of spatial variability in occurrence of drought, with no obvious trend by the mid and end of century, apart from a general increase in droughts in central area of GRB.	Large degree of spatial variation across basin, with general trend of increase in drought in north-east and decrease in south west areas of basin by mid and end of century.	Gosain et al, 2011
Floods	Overall trend of increase incidence of flooding up to 26% throughout basin, including the LKRB by mid-century. Slight reduction in flooding by end of century.	Significant trend of increase incident of flooding by up to 50% throughout the basin, including LGRB by mid-century, increasing in intensity by end of century.	General trend of reduce flooding by mid-century, followed by increase in flooding by end of century.	Gosain et al, 2011
Evapotranspiration	Rise in rate of evapotranspiration throughout the basin by up to 15% on baseline by end of century (owing to higher temperatures).	Rise in rate of evapotranspiration throughout the basin by up to 15% on baseline by end of century (owing to higher temperatures).	Rise in rate of evapotranspiration in the basin by up to 15% on baseline by end of century (due to higher temperature).	Gosain et al, 2011
Sediment yield (of rivers)	Increase sediment yield (up to 60%) in western and eastern (including LKRB) areas of basin, reduction in central areas by end of century.	Significant rise of river sediment content by up to 60% on baseline by end of century thought the basin.	Reduction in sediment yield by mid-century across the basin, followed by increase in sediment yield by end of century	Gosain et al, 2011

2.4 Water management and institutional responses to climate change

This section introduces the challenge of managing water in the context of climate change impacts. It then leads onto an examination of water management strategies and planning approaches in adapting to climate change. Institutional adaptation in the form of policy, organisation and overall institutional approaches are then discussed. The section finishes with a more detailed examination of water management strategies, the concept of river basin closure, and a discussion on the multitude of factors that influence the particularly choice of a water management strategy.

2.4.1 The challenge of managing water in the context of climate change

Climate change poses a new and uncertain challenge for water managers. Milly et al (2008) claim that increasing climate variability challenges the commonly held notion of stationarity, that hydrological systems fluctuate within a known unchanging boundary of variability based on historically observed and measured data, which has been used to plan and manage water resources both in the past and present. Milly et al (2008) declares that stationarity is now dead owing to anthropogenic climate change altering means and extremes in precipitation, evapotranspiration and river discharge. Stationarity should no longer be used as the central default assumption in water resource risk, assessment and planning. Rather, water resource management now operates under the concept of non-stationarity, in terms of managing water under relative uncertain present and future changes in hydro-meteorological conditions (ibid). Such is confirmed by the IPCC in so much as climate change challenging conventional assumptions of known hydro-meteorological variation, that may alter the reliability of water management systems (IPCC, 2008).

Molle and Wester (2009) acknowledge that increasing precipitation variability through climate change adds further complexity to the hydrology of river basins, particularly for closing or closed basins accompanied by water scarcity. Such is reiterated by the recent second NATCOM report from the MEF, which states that 'clearly the impact of climate change on water resources in India adds another dimension to the complexity of managing and using water resources' (GoI, 2012a:116). Molle and Wester (2009) note that when also considering meeting water demand drivers (population growth, economic development manifested in increasing agricultural, urban and industrial water demands) along with projected climate change induced hydro-meteorological variation, poses water managers a highly complex, interconnected and uncertain challenge (Molle 2009; IPCC, 2008; Miley et al, 2008; Lach et al, 2005).

It is important to note that precipitation variability across South Asia is not a new physical phenomenon, as noted by Lundqvist et al (2008), with summer monsoon precipitation exhibiting a 9.8% variation on the mean over the last 130 years (Kripalani et al, 2003) (Figure 2.1). Government water planners and farmers have had to adapt to precipitation variability. However, climate change projected increase in inter and intra annual and intra seasonal precipitation variability, poses significant challenges to water resource managers (GoI, 2012a;

Gosain et al, 2011, Kumar et al, 2011). However, the IPCC acknowledge that there is a low level of consensus (e.g. high uncertainty) amongst climate models regarding the signal of change in precipitation over large parts of Asia (IPCC, 2007).

2.4.2 Water management strategies and planning approaches in adapting to climate change impacts

There exist a number of water management strategies and planning approaches to adapt to climate change impacts. In this section, water management strategies in the context of climate change are introduced including supply and demand options, followed by an examination as to whether they are autonomous or planned adaptation in the water sector. Scenario-based and bottom-up planning approaches are then discussed, leading onto adaptive water management and robust adaptation to climate change.

2.4.2.1 Water management strategies

There are no universal blueprints for successful water management in adapting to climate change impacts. The particular choice of supply and demand management strategies for climate change adaptation should be considered in relation to specific hydrological conditions and existing water management practices in a river basin. The IPCC recommends a mixture of both supply and demand management strategies in adapting to climate change impacts (IPCC, 2008), detailed in Table 2.3. In some cases, the construction and development of water storage in the form of reservoirs could be an appropriate adaptation response, particularly for increasing intra annual precipitation variability or a reduction in long-term precipitation levels. Whereas in other cases, a focus on demand management strategies, for instance, to increase the efficiency of water use for agriculture particularly within large irrigation systems, could be a suitable response especially if precipitation levels decrease in the long term with climate change. The IPCC recommend that a blend of both supply and demand management strategies should be considered on a case by-case-basis (ibid). Section 2.4.4.1 provides a more detailed examination of water management strategies. Within India, water management discourse and practice is polarised in nature. With the government's historic and present day focus primarily on the supply side interventions consisting of the construction of large-scale reservoirs and canal irrigation systems allowing control of surface water; and non-state actors pursuing alternative approaches such as groundwater withdrawal, watershed development and community based initiatives, focusing on both small-scale supply and demand management strategies. This research focuses on the government's water policy response and the strategies it advocates to manage climate change impacts.

Table 2.3: Climate change adaptation options for water supply and demand (list not exhaustive) (IPCC, 2008:63)

Supply management	Demand management
Prospecting and extraction of groundwater	Improvement of water-use efficiency by recycling water
Increasing storage capacity by building reservoirs and dams	Reduction in water demand for irrigation by changing the cropping calendar, crop mix, irrigation method, and area planted
Desalinisation of sea water	Reduction in water demand for irrigation by importing agricultural products, for example, by virtual water (Allan, 2002)
Expansion of rainwater storage	Promotion of indigenous practices for sustainable water use
Removal of invasive non-native vegetation from riparian areas	Expanded use of water markets to re-allocate water to higher valued uses
Water transfer	Expanded use of economic incentives including metering and pricing to encourage conservation

The IPCC defines adaptation as 'initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects' (IPCC, 2008:221). Whereas vulnerability is defined as 'the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes' (ibid:237)[30]. Water management strategies can be considered as either autonomous or specific adaptations to climate change. The IPCC (2008) defines autonomous adaptations as 'those that do not constitute a conscious response to climate stimuli, but result from changes to meet altered demands, objectives and expectations which, whilst not deliberately designed to cope with climate change, may lessen the consequences of that change (ibid 2008:63). Autonomous adaptations are widespread in the water sector, as illustrated in the strategies detailed in Table 2.3, which constitute conventional supply and demand management strategies to meet water demand drivers.

Climate change specific or planned adaptations *'are the result of deliberate policy decisions and specifically taking climate change and variability into account'* (ibid:63). Specific adaptations are rare in the water sector. However, there are a few examples of where methods and procedures have taken climate change projections in direct consideration for flood and water supply management practices. These include flood preparedness in the UK and the Netherlands (Richardson, 2002; Klijn et al, 2001), water supply in the UK (Arnell and Delaney, 2006) and Australia (Dessai et al, 2005), as well as for general water planning in Bangladesh (IPCC, 2008). Specific adaptations are rare owing to the uncertain nature of climate change projections and associated future hydrological change (ibid). Furthermore, climate change may be one of many drivers affecting the choice of water management strategy and investments programmes and may not be the most important one, particularly for short-term planning (ibid). Water managers are posed with the task of how to include non-stationarity considerations for water management, characterised by uncertainty in both the present and future hydro-meteorological conditions (Wilby and Dessai, 2010; IPCC, 2008; Milly et al, 2008). It may also be very difficult to detect an underlying trend, meaning that adaptation decisions may have to be made before it is clear how hydrological regimes may actually be changing (Wilby and Dessai, 2010).

[30] Resilience is 'the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self organisations, and the capacity to adapt to stress and change (IPCC, 2008:233-234).

2.4.2.2 Water management planning approaches for climate change adaptation

There is general consensus that adaptive water management informed by a robustness decision making framework is a viable method to plan in the face of climate change uncertainty, facilitating a flexible management approach that reduces overall system vulnerability (WWDR, 2012; Wilby and Dessai, 2010; Hallegate 2009; IPCC, 2008; Pahl-Wostl, 2007; Stakhiv, 1998). The effectiveness of scenario-based planning has been found to be somewhat limited, owing to the uncertainty of RCMs and downscaling projections to assess climate change impacts leading to direct management and operational responses (Wilby and Dessai, 2010; IPCC, 2008). Bottom-up approaches offer a viable method to reduce vulnerability and build system resilience, particularly in relation to past extreme events (van Pelt and Swart, 2011; Wilby and Dessai, 2010). These planning approaches are discussed in more detail below.

The IPCC advocate a scenario based approach[31] to planning future water management (IPCC, 2008; Dessai and van der Sluis, 2007; Beuhler, 2003; Simonovic and Li, 2003). Scenario approaches involve downscaling climate projections from General Circulation Models (GCMs) to higher resolutions for a region or river basin. Results are then fed into hydrological impacts models, for instance, with outcomes used to inform adaptation measures. The IPCC as well as most national and regional adaptation assessments in Europe use the scenario-based approach (Wilby et al, 2009). However, there are few tangible examples of planned adaptation decisions arising from this approach (Wilby and Dessai, 2010; IPCC, 2008). Uncertainty increases as projections are downscaled from GCMs to regional levels and finally to impact models, to the extent that potential impacts and their implied adaptation responses span such a wide range that they are practically unhelpful (Wilby and Dessai, 2010). Although more exhaustive characterisation of uncertainty may be scientifically tractable, the prospect of reducing uncertainty depends on further progress being made in the underpinning climate science (Hawkins and Sutton, 2009). Experience from the UK Climate Projections highlights that considerable time and effort must be invested in training users to discern the most appropriate scenarios and tools to plan adaptation responses (Wilby and Dessai, 2010).

An alternative method to scenario planning is what is termed bottom-up approaches[32] (ibid; IPCC, 2008). This method focuses on reducing vulnerability to past and present climate vulnerability and strengthening resilience[33], usually after an extreme event such as a drought or flood (Wilby and Dessai, 2010). This method attempts to seek adaptation strategies that make a system less vulnerable to uncertain climate change impacts and unpredictable variations in the climate system (van Pelt and Swart, 2011; Dessai and van der Sluis 2007). Analysis focuses on what factors and conditions enable successful coping strategies to climate-related threats at the level of individuals and communities, as well as formal organisations such as government departments.

[31] Van Pelt and Swart (2011) refer to the scenario-based approach as the 'predict-then-act' approach.
[32] Van Pelt and Swart (2011) refer to the bottom-up approach as the 'assess-risk-of-policy' approach.
[33] The IPCC (2008) defines resilience as 'the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change' (ibid:233-234).

This approach does not rely on climate change scenarios. Although lengthy hydro-meteorological observations can aid in understanding the range of frequency and intensity of events, useful to assess how a system coped under such conditions. However, such historical data cannot be used for future planning owing to non-stationarity. Examples of bottom-up approaches for formal organisations include the upgrading of flood monitoring systems or improved dam safety analysis (Tanner et al, 2007).

There is general consensus that adaptive management offers a viable framework to facilitate a robust decision making planning process in the face of climate change uncertainty (WWDR, 2012; Wilby and Dessai, 2010; Hallegate 2009; IPCC, 2008; Pahl-Wostl, 2007; Stakhiv, 1998). In its broad form adaptive management is 'a process that promotes flexible decision-making in the face of uncertainties as outcomes from management actions and other events become better understood' (US National Research Council, 2004). Stakhiv (1998) was one of the first to advocate an adaptive management approach, involving the increased use of water management strategies that are relatively robust to uncertainty, in addition to stressing the importance of anticipatory over reactionary strategies. In its broadest sense, robustness indicates how well a system performs over a range of possible input scenarios pertaining to what is uncertain (Hashimoto et al, 1982). Flexible and adaptive strategies are more likely to be robust to uncertainty as opposed to static strategies, such as large-scale infrastructures (reservoirs and canal irrigation systems) that lead to 'lock-in' with regards to design specifics and performance once constructed (Hallegatte 2009). An adaption strategy is robust when it performs well across a wide range of future scenarios and uncertainty, reducing water system vulnerability to climate change impacts (Lempert and Collins, 2007). Numerous demand management strategies are robust to climate change impacts and uncertainty, offering flexibility and reducing overall system vulnerability. Hallegate (2009) offers an inclusive framework on what constitutes robust adaptation in the water sector. This includes measures that are low regrets, or reversible, incorporate safety margins, are flexible and mindful of actions being taken by others to adapt to climate change. So called low regrets water strategies are those that yield benefits regardless of climate change impacts (Wilby and Dessai, 2010; UKCIP, 2003). They address present water requirements whilst still keeping open or maximising options for adaptation in the future (Wilby and Dessai, 2010). However, in practice there are opportunity costs, trade-offs or externalities associated with adaptation actions[34]. Low regret strategies are sometimes used to describe decisions where the cost implications of the decision are very low while whilst considering the uncertainties in future climate change projections, the benefits under future climate change may potentially be large (UKCIP, 2003). Reversibility refers to strategies that are flexible enough by their very nature to allow moderation and alteration in time under a changing climate. Safety margin strategies are those that reduce vulnerability at null or low costs (ibid).

[34] A 'no regret' adaptation is a decision option that is assessed to be worthwhile now (in that it would yield immediate economic and environmental benefits which exceed its cost), and continues to be worthwhile irrespective of the nature of future climate (UKCIP, 2003).

2.4.3 Institutional adaptation to climate change

2.4.3.1 Adaptive water policies

Developing and integrating climate change into water policies is an emerging field in recent years (Pittock, 2011; Dovers and Hezri, 2010; IPCC, 2008). Water policies that promote an adaptive water management approach are advocated to manage non-stationary hydro-meteorological and water demands (IPCC, 2008; Pahl-Wostl, 2007; Gleick, 2003; Stakhiv, 1988). Policy approaches that emphasise integration between government ministries and departments, flexibility and learning, participation of all water users, open and transparent government decision making and sharing of information and data, decentralisation, application of efficient technologies, environmental protection, and the development of water management strategies and projects at appropriate scales (Pahl-Wostl, 2007). These approaches closely align with measures advocated to promote institutional water reform (Merry et al, 2007; Mollinga et al, 2007) (Section 2.6). Decentralisation of water management is advocated in water policy response to climate change, in order to strengthen resilience and reduce vulnerability to climate change impacts (Pittock, 2011; Dovers and Hezri, 2010). Water policy focusing on decentralisation consists of the redistribution and delegation of power and authority from centralised government ministries and irrigation departments to users including non-state actors (Wester, 2008). Such decentralisation includes the devolution of power to water user associations, irrigation transfer management programmes, river basin organisations, water regulatory authorities and water management committees (Robinson, 2000). In the case of India, such decentralisation directly challenges the government's control of water in the form of its historic and present day focus on the construction and management of large-scale reservoirs and canal irrigation distribution systems. Section 2.6 for further discussion on decentralisation.

2.4.3.2 Adaptive organisations

Organisational adaptation and resilience to climate change is an emerging field of enquiry (Linnenluecke and Griffiths, 2012; WWDR, 2012; Dovers and Hezri, 2010; IPCC, 2008; Berkhout et al 2006). There are very few insights into the concept of organisational resilience to future climate change impacts, with the few existing studies based on retrospective assessments of adverse extreme weather events (floods and droughts) (Somers, 2009). However, theoretical insights suggest that strengthening organisational resilience is promoted by decentralisation[35] of water resource management (Section 2.6 for further discussion on decentralisation), the availability of resources (financial and human development capacity), flexible internal structures; in addition to processes to identify problems, establish priorities and mobilising and deploying resources accordingly (Sutcliffe and Vogus, 2007; Bruneau et al, 2003). Berkhout et al (2006) found that organisational adaption to climate change has many similarities with the on-going (non climate change orientated) process of

[35] Decentralisation essentially involves a redistribution of power and authority for water management and development (Wester, 2008), from centralised government to non-state actors.

organisational learning and reform. Organisations had difficulty specifically adapting to climate change owing to the weakness and ambiguity of impact signals and the uncertainty of benefits from climate change specific adaptation measures (ibid).

In order to deal with climate change impacts as well as managing water challenges to meet increasing demand, the IPCC advocates exploring IWRM[36] approaches, set within a broader institutional framework including appropriate policy and legislative development (IPCC, 2008). However, Moench et al (2003) states that a fully integrated approach is not always needed, rather the appropriate scale for integration will depend on the extent to which it facilitates effective action in response to specific needs. The World Water Development Report (2012) advocates creating adaptable and flexible organisations in line with the IWRM approach to manage climate change, drawing on a broader institutional development capacity framework. It calls for strengthening institutional capacity and resources to deal with climate change risk and uncertainty; creating a learning orientated institutional process; aligning and integrating policies within formal and informal water institutions; multi-sector and disciplinary integration and collaboration; developing adequate financing; strengthening formal institutions accountability and transparency; increasing internal staff capacity; developing appropriate infrastructure and technology to deal with climate change; and to increase and incorporate informal institutions and actors into water management (WWDR, 2012). Many of these recommendations although cited in this context to strengthen organisational institutional capacity in adapting to climate change, are by their very nature measures that constitute institutional reform (WWDR, 2012; IPCC, 2008; Merry et al, 2007; Berkhout et al, 2006); with the exception of understanding and appropriately managing climate change risk and uncertainty. Section 2.6 for further discussion on organisational reform.

2.4.3.3 Adaptive water management institutional approaches

The IPCC (2008) recommends an integrated institutional approach aligning with the principles of Integrated Water Resource Management (GWP, 2000) to manage water resources under non-stationarity conditions in a sustainable manner (Section 2.6 for overview of institutional reform including IWRM). In the face of the challenges posed both by climate change non-stationarity and to manage increasing demands from all sectors, Pahl-Wostl (2007) advocates the need for a transition to more adaptive water management institutions and regimes. The term regime is used in the broad sense to include the entire complex and inter-connected structured system of water management to fulfil societal functions. It includes formal water institutions, other water (informal) organisations and users, as well as environmental factors and technology (ibid). Adaptive management refers to a systematic process of continually improving management policies and practices by learning from the outcomes of implemented management strategies, including the ability to change practices based on new experience and insights (Richter et al, 2003). Adaptive capacity reflects learning, flexibility to experiment and adopt novel solutions, and development of generalised responses to broad classes of

[36] The most commonly used definition of IWRM is that of a process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP, 2000).

challenges (Walker et al, 2002). Pahl-Wostl (2007) offers a framework that identifies key components of water regimes, many of which relate to formal water institutions (government) that can be used to gauge the transition to more adaptive management approaches (Table 2.4). At one end of the scale is what is termed 'prediction and control', considered as the most common approach globally, and at the other end is 'integrated and adaptive'.

Table 2.4: Comparison between prediction and control, and integrated and adaptive water management institutions and regimes (Pahl-Wostl, 2007)

	Prediction and control regime	**Integrated, adaptive regime**
Management paradigm	Prediction and control based on a mechanistic systems approach	Learning and self-organisation based on complex system approach
Governance	Centralised, hierarchical, narrow stakeholder participation	Polycentric, horizontal, broad stakeholder participation
Sectoral integration	Sectors separately analysed resulting in policy conflicts and emergent chronic problems	Cross sector analysis identifies emergent problems and integrates policy implementation
Scale of analysis and operation	Transboundary problems emerge when river sub-basins are the executive scale of analysis and management	Transboundary issues addressed by multiple scales and analysis of management
Information management	Understanding fragmented by gaps and lack of integration of information sources that are proprietary	Comprehensive understanding achieved by open, shared information sources that fill gaps and facilitate integration
Infrastructure	Massive, centralised infrastructure, single sources of design, power delivery	Appropriate scale, decentralised, diverse sources of design, power delivery
Finances and risk	Financial resources concentrated in structural protection (sunk costs)	Financial resources diversified using a broad set of private and public financial instruments
Environmental factors	Quantifiable variables such as biological oxygen demand or nitrate concentrations that can be easily measured	Qualitative and quantitative indicators of whole ecosystems and ecosystem services (environmental flow allocation)

The management paradigm[37] considers that the water systems to be managed are complex adaptive systems. Prediction and control approaches reduce the degrees of freedom by attempting hierarchical and centralised control through water strategies and risk management (e.g. highly regulated top-down governance, large scale technologies). Whereas a more integrated and adaptive paradigm is flexible and builds on strengths of complex adaptive systems to perform well under uncertain environments (Pahl-Wostl, 2007). Management facilitates and guides learning processes in complex adaptive systems (ibid). Polycentric governance is considered more flexible and adaptive than unicentric arrangements (Ostrom, 1990; 2005; Folke et al, 2005; Molle, 2010). Adaptive governance relies heavily on participatory processes and active stakeholder involvement to build commitment and social capital required to include a wide range of perspectives and approaches (Pahl-Wostl, 2007). Rather than advocating the dominance of a single governance approach, adaptive and multi level governance, such as the polycentric model, integrates bureaucratic hierarchies, networks and stakeholder interests (ibid). Sectoral integration is considered essential in adaptive regimes, being one of the central components of IWRM. In many developing countries, water sectoral integration is fragmented with policies and projects implemented in isolation. Adaptive water management regimes require

[37] Pahl Wostl (2007) defines the water management paradigm as a set of assumptions about the nature of the system to be managed, the goals of management, and the ways in which these goals can be achieved. The paradigm is manifested by technical infrastructure, planning approaches, regulations and engineering practices; being shared by an epistemic community of actors.

sectoral integration in order to plan and implement policies and strategies in the face of uncertainty (ibid). Adaptive water management regimes require the scale of analysis and operation to span political and administrative boundaries of river basins, both within and between riparian states and countries. Non-stationarity hydro-meteorological variations will require collaboration between actors across political and administrative borders in order to understand and manage water resources accordingly. Information management is a key requirement for integrated and adaptive regimes, particularly in understanding present and future climate change impacts through data collection and monitoring. Information and data should be shared between relevant stakeholders to facilitate understanding and project planning (ibid). Water supply management including augmentation through large-scale infrastructure with decade-long life-spans runs the risk of leading to 'lock-in' situations under a changing climate (Hallegatte, 2009), with adaptive management mainly limited to an operational level (Pahl-Wostl, 2007). Careful consideration at the appropriate scale, an increased use of decentralised strategies and technologies, and diverse sources of design adapted to regional contexts are advocated as more promising strategies for achieving integrated and sustainable water management (Pahl-Wostl, 2002; Gleick, 2003).

Gleick (2003) advocates a soft path to build greater flexibility in water management regimes to address the rising uncertainty from global change, including climate change: 'a transition is under way to a soft path that complements centralised physical infrastructure with lower cost community-scale systems, decentralised and open decision-making, water markets and equitable pricing, application of efficient technology, and environmental protection' (ibid:525). Essentially Gleick is advocating a fundamental shift in water management paradigm from management as control to management as learning, aligning with the move beyond the hydraulic mission to the reflexive modernity stage of water management (Allan, 2003) (Figure 2.13).

2.4.4 Water resource management at the river basin level

2.4.4.1 Water resource management strategies

Society manages water resources by three primary water resource management (WRM) strategies: water supply management (WSM), allocation and conservation (Molle, 2003). Conservation and allocation are grouped together and termed water demand management (WDM) for the purpose of this thesis, as is often the case, being pooled together under the concept of WDM typified by 'doing better with what (water) we have' (ibid:13); as opposed to WSM strategies focusing on augmentation (Brooks, 2006). Table 2.5 details some of the main WSM and WDM practices at the river basin and field level, although this list is not exhaustive. There exists a large degree of interaction and overlap between these two levels, with decisions made at the river basin level having direct hydrological implications at the field level; and vice versa. State governments primarily decide and manage the strategies identified at the river basin level, with greater involvement and choice of farmers and other water users at the field level.

Table 2.5: WRM strategies at the river basin and field level (adapted from Molle, 2003)

	Supply management	Demand management	
		Conservation	**Allocation**
River basin level	Construction of reservoirs Developing carry-over reservoir capacity Inter-basin transfer Groundwater extraction Desalinisation Water treatment Cloud seeding	Irrigation efficiency; canal lining Improved dam management Water management practices Awareness campaigns Water (irrigation) pricing Water audits and benchmarking Basin level organisations Participatory approaches including WUA	Sectoral reallocation policy and framework Sector quotas Water markets Water Regulatory Authorities Basin level institutions
Field level	Construction of check dams Rainwater harvesting Conjunctive use Groundwater extraction	Micro irrigation Improved management (crop rotations) Changing cropping techniques On-farm storage Reduce water flow	Directing water to more (economically) productive crops Changing cropping patterns and varieties Arrangement for greater equity Release excess water not productively used.

Water supply management

Augmenting the supply of water from existing sources by increasing the quantity of controlled water, in addition to tapping additional sources, is a principal and well established WRM strategy, a common solution to meeting scarcity and river basin closure (Molle, 2003). The most widespread methods at the river basin level are the construction of new reservoirs and drilling tubewells to extract groundwater, in addition to transferring water from an adjacent basin. Desalination also increases the supply of water, although high energy requirements and costs limit the widespread use beyond drinking water. WSM strategies at the river basin level generally involve centralised large-scale infrastructure development and operationalisation, managed and controlled by government water ministries and departments. Field level WSM include smaller scale strategies such as the construction of check dams and rainwater harvesting.

Water demand management

There are numerous definitions of WDM[38]. In its simplest form, WDM means getting the most from the water we have (Brooks, 2006). A commonly used definition of WDM is a policy option or practice that emphasises making better use of developed water sources or a reduction of use of existing developed sources, rather than the development of new ones (Brooks, 2006; Molle, 2003; Grover, 2002)[39]. Conservation responses include making better use of existing water resources without increasing the supply of the source of water, essentially 'efficiency in use' (Molle, 2003:11). At the river basin level state water departments enforce policies that may

[38] Grover (2002) identifies several other definitions of WDM, such as any socially beneficial action that reduces or reschedules average or peak water withdrawals or consumption from either surface or groundwater, consistent with the protection or enhancement of water quality (Tate, 1993); a practical strategy that improves the equitable, efficient and sustainable use of water (Deverill, 2001); the development and implementation of strategies aimed at influencing demand, so as to achieve efficient and sustainable use of a scarce resource (Savenije & van der Zaag, 2002).

[39] Brooks (2006) offers an operational definition of WDM consisting of five components: 1) reducing the quantity or quality of water required to accomplish a specific task; 2) adjusting the nature of the task so it can be accomplished with less water or lower quality water; 3) reducing losses in movement from source through use to disposal; (4) shifting time of use to off-peak periods; and (5) increasing the ability of the system to operate during droughts.

elicit water savings such as water pricing, rationing or quotas, as well as supporting the development of river basin organisations and participatory approaches including water user groups. Other strategies include irrigation efficiency measures such as canal lining, reducing leakage, water audits and benchmarking, and improving dam management. At the field level, conservation responses centre on the farmer, including adoption of micro irrigation techniques, selection and rotation of crops, and on-farm efficiency of water use through control structures and storage techniques. Although the state is primarily responsible for some of the strategies, essentially WDM entails decentralisation of control and management of water from the state, in promoting greater involvement and ownership of water management to farmers, particularly through participatory approaches such as WUA.

Allocation responses essentially consist of reallocating water from one user to another, either intra-sector reallocation within the same sector (e.g. within or between irrigation schemes), or inter-reallocation across sectors. Reallocation may be justified in order to raise water productivity, or to ease tension on water resources by favouring uses which improve land productivity, food security or reduce conflicts (Molle, 2003). Reallocation is often conceived on the grounds that scarce water should be moved to more economically valued use, for instance, inter-sectoral reallocation from agriculture to cities for drinking purposes where the return per unit volume is greater (Seckler, 1996). Government has an important role in reallocation, particularly by developing appropriate policy and frameworks, identifying, enforcing and regulating sector quotas, as well as by developing water markets and establishing basin level institutions and regulatory authorities. Enforcing an allocative framework between users is problematic, owing to the informal nature of the water economy in many developing countries, including India (Shah, 2005). Reallocation of water at the field level includes farmers re-directing water to more productive crops in times of shortage; or at the irrigation system level between plots, for instance, to reduce head-tail differences in promoting higher equity and to increase economic efficiency (Hussain et al, 2003).

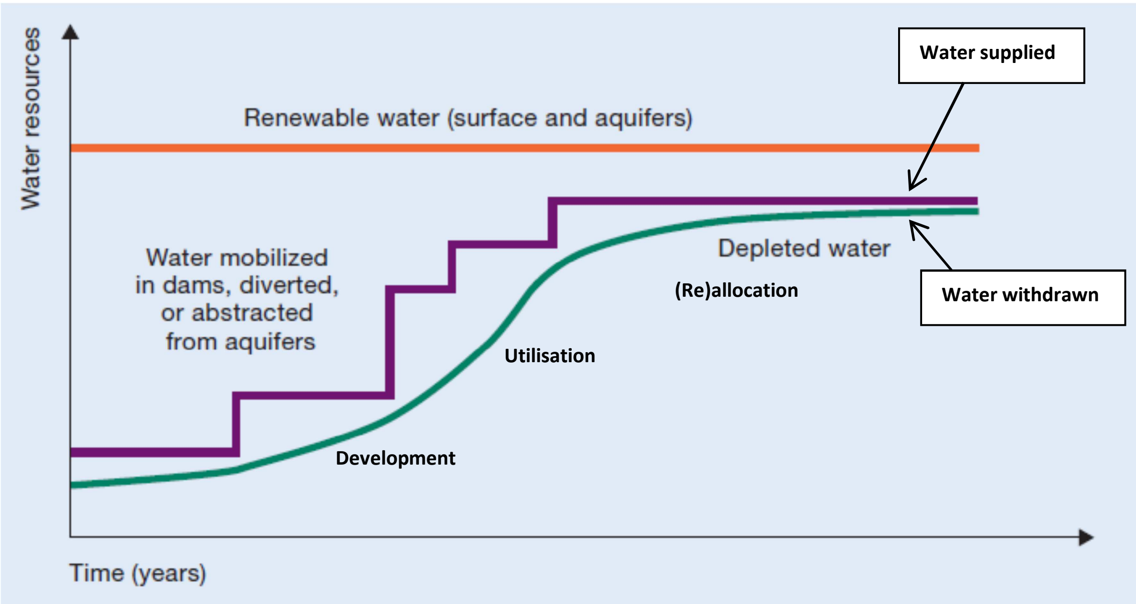
2.4.4.2 River basin development and the concept of closure

The concept of the river basin as the natural and most appropriate unit for water resources development and management has heavily influenced water-society interactions over the last 150 years (Warner et al, 2008; Molle et al, 2007). A river basin trajectory is loosely defined as 'the long-term interactions between society and their environments, with a focus on the development and management of water and associated land resources'[40] (Molle, 2009:1). The development of basins and associate water management practices is influenced by a number of factors, including physiography, population growth, economic development, history, politics, culture, technology, and engineering, and society dynamics. Wester (2008) states that 'a basins trajectory encompasses human efforts to assess, capture, convey, store, share and use available water resources, thereby changing waterscapes and turning parts of the hydro-cycle into a hydro-social cycle (ibid:8).

[40] Conceptualisations of river basin trajectories have been developed by Keller et al (1998), Keller (2000), Turton and Ohlsson (1999), and further developed by Molle (2003) and Molden et al (2005).

Figure 2.11 schematically portrays the trajectory of river basin closure over time, as a basin passes through three stages: development, utilisation and allocation (Molden et al, 2005)[41]. As society develops and prospers in time, humans develop the facilities to withdraw, divert and use more surface and groundwater. Increasing water use over time leads to further depletion and reduction in river flows, eventually approaching the total annual renewable water available[42] in a basin. The proportion of water that can be used under existing economic and technological conditions is generally less than the total annual renewable water available (Wester, 2008). For example, significant volumes of flood water generally flows to the sea, or groundwater may be too deep in the aquifer to extract economically. Water depletion may be higher than availability in river basins where dams can capture all or most of the runoff and groundwater aquifers are over-exploited (Molle et al, 2007).

Figure 2.11: Schematic representation of river basin closure passing through three stages: development, utilisation and allocation (adapted from Molden et al, 2005)



The rate of water withdrawal is at its most pronounced at the development stage[43] of the river basin trajectory identified by Molden et al (2005) (Figure 2.11). WRM strategies almost exclusively consist of supply management and augmentation, manifested in large-scale infrastructure developed to harness and control water resources, primarily for agricultural and irrigation purposes. The development stage of the river basin trajectory closely aligns with the second water management paradigm identified by Allan (2003), that of the hydraulic mission (Figure 2.13). As water withdrawal increases as society develops, water scarcity increases as

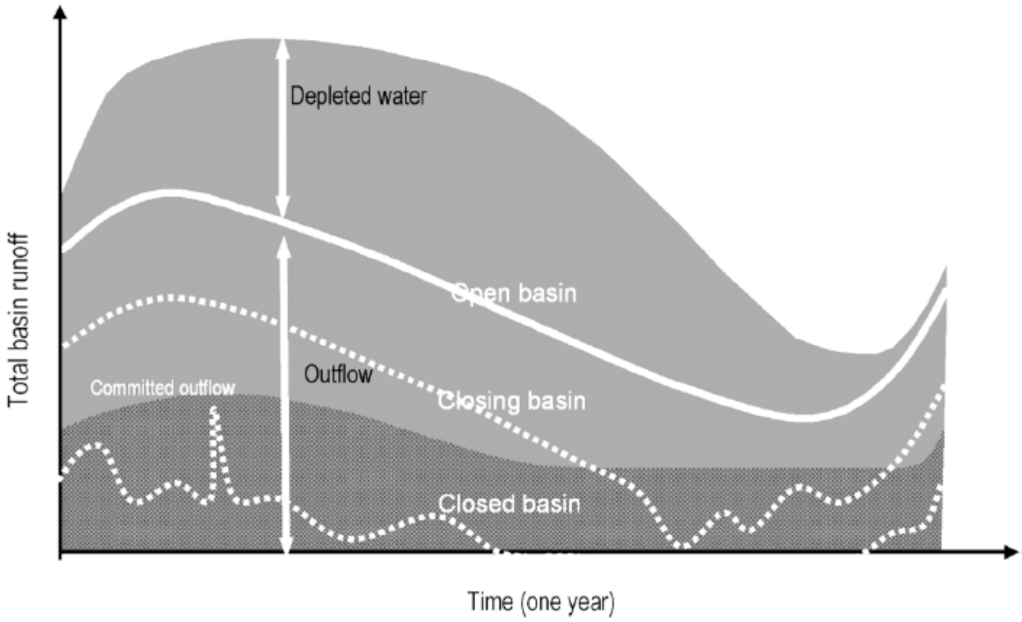
[41] Molden et al (2005) base the three stages on similar work carried out by Keller et al, 1998.
[42] Total annual renewable water in a basin is defined as the total runoff in a basin plus the safe yield of aquifer, where the safe yield is the lowest level of withdrawal whose consequences, in average reduction in groundwater stock and base flow, are considered acceptable (Molle et al, 2007).
[43] Keller (1998) terms this as the exploitation stage; and Turton and Ohlsson (1999) the supply stage.

does competition between users, heralding the utilisation stage identified by Molden et al (2005)[44]. During this stage, WDM approaches, primarily conservation strategies, are considered of growing importance and managed accordingly by society. As the level of water withdrawal approaches the total renewable water resources available with increasing scarcity towards river basin closure, reallocation becomes increasingly more important to manage the demands of competing users. During the reallocation stage[45], WDM strategies including reallocation between and within sectors are pursued. There are parallels in similarity of concept between with the utilisation and allocation stages identified by Molden et al (2005), with the reflexive modernity water management paradigms noted by Allan (2003) (Figure 2.13), in terms of moving away from primary focus on supply side augmentation to consider and manage water from a demand management and institutional perspective.

Continued water resource development over time has led to the over-exploitation of water in many river basins throughout the world. Eventually, river basin closure ensues, when the quantity of water withdrawn is too high to ensure regular supply to downstream users or sufficient river outflows to dilute pollution, control salinity intrusion, flush sediments and sustain healthy ecosystems at the mouth of the river (Molle et al, 2007; Molden et al, 2005; Molle, 2003; Seckler, 1996[46]. This process can be transient when closure only occurs in a few dry months of the year, where the basin is considered to be closing; or in an almost permanent or permanent state, when a basin is considered as closed[47] (Figure 2.12) (Molle, 2009). Basin closure occurs due to the extraction of surface and groundwater for urban, industrial and agricultural with a disregard for environmental flows; to the point that no more water is consumed than is renewably available (Molle et al, 2007; Molle, 2008). Rivers no longer reaching the sea or shrinking lakes are visible signs of basin closure, as witnessed by the Colorado River, the Aral Sea and Dead Sea (Molle et al, 2007). The overbuilding of river basins is a socially and politically constructed process that generates basin closure through the over extension of the water abstraction capacity, usually for irrigation purposes, as noted by Molle et al (2010) in claiming that 'enough is never enough' in the relentless construction of large-scale infrastructure (ibid:218).

[44] Keller terms this stage as the conservation stage; Turton and Ohlsson (1999) the demand stage.
[45] Keller (1998) terms the phase of river basin closure as the augmentation stage; whilst Turton and Ohlsson (1999) refer to the adaptive stage.
[46] Seckler (1996) was the first to coin the term basin closure to characterise river basins with no utilisable outflows.
[47] Closure can occur in sub-basins or catchments, while the wider basin remains open.

Figure 2.12: The process of river basin closure (Molle et al, 2010)



Basin closure and associated water scarcity therefore gives way to three types of responses: water supply management consisting of augmentation, and demand management entailing conservation and reallocation. It is hypothesised that these three types of responses occur sequentially along the basin trajectory closure (Molden et al, 2005). Whilst it is found that early phases of basin development almost exclusively focus on supply augmentation, in closing and closed basins under increasing water scarcity and pressure, all three options are pursued concurrently (Molle et al, 2010). A common approach in closed basins and to water scarcity even when demand management is being pursued is further augmentation, particularly by inter-basin transfer to re-open a basin (Molle, 2003).

River basin closure is common process throughout the world. An estimated 1.4 billion people live in closing or closed basins (Falkenmark and Molden, 2008). As a river basin moves towards closure with time, society is posed with the difficult task of managing finite water resources amongst competing users. If a river basin passes beyond the point of closure, sustainability questions arise, with the basin unable to support its multiple functions. Falkenmark and Molden (2008) proposes the notion of soft and hard basin landings. Hard landing characterised by increased pollution, loss of ecosystems services, over-abstraction of groundwater, increased competition and inequitable sharing of benefits. The basin cannot adequately support its many functions, and often ecosystem services are lost unless society decreases demand or finds an alternative supply. A soft landing is defined as an equitable, sustainable and efficient use of water (ibid).

Increasing water scarcity[48] often accompanies river basin closure, particularly evident where the further exploitation of water is limited. However, using the term water scarcity to describe the situation of overexploitation is misleading, as it obscures issues of unequal access to and control over water (Bakker, 2003; Mehta, 2001). Although over-exploitation does lead to water scarcity, it is not the only factor contributing to it. Water scarcity can be physically induced, for instance, by a meteorological drought leading to (supply induced) scarcity; or by population growth leading to (demand induced) scarcity (Molle et al, 2010). However, scarcity is also a result of competition between users and by political, technology and economic restraints; often termed as economic scarcity or structural scarcity (Homer-Dixon, 1994). Turton and Ohlsson (1999) consider that water scarcity is not the key issue of river basin closure, but rather whether a society has the adaptive capacity to manage the challenges of water scarcity[49].

2.4.4.3 Choice of water resource management strategy

The choice of a particular WRM strategy (by government) at a particular point in time along the river basins trajectory[50] to address water resources problems must be understood within 'a framework that spans not only hydrological, physical or economic constraints, but also the distribution of agency and power among actors, and their respective interests and strategies' (Molle, 2003:28). The government is considered the main actor that shapes river basin evolution, by virtue of its investments and politics (Molle, 2009; Turton and Ohlsson, 1999). The blend of options selected depends on the political, economic and social factors, as well as the physical hydrological conditions at the river basin level (that of the hydro-social).

Water management is considered as a politically contested process and resource base (Mollinga, 2005; Mosse, 2003; Mehta 2001). Wester (2008) considers the closure of river basins as a political process, with the sanctioned discourse legitimising which strategies can be pursued in a given political context (Allan, 2002; Ingram, 1971). Understanding government elite policy makers decisions is complex, however, political considerations are found to generally over-run what would like to be seen as the result of rational planning (Schlager and Blomquist, 2000). Policy decisions are considered to be overtly reactionary, driven by the need to find solutions to relatively immediate specific problems (months to years), and not grand visions of river basins or regional development (Winpenny, 1994).

The political economy of water resources development is influential in understanding strategic approaches (Keller et al, 1998). Although economic rationality has a strong impact on water management choices, it is insightful to look beyond formal models of rationality (e.g. transition costs) to envisage political dimensions (Molle, 2003; Wester and Warner, 2003). Strategies employed by government should be understood with

[48] Falkenmark et al (1989) developed the water stress index to quantify levels of scarcity. 1700m^3 of renewable water resource per capita per year is the threshold value, below which a country or region experiences regular or occasional water stress. Chronic water scarcity occurs from 1000-500m^3; and below 500m^3 denotes absolute scarcity.
[49] Turton and Ohlsson (1999) distinguish between 'first-order scarcity' of physical water availability, and 'second-order scarcity' of the social (and institutional) resources, required to adapt to the former.
[50] Often with increasing water scarcity with basin closure (Molle, 2003).

regards to the benefits and increased power and control over water resources that they allow (Molle, 2003). Turton and Ohlsson (1999) identified the building up of government's power with the launch of the hydraulic mission. The financial costs of supply, conservation and allocation are generally of decreasing order[51]. Expensive supply strategies (such as inter-basin transfer) are often justified and implemented to serve political agendas and accrue financial benefits to involved parties, often in preference to demand management options which can be politically more risky to implement with large farmer vote blocks (ibid).

Agrarian pressure is a significant factor in many developing countries whose rural economy is primarily agrarian based. The pressure on government to expand and provide sufficient irrigation water to rural areas is significant, particularly the political clout of the farmer sector block vote in elections. Furthermore, the wider political importance of maintaining and expanding national and state food sufficiency and security cannot be over emphasised (Allan, 2002). Achieving spatial development equality over a country, state, or river basin has been found to drive supply strategies. Regions with comparative disadvantages[52] that lag behind other regions in terms of overall development are often targeted for investment characterised by large-scale supply strategies, even if the economic return is low, with wider political and social concerns over-riding the decisions process. The over-building of river basins is an example of this, where regulated water resources are insufficient to supply existing irrigated areas, but where further irrigation projects are constructed on the claim that under-developed regions have not benefited so far also have the right to receive investment (ibid). Shock or extreme weather events such as flooding or droughts[53] have been found to create windows of opportunity, upon which government acts as they responses consider accordingly in policy development and water management practice (Molle, 2003; Kingdon, 1984). The increased frequency and intensity of floods and drought with climate change projections is particularly relevant in this case. Phases of dam construction have been launched after severe droughts in numerous countries, including Australia (Turral, 1988), Israel (Allan, 1999), and Thailand (Molle and Floch, 2008). Dams are also designed in response to floods, such as the case with the Tennessee Valley Authority and subsequent multi-use schemes (Molle, 2003). Physical restraints influencing the choice of water strategy include the availability of water resources and the degree of water scarcity within a river basin, which can set the limits to water development and management. Increasing rainfall variability at various temporal scales (intra and inter annual) under climate change projections impacting on river basin hydrology, poses significant challenges to water managers (IPCC, 2008; Miley et al, 2008).

[51] With the exception of water treatment, with the potential for investments in urban water supply and sanitation creating the potential for a wave of construction similar to the hydraulic mission (Turral, 1998).

[52] Disadvantaged regions are often characterised by arid or semi arid conditions where agriculture is traditionally rainfed and the general physiographic conditions are relatively less conducive to medium or large scale canal irrigation.

[53] Often resulting in accompanying food shortages, disruption to livelihoods, humanitarian disasters, and the potential for migration from rural to urban areas in some case.

2.5 The hydrocracy and the hydraulic mission

The section begins with a definition of GoI water organisations, termed the hydrocracy in this thesis. The five paradigms of water management identified by Allan (2003) are discussed to understand the historical and present day development and management of water in a country. It then moves on to explain the role of the hydrocracy in the hydraulic mission. Chapter 4 details the Indian national and AP state hydraulic missions (Section 4.4).

2.5.1 Hydrocracy

A common definition of an organisation is 'players within the game', in clear distinction to that of institutions[54] being 'the rules of the game' (North, 1990). Organisations are also defined as 'groups of individuals bound by some common purpose to achieve objectives' (North, 1995:38); and 'a group of people with shared goals and some formalised pattern of interaction' (Merry et al, 2007:196). Organisations can also include political, social, economic and educational bodies.

The focus of this thesis is on government as organisations, that of the GoI Ministry of Water Resources (MWR) and AP state Irrigation and Command Area Development (ICAD) department. However, water user associations, privatised water companies, water research organisations, farmer unions, non-government organisations and regulatory bodies are also water organisations; exhibiting the diversity in scope, size, structure, permanency and organisational purpose (Merry et al, 2007). The MWR and ICAD are government bureaucratic organisations characterised by rules of procedure and accountability, hierarchical relationships, and role differentiation (ibid). They are defined as the executive and implementing arms of government, created for the translation and enforcement of legal and water policy provisions (Saleth, 2004). They are formal organisations, particularly when compared to non-government organisations and water user groups (Merry et al, 2007).

The term hydrocracy is used in this thesis in a collective sense to denote government water organisations such as ministries and departments responsible for water resource management and irrigation, specifically, the MWR and AP ICAD. The origin of the word hydrocracy arises from a combination of two words, hydraulic bureaucracy, in specific reference to government ministries and water departments (Wester, 2009, 2008; Molle et al, 2009; Mollinga, 2005). The hydrocracy consists of 'powerful state water bureaucracies' (Molle et al, 2009:336) who control, manage and monitor water resources (ibid; Suhardiman, 2008; Wester 2008; Mollinga, 2005) (Section 4.2 for organisational arrangement and responsibilities of the MWR and AP ICAD).

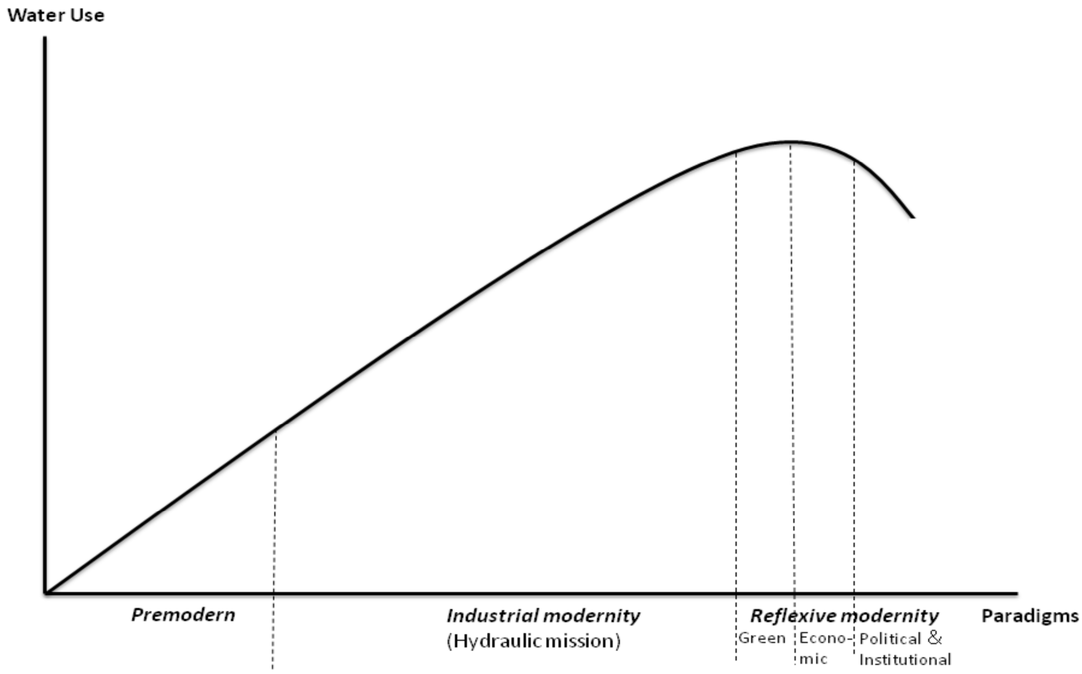
[54] Water institutions (government) consist of three components: policy, organisations and law (Saleth, 2004; North, 1990). Saleth (2004) refers to government institutions as 'entities defined by a configuration of policy, legal and organisational rules, conventions and practises that are structurally linked and operationally embedded in a specified environment '(ibid:3). The identification of these three components originates from the Institutional Analysis and Development Framework developed by Ostrom (1990), drawing on new institutional economic theory (North, 1990; Williamson, 1975).

As discussed in this thesis, the hydrocracy as government organisations (MWR and ICAD) is part of the iron triangle of actors set within a larger web of interests including other non-government actors, operating in the wider political economy and institutional context in India (Section 2.5.3).

2.5.2 Hydraulic mission

In charting the historical evolution of water management, Allan (2003) identified five paradigms[55] along which a country or region passes. The vertical axis on Figure 2.13 represents water use typically for agricultural and irrigation purposes, with the horizontal axis representing time.

Figure 2.13: Five paradigms of water management (adapted from Allan, 2003)



The first paradigm is that of pre-modern, characterised by limited and centralised technical and organisational (government) capacity, with water being primarily controlled and managed at a small scale at the local level. The relative volume of water use in agriculture is low owing to low technical advancement and organisational capacity to utilise and storage water (ibid). The second paradigm is that of industrial modernity, in which the hydraulic mission is launched, with increasingly large volume of water being used in agriculture, primarily for surface water irrigation purposes. During this phase, ideas of scientific enlightenment, engineering capacity, technical knowledge, science and major investment initiatives centralised by government are witnessed. Control of water through increasing supply side infrastructure dominates, characterised by large scale water storage in reservoirs and canal infrastructure for irrigation purposes to increase food production. By the mid-twentieth century, the hydraulic mission was firmly in place in many developed countries, particularly in the

[55] The Oxford dictionary (2001) defines a paradigm as 'a pattern or model'.

USA (Reisner, 1993), as well as in centrally planned Soviet Union (Josephson, 1995). From the mid-1950s, the hydraulic mission was readily exportable to developing countries (Allan, 2003). The third to fifth paradigms are collectively referred to as reflexive modernity[56] stage, in which the dominant approach of the hydraulic mission is questioned by the emergence of alternative approaches, such as demand management strategies. The third paradigm is that of environmental awareness or green thinking (ibid). The hydraulic mission was challenged by environmental awareness campaign and protests from the 1970s onwards, particularly in western USA (Espeland 1998; Reisner, 1993; Feldman, 1991; Berkman and Viscusi, 1973), the Netherlands (Wiering and Arts, 2006; Disco, 2002), as well as in other developed countries (Allan, 2003). A change in water allocation and management priorities was advocated, first witnessed in semi-arid region of Australia, Israel, western USA, allocating surface water flow for environmental use and reducing the volume used by agriculture, essentially putting water back into the environment (ibid). Internationally, large post-war investment in irrigation started to decline from the 1980s, with increasing concerns regarding improving the management of existing irrigation as opposed to constructing new systems (Chambers, 1988). From the 1980s onwards, hydrological data in western countries began to reflect the allocation of a proportion of surface water to the environment (Allan, 2003). The fourth paradigm heralds the economic valuation of water, promoting water demand management to improve water use efficiency. In many developed countries, this paradigm began in the early 1990s, with many international organisations (World Bank, GWP, WWC) attempting to export this approach to developing countries from the early 2000s onwards (ibid). The fifth paradigm represents water managed as a political and institutional process. In some developed countries, this paradigm began in the early 2000s, epitomised by IWRM approaches including inclusive participatory processes, establishing river basin organisations and considering the river basin as the hydrological unit of examination. This stage also witnesses increased technology orientated management, building organisational and management capacities, sectoral integration, and equitable allocation of water between sectors, including sufficient environmental flow allocation (ibid).

A country's location along the management paradigm trajectory is determined by the specific context of a number of factors, including the physical, hydrological, socio-political, economic, culture and history (ibid). The majority of developed countries have passed beyond the hydraulic mission paradigm by the mid to late 1970s, and can be considered to be operating within the reflexive modernity stage. However, although not without exception, many developing countries are largely operating in the mid to latter phase of the hydraulic mission, with tentative moves in policy and practice towards the reflexive modernity stage, with some countries more advanced along the paradigm trajectory than others. Shah (2006) considers the level of a countries' economic development to be influential in the level of formalisation of the water economy[57].

[56] Reflexive modernity is a termed used by Beck (1999) and Giddens (1990) to denote the questioning and potential change in direction from prior stages of development as society modernises and develops.

[57] Based on institutional economic theory, Shah considers that as the economy of a country develops, the proportion of rural and agrarian population declines, and hence does the total volume of water used in agriculture and irrigation. The self-provision of water which characterises an informal water economy, is increasingly replaced by service providers (including government) (Shah, 2006). Fiege (1990) provides detailed elaboration on the nature of formal and informal economies, based on new institutional economic theory.

2.5.3 The role of the hydrocracy in the hydraulic mission

The historical development of the hydraulic mission can be traced back to the mid-late 1800s during the 'irrigation crusade', with increasing calls for central government to take a lead role in irrigation development within colony countries (Wester, 2008). In colony countries, the British (Stone, 1984), Dutch (Ertsen, 2005) and French (ibid) actively embarked upon irrigation development as part of their 'civilising mission' (Wittfogel, 1957). A number of powerful irrigation agencies were created in the early 20th century. First and foremost was the Bureau of Reclamation in the USA created in 1902, along with the National Irrigation Commission in Mexico (1926), the Department of Canals in Siam (1902), and the General Directorate of Public Works in Turkey (1914). However, in European countries Corps of Engineers had been created much earlier in the late eighteenth century in France, Spain and the Netherlands (Molle et al, 2009).

Large-scale infrastructure-based water resources development was pioneered by the Bureau of Reclamation in the USA (Reisner, 1993). Technological innovations and a powerful political lobby mobilising significant funds led to the advent of the Tennessee Valley Authority in the 1930s, following the great depression. River basin development was taken to a grand and unprecedented scale. Under the design of bringing river hydrology under total control, all major rivers in the basin were dammed with multipurpose schemes proving irrigation water, hydropower, flood protection, transportation and other uses. This approach was taken up in the Colombia basin regarding the Colorado River in western USA, first with the Grand Coulee dam, and then the Hoover dam (the largest in the world at the time), ushering in a generation of large dams and multipurpose schemes (primarily for irrigation) in mid-west USA[58]. Post second world war decades witnessed a surge in the hydraulic mission globally. From 1950 to 1990, the number of large dams[59] at a global level increased from 5,000 to 45,000 (WCD, 2000); whilst the total area under surface water irrigation doubled from 140 to 280 million hectares (Merry et al, 2007).

The advent of the hydraulic mission[60] can be witnessed with the onset of water resources development led by the state, characterised by extensive and intensive water capture and control through investment in and construction of large-scale hydraulic and other related infrastructure (Molle et al, 2009; Wester 2008; Turton et al, 2004; Allan, 2003; Swyngedouw 2004; Reisner 1993). Wester (2008) defines the hydraulic mission as: 'the strong conviction that every drop of water flowing to the oceans is lost, and that the state should develop hydraulic infrastructure to capture as much water as possible for human uses (ibid:10)[61]. The hydraulic mission aims at capturing water for increasing irrigation capacity, preventing disasters from flooding, and increasing hydropower capacity, with the overall aim of securing water for the state (Molle et al, 2009:333).

[58] In a speech by Theodore Roosevelt, the president of the USA in 1901, stated that 'The western half of the United States would sustain a population greater than that of our whole country if the waters that now run to waste were saved and used for irrigation' (Reisner, 1993:79).
[59] Large dams are defined as dams with a depth of over 15 m and/or a capacity over 3.5 million m3 (WCD, 2000).
[60] Reisner (1993) does not use the term 'hydraulic mission'; whilst Swyngedouw (1999) refers to the 'hydraulic engineering mission' without defining it.
[61] Turton (2004) offers a similar definition of the hydraulic mission as 'the official policy that seeks to mobilise water and improve water and improve water security of supply as a foundation for social and economic development' (ibid:11).

The advent of the hydraulic mission signals the beginning of the river basin development stage identified by Molden et al (2005) (Figure 2.11). Before the onset of the hydraulic mission, water was controlled at a local small scale. Ultimately, if left unchecked, the hydraulic mission will lead to river basin closure (Wester, 2008; Molden et al, 2005) (Section 2.4.4.2 for discussion on river basin closure).

The hydrocracy is the carrier of the hydraulic mission (Wester, 2008), informed by industrial or high modernity[62] (Scott, 1998), emphasising technical progress to make 'deserts bloom' (Molle et al, 2009:330) in controlling nature and to conquer the desert by developing water resources for the sake of progress[63] (Wester, 2008; Allan, 2002). Furthermore, its pursuit is considered as an intentional political strategy for controlling space, water and people, an important part of everyday forms of state formation (Wester, 2008; Swyngedouw, 2007; Wehr, 2004; Allan, 2002; Reisner, 1993; Worster, 1985; Wittfogel, 1957). Technical expertise and managerial bureaucracy of the hydrocracy are considered to constitute an instrument of social power (Molle et al, 2009; Swyngedouw, 1999; Worster, 1985), in the mutual dependence of capital investment in hydraulic infrastructure and the command of knowledge and technical expertise to administer and manage it. For instance, Worster (1985) states that the 'hydraulic means of production depended on the conversion of water from nature into a quantifiable commodity, which required the application of rational technical knowledge, and which in turn made technocrats and their practices inherently authoritarian' (ibid:51). Hydraulic infrastructure projects have been justified because they are symbolic to the development of the state and represent national prestige (Molle et al, 2009). In sustaining the hydraulic mission, the hydrocracy mobilise knowledge, expertise and human resources, and also large amounts of funding to support these major projects (ibid). The hydrocracy is staffed by a cadre of professional, mostly consisting of civil engineers, driving the infrastructure development approach to control water (ibid).

The hydrocracy should not be understood as an all powerful government agency relatively effortlessly imposing its will through the construction of large-scale water infrastructure (Wester, 2008). The hydrocracy's ambitions closely align with that of other key actors set within a wider political and economic context, which has been found to sanction and allow such an approach to water management. Molle (2008) identifies the hydrocracy within a 'web of interest' group including politicians, construction companies, land elites, development banks, donors, consultants, private water companies and business contractors, 'whereby the ways the flows of water are created or modified by water infrastructure are intertwined with flows of power and influence, often manifested in the form of political or financial benefits, whether private or collective' (Molle et al, 2009:336). The convergence of interests between these actors creates a powerful coalition (Moore, 1990). Politicians regard large-scale infrastructure projects as a means to create a powerful supportive constituency that will ensure political control over many years (O'Mara,1990). Private infrastructure companies and consultants benefit financially, and often have the political clout to push large

[62] High modernity is defined by Scott as a vision of how the benefits of technical and scientific progress might be applied by the state in every field of human activity (1998:90).
[63] Large dams have been described as 'much more than simply machines to generate electricity and store water. They are concrete, rock and earth expressions of the dominant ideology of the technological age; icons of economic development and scientific progress' (McCully, 2001:3).

infrastructure projects (Scudder, 1994). In developed countries, iron triangles (Woodall, 1993) of vested interests between politicians, business and the hydrocracy have been documented (Repetto, 1986), including Japan (Feldoff, 2002) and the USA (McCool, 1994; Reisner, 1993); characterised by a climate of bribery, bid-rigging, exchange of favours, or overestimation of benefits and neglect of costs in order to secure a steady flow of projects (Molle et al, 2009). In developing countries, interest groups consisting of 'iron rectangles' of politicians, the hydrocracy, private construction companies and development banks, who consider large projects as a concrete development intervention, maximising aid flow and minimising project management costs (Howe and Dixon, 1993). According to Briscoe (1999) 'rent-seeking behaviour is deeply embedded in the social and political fabric of major irrigating countries and thus changes only slowly and usually because of major exogenous threats' (ibid:463). The support of politicians for the hydrocracy's approach is an important feature of the hydraulic mission (Molle et al, 2009). Often large investments are organised by the hydrocracy along with politicians who are involved in the management of water resources (ibid; Wester 2008). As regarded by Allan (2002): 'engineers solve problems and engineers show themselves to be very competent in solving water problems in early modernity. They came to be essential allies of the state in achieving economic goals such as food self-sufficiency. Politicians, engineers, farmers and food consumers were all certain that the progressively larger withdrawals of water were good' (ibid:188).

2.6 Institutional reform

Reforming water institutions in developing countries has received much attention in recent decades, with a large body of literature examining different approaches of the three institutional components of policy, organisation and legal; the 'three pillars' of water institutions (Merry et al, 2007; Shah, 2005, 2006; Saleth, 2004). The focus of this thesis is the organisational response of the hydrocracy, particularly the policy and water management practices to respond to climate change. Therefore this section focuses on the reform process of government water institutions, focusing on policy and organisational components.

2.6.1 Triggers that set-off institutional reform

There are numerous pressures that can initiate institutional reforms. Governments in developing countries are faced with increasing water challenges in feeding growing populations, improving rural livelihoods and incomes, reducing poverty whilst managing finite water resources in a sustainable manner (Merry et al, 2007). Pressures include internal and external factors to the water sector. Internal factors include water scarcity, increasing demand and competition from water sectors and users, water conflicts, physical deterioration of infrastructure (ibid); as well as challenges from other rival government bureaucracies, especially the agriculture department (Molle et al, 2009). External factors include economic development, demographic growth, achieving and sustaining food security, technical progress, economic and political reforms, international development commitments, changing social values and ethos, global trade, requirements of development partners, poverty, climate change, financial and funding restrictions, the rise of environmental movements particularly lead by civil society, and natural disasters including floods and droughts (Molle et al, 2009; Merry et al, 2007; Shah, 2006; Saleth and Dinar, 2000). Water crises, particularly droughts and floods, have been found to be a factor in motivating reform initiatives (Saleth, 2004), in line with the policy window hypothesis developed by Kingdom (1984).

2.6.2 Reforming the hydrocracy

With the historical and present day focus of many hydrocracies on the hydraulic mission, reform essentially entails a transition from a primary focus on water resource development defined by the construction of large-scale hydraulic infrastructure increasing storage, to polycentric[64] water governance practices including the promotion of demand management and IWRM principles (Merry et al, 2007; Wester et al, 2005; Allan, 2003). Such a transformation requires significant institutional transformations (Turton and Ohlsson, 1999). Reform essentially entails a paradigm shift, moving beyond the hydraulic mission to the reflexive modernity stage of water management paradigms identified by Allan (2003) (Figure 2.13). Such a shift should be in both organisational approaches and policy declarations, as well as policy implementation and water management practices on the ground. Policy statements are considered to signify the beginning of the long-term process of institutional change, although it is acknowledged that the policies may not mean much unless they are implemented on the ground (Saleth, 2004:13).

Reform initiatives generally focus on decentralisation, privatisation and promoting participatory approaches for Water Resource Management (WRM). Particularly challenging are implementing demand management and IWRM-orientated reforms, as highlighted by the interactive model in negotiating the politically contested nature of organisational reform and issues of implementation on the ground. Based on a detailed review of water reforms in developing countries over the last three decades, Merry et al (2007) concludes that the hydrocracy should play a leading role in water reforms, whilst paradoxically at the same time, it itself is in need of significant reform.

Decentralisation

Decentralisation is considered as a key factor in water sector reform, an important process in moving beyond the hydraulic mission to the reflexive modernity stage (Allan, 2003; Saleth and Dinar, 2000). The process of decentralisation essentially involves a redistribution of power and authority for water management and development (Wester, 2008). Decentralisation is understood as 'the delegation of power to lower levels in a territorial hierarchy, whether the hierarchy is one of governments within a state or offices within a large

[64] The polycentric governance is considered to include integrated and adaptive inter-sectoral linkages, with coordination amongst stakeholders, agencies and other jurisdiction responsibilities for a range of policy sectors (Molle et al, 2007). It is considered to be more flexible and adaptive than unicentric arrangements (Pahl-Wostl, 2007).

organisation' (Smith, 1985:1)[65], and also the inclusion and delegation of authority to non-state actors for water management. Over the course of the hydraulic mission, the hydrocracy has played a leading and formative role in developing hydraulic infrastructure to control water resources development, as a centralised and highly technical organisation. The control of water by the hydrocracy has often been at the expense of local water user groups and other water-related government departments (for instance, agricultural and rural development departments). The decision making process has been internalised by the hydrocracy over time, both at the national and state government level, with decisions often made by a handful of powerful bureaucratic elites (Wester, 2008; Mollinga, 2005). Decentralisation can include devolution of power to water user associations promoting participatory approaches, irrigation management transfer programmes, river basin organisations, water regulatory authorities, water management committees, and deconcentration[66] of government bureaucracies (Robinson, 2000).

Privatisation

Increased private sector involvement in the construction and management of water systems is often advocated in response to inefficiency of pubic sector agencies (Merry et al, 2007); as they are perceived to have lower labour costs and stronger incentives to provide a better service. However, private sector involvement is primarily focused on delivering domestic water supplies and desalinisation and more recently in partnerships in regulation, rather than large-scale irrigation systems of South Asia; where involvement is limited to operation and maintenance in some cases and construction of hydraulic infrastructure (ibid). Financially viability and technical feasibility often defines the scope of private sector involvement, limiting their role to that of service provider to the government for large scale irrigation management along with construction of infrastructure. Furthermore, as water is a public resource under legal provision, it is the governments role and mandate to manage large scale irrigation systems. The hydrocracy is resistant to relinquishing significant control of water (Molle et al, 2009), thereby bringing in the private sector for task-specific activities in the irrigation sector, and not complete management. However, an important feature of private sector involvement is that of technological innovation throughout different sectors of water management (Shah, 2009).

2.6.3 The hydrocracy's resistance to reform

The hydrocracy's resilience to internal challenge in reproducing themselves was first noted by Wittfogel (1957) with reference to colonial countries irrigation operations in various Asian colonies: 'dominated by its monopoly bureaucracy, it continued to muster the technical and intellectual skills necessary to it's perpetuation' (ibid:422). The resistance of the hydrocracy to reform in more recent times has been documented by Bolding

[65] Smith (1985) goes on to further explain decentralisation as: 'the extent to which power and authority are dispersed through the geographic hierarchy of the state, and the institutions and processes through which such dispersal occurs. Decentralisations entails the subdivision of the state's territory into smaller areas and the creation of political and administrative institutions in those areas' (ibid:1).
[66] Deconcentration is used to describe decentralisation within bureaucracies, transferring administrative responsibilities to local offices of national and/or state government (Robinson, 2000).

and Mollinga (2004), based on in-depth examination of irrigation reform in seven developing countries. Internally, hydrocracies have been found to be resistant to fundamental change (Molle et al, 2009), including in Mexico (Wester, 2008; Rap, 2004), Indonesia (Suhardiman, 2008), Thailand (Molle and Floch, 2008), the USA (Reisner, 1993), and the Philippines (Panella, 2004). Furthermore, hydrocracies in developed countries have also been found to be somewhat resistant to change, unable to completely move on from hydraulic infrastructure approaches, even whilst promoting and implementing the reflexive modernity stage, including demand management and IWRM approaches (Molle et al, 2009). As in the western USA, documented by Lach et al (2005) and McCool (1994), who found that 'the nature of the region's water management regime allowed those who benefited from the status quo (e.g. large-scale infrastructure development) to effectively resist needed reforms' (1994:13)[67].

Molle et al (2009) identify a number of strategies by which the hydrocracy resists and effectively deflects deep-rooted change, and in doing so, reinvents itself in a changing world under different pressures to reform. Such strategies include shifting (irrigation operation and maintenance) costs to the users (primarily famers), and capitalising on the rhetoric of privatisation and its alleged benefits (ibid). A counter strategy to decentralisation has consisted of 'taking advantage of the observed difficulty in harmonising competing claims from provinces or sub-basins, coordinating their needs and action to recentralise decision making' (ibid:342). Hydrocracies have been found to divert, neutralise and reconfigure institutional reform initiatives to essentially continue with hydraulic infrastructure construction in line with the hydraulic mission (ibid). However, Merry et al (2007) do not suggest that no water reforms have taken place in the last three decades, but that an emphasis on a deeper transition is required (ibid).

The Indian hydrocracy's resistance to change

Mollinga (2005) highlights the paradox of Indian water policy processes and institutional reform. On one hand, India has a very active civil society sector campaigning on water issues at the local, national and international level. It is the largest functioning democracy in the world, with over one billion electorally empowered citizens. There exists a free and vibrant press, generally critical of government policies and procedures, exposing contemporary corruption practices within government. However, on the other hand, in spite of pressure from numerous quarters for change, Mollinga (2005) claims there has been little movement regards to the redefinition of mandates, roles and activities of the Indian hydrocracy. The Indian hydrocracy has been 'extremely resistant to change' (ibid:5); very few of the new demands for change in the water sector have been internalised. Mollinga (2005) concludes by stating that 'so far the Indian hydrocracy has been largely successful in ignoring the societal demands for new and different approaches to water management, and has been able to keep itself to its main professional orientation, the planning, design and construction of water infrastructure – preferably large-scale' (ibid:5). Furthermore,' at the level of formulation of new public policy,

[67] Walker (1994) examined how California's water agencies are well versed in 'non-political politics', depoliticising issues, whilst at the same time, establishing alliances with economic elites to keep the water flowing (Wester, 2008; Walker, 1994).

the changes have been very limited, even at the symbolic and discursive level the faithfulness to the old paradigm (e.g. large-scale infrastructure development) is very strong, and those who advocate the need for alternative approaches seem to be making very little headway within the domain of governance and policy' (ibid: 5). However, these insights were written in 2005. This thesis will explore the policy response of the Indian hydrocracy to climate change in more recent times, to examine if and how the resistance of the hydrocracy has changed.

2.6.4 Results of reform in the water sector

In an overview of reform attempts in agricultural water management in developing countries in recent years, Merry et al (2007) concludes that none of these reforms have 'substantially improved water management at any scale' (ibid:198), owing to a number of factors. The first is a bias towards social engineering[68] that went largely unquestioned until the late 1990s (Mollinga et al, 2007); another is a disproportionate focus on the river basin as the unit of examination, instead of the problemshed[69]; and finally a lack and neglect of pluralities, such as legal pluralism, polycentric and multiple uses of water. Central to the lack of progress is that water reforms are conceived and implemented as 'neutral and technical interventions aimed at assisting central water agencies in controlling and managing water resources and crisis' (Boelens et al, 2005:753). The deeply embedded political nature of water reforms and the struggles they entail is often glossed over, or at best, under emphasised (Wester, 2008; Merry et al, 2007).

Significant fault for the relative lack of reform progress is attributed to the dominance of the social engineering paradigm in recent years, based on the linear policy model (Section 2.7.2), characterised by simplistic assessments and policy prescriptions without considering local specific contexts and policy implementation, as conceptualised in the interactive model which regards policy implementation as a politically contested process (Section 2.7.3) (Mollinga et, 2007; Grindle and Thomas, 1990; Warwick, 1982). Part of the explanation for this lies in the fact that multilateral, bilateral donors and politicians overly focus on single-factor panaceas, as they can be communicated with progress monitored by relatively few simple indicators (ibid). When considering the investment and efforts in water (particularly irrigation) reform in the last thirty years, the progress witnessed is very limited. Experience shows that institutional transformation and reform is inherently complex, uncertain, slow, and politically contested (Wester, 2008; Merry et al 2007; Mollinga et al, 2007; Perry, 1995).

However, the linear model and social engineering approaches still hold relatively strong in contemporary times. Mollinga et al (2007) offers three potential explanations for its longevity. The first regards the view

[68] Merry et al, 2007 defines social engineering 'in a narrow sense to refer to linear models for changing societies or organisations, where blueprints are used to replicate a structure in a new context that may have worked elsewhere. Application of this model to achieve social change—if x then y follows—is based on a misunderstanding of the complex, nondeterministic, and stochastic nature of social organisations. Social engineering as used here does not imply pessimism about the possibility of facilitating and guiding social change, but cautions against overly simple prescriptions' (Merry et al, 2007:198).

[69] Problemsheds are the boundaries of a particular problem as defined by a network of issues, often inter-linking issues outside of the physical watershed as a unit of purely hydrological examination, including issues such as trade in food, politics and wider political economy issues (Allan, 1998).

that few policy makers want to acknowledge that the reform process in inherently complex and uncertain, preferring to couch terms of engineering analogies more appropriate to the water sector, with scientifically based higher degrees of certainty that may be appropriate. Secondly, reform initiatives are usually promoted through projects, which by definition are defined by relatively short time frames, and through which the advocates of such (politicians, donors) are judged accordingly. This short-sightedness misses the point that institutional change is inherently a long-term process, taking years to decades. And finally, the negotiation, communication and consensus building skills required for successfully championing reforms are in short supply. Civil servants and politicians generally tend to be risk averse; promoting institutional reform is always resisted by those with vested interests in keeping the status quo (ibid). Based on the fact that institutional reform is highly contextualised to each case and location, no blueprint for success is possible; rather, reform remains a process of learning and adapting over time (ibid; Merry et al, 2007).

2.6.5 Political aspects of reform

Water reform is considered as essentially a political process (Merry et al 2007; Mollinga et al, 2007; Boelens et al, 2005; Mollinga and Bolding, 2004; Perry, 1995). Institutional transformation is 'inherently political and typically slow and difficult with winners and losers and outsiders who also have their own interests' (Merry et al, 2007:218). The political nature of water management involves the mediation of social relations of power amongst the actors involved (Mollinga et al, 2007). Some interests are politically more powerful than others, often distorting outcomes (and policy implementation) in favour of special interests (ibid). The complex, political and contentious nature of reform requires an analysis of options, vested interests, potential costs and benefits, as well as potential allies and opposition (ibid).

North's influential analysis of institutional change, rooted in new institutional economic theory, concluded that institutional change is 'often slow, complicated and glacier in character with change typically taking place incrementally rather than in a discontinuous fashion' (North, 1990:6). 'Key aspects of institutions persist over time, change is path dependent; where an institutions is going is shaped by where it has been' (ibid:6). Although formal rules may change overnight as a result of policy change, informal constraints embodied in customs, traditions and codes of conduct are much more impervious to deliberate politics (North, 1990). Such is also confirmed within the water sector, with reform characterised by a slow and gradual process, in an open ended, slow, non-linear fashion with a high level of uncertainty (Merry et al, 2007).

2.6.6 Enabling reform

There is general consensus that successful and lasting reform will require the government, primarily the hydrocracy, to play a leading and instrumental role (Merry et al, 2007). Successful water reform initiated by civil society are rare (Mollinga et al, 2007); donor led reform tends not to last beyond the project timeframe, if implemented at all; private sector involvement may create demand for institutional change but its effectiveness is limited without state ownership of the reforms (Merry et al, 2007). This is a crucial issue, that institutional reform has to be owned from within the government, and not imposed externally. The government will remain the principal driver of reform for the foreseeable future, but paradoxically, it is also the organisation in most need of reform (ibid). In most governments there are few incentives for reform, for instance, in overcoming the male-orientated engineering human resource profiles and the elite capture of reforms (Bolding and Mollinga, 2004). Based on reform initiatives over the last thirty years, Merry et al (2007) make a number of suggestions to enable effective and lasting reform.

In recognising the political dimensions of reform, the process must consider political feasibility in the proposed change. Mollinga et al (2007) offers a number of key question to consider, each of which are to be considered as highly context specific[70]. How government acts with regards to water management and policy depends on their position and interests (ibid). Coalition building along mutual line of interest, both within government and outside of government is considered important, particularly the private sector and civil society to help facilitate the sufficient 'push' for long-term change (Merry et al, 2007).

The presence of champions or agents of change within government is important. Sutton (1999) considers an agent of change to be an individual or group who sees reform as an opportunity rather than a threat, who will be instrumental in managing and taking it forward. The individual (or group) 'will give direction and momentum to the implementation of new policies and methods' (ibid:6, quoting Ambrose, 1989). Israel (1987) concluded along similar lines, stressing the importance of outstanding managers in fostering institutional reform from within government (ibid:4); also confirmed by a DFID report on capacity development and institutional performance in developing countries (Teskey, 2005). Working within often hierarchal top-down procedure-driven government structures requires personnel with skills to assess the situation, draw lessons from experience, and to create effective strategies to move forward (Forester, 1999; Schon, 1983).

Consistency of a proposed reform within specific socio-economic and technical context is crucial, shaped by history, culture, social relations, hydrology, political and economic conditions (Perry, 1995); in moving away from the social engineering solutions that have been the main focus of reform in recent decades. The enabling environment has its own dynamics of change, necessitating on-going technical and institutional adjustment (Molden et al, 2005). Information, knowledge and human resource capacity is deemed important to promote water sector reforms. However, the availability and reliability of data is often limited, particularly in case where inter-state water conflicts exist, with data being declared as state secrets. Information and data has

[70] Mollinga et al (2007) offers a number of questions in negotiating the political feasibility of reform: 1) What will be the benefits of institutional and policy reform and how will these benefits be distributed? What will be the costs and who will bear them? 2) Who will be the bearers of institutional transformation: who will constitute the coalition of interest groups to push forward and implement the change?
3) Around which issues can such efforts be organised most productively? 4) How can these coalitions be supported? 5) What can realistically be done to adapt the enabling and constraining conditions for this institutional transformation? 6) How can knowledge producers and processors such as academics, consultants, and reflective practitioners play a more active role in this process? (ibid:706).

been found to be manipulated to serve political agendas, and on occasions, to undermine reform initiatives (Vander Velde and Tirmizi, 2004). Information and data dissemination and sharing within the public domain is considered important to empower stakeholders by increasing their knowledge, particularly to instil public trust and promote greater government accountability and transparency (Merry et al, 2007; Moench et al, 1999). Diversifying human resource capacity of the hydrocracy to include multi-disciplinary training and approaches to water management is considered important, particularly considering the heavy bias towards technical and engineering staff training. Government staff retention of individuals who are promoting reform within key government positions is imperative, particularly avoiding or minimalising post transfers within government or loss of staff to other employment sectors.

2.7 Understanding public policy processes

2.7.1 Policy

Water institutions (government) consist of three components: policy, organisations and law (Saleth, 2004; North, 1990)[71]. This section discusses the theory relating to policy and policy processes, whilst the organisational component of government is examined in Section 2.5. The general definition of a policy is 'a set of interrelated decisions taken by a political actor or group concerning the selection of goals and the means of achieving them within a specified situation where these decisions should, in principle, be within the power of those actors to achieve' (Howlett and Ramesh, 1995:36). Or another often quoted definition is policy as 'an intrinsically technical, rational, action-orientated instrument that decision makers use to solve problems and affect change' (Shore and Wright, 1997:5). Any organisation can have a policy. However, the focus of this thesis is on public (government) policy. Policy science literature offers a number of approaches to understand public policy development and implementation (Grindle, 1999, 1977; Mackintosh, 1992; Grindle and Thomas, 1990; John, 1998; Hill, 1997). It is noted that the stabilisation of a particular interpretation of policy-related events is what Mosse (2003) terms a policy model. Such policy models include the linear and interactive models, window of opportunity policy formulation, and policy discourse.

2.7.2 Linear policy model

Understanding policy is historically rooted in the linear model of public policy development. This model, often referred to as 'policy as prescription', assumes that the policy process consists of various subsequent stages: problem identification, evaluation of alternatives, policy formulation, political decision and finally implementation (Mackintosh, 1992). It is based on the assumptions of rational and instrumental behaviour on the behalf of a benevolent agency (the government), offering a prescriptive and essentially top-down

[71] Saleth (2004) refers to government institutions as 'entities defined by a configuration of policy, legal and organisational rules, conventions and practises that are structurally linked and operationally embedded in a specified environment '(ibid:3). The identification of these three components originates from the Institutional Analysis and Development Framework developed by Ostrom (1990), drawing on new institutional economic theory (North, 1990; Williamson, 1975).

approach as to how policy should work (Sabatier, 1999). The model is founded upon the notion that the policy decision is the key process, and once this decision has been made, all that remains is implementation (Mackintosh, 1992). As stated by Grindle and Thomas (1989): 'according to the linear model, a proposed reform gets on the agenda for government action, a decision is made on the proposal, and the new policy or institutional arrangement is implemented, either successfully or unsuccessfully' (ibid:1164). Warwick (1982) terms the linear model as the 'machine model' of policy implementation, derived from classical administrative theory, a quasi-mechanical exercise in which organisational units and individual implementers from a delivery system to the program clients become receptacles of the service delivered' (ibid:40). Furthermore, 'it assumes that a clearly formulated plan back by a legitimate authority contains the essential ingredients for its own implementation' (ibid:179). Partial or whole failure to implement policy has been blamed on bottlenecks, political interference or lack of political will; with external factors having little to do with policy proper, namely, the policy decision (ibid; Grindle and Thomas, 1989). The important distinction between the policy decision and implementation can be ascribed to socially-based thought on inevitability - as societies become more complex and differentiated into specialist areas, so does the iron cage of rationalism and bureaucratisation (Weber, 1991). The linear model has been the dominant model to understand public policy throughout the 1970s and 1980s (Grindle and Thomas, 1989; Mooji, 2003; DeLeon, 1999); and still to this day remains enduring in understanding public administration and policy (Long and van der Ploeg, 1989), at least in part because it portrays the world as controllable and amenable to rational analysis (Fischer, 2003).

The linear model has received significant critical analysis as it excludes the implementation phase of the policy process (Grindle and Thomas, 1990; Hill, 1997; Warwick, 1982). The separation between the policy decision and implementation enables policy makers to escape responsibility (Apthorpe and Gasper, 1996; Clay and Schaffer 1984), stressing that 'policy is what it does' (ibid:18), emphasising the way in which decisions are put in practice, rather than the decisions themselves. It is claimed that this model suits some policy makers who are not interested in policy implementation, or consider it the responsibility if lower-level managers (Wester, 2008; Grindle and Thomas, 1990). Such has beneficial side effects for policy makers as they can blame policy failure on the implementation process and the responsible officials (Wester, 2008).

2.7.3 Inter-active policy model

The inter-active model conceptualises policy as an inherently political activity, with different perceptions and interests contested at all stages, from policy formulation to implementation (Grindle and Thomas, 1990; Grindle, 1989)[72]. The inter-active model, or 'policy as process' (Mackintosh, 1992), considers policy as a

[72] Warwick (1982) offers seven assumptions upon which the interactive model is based: 1) Policy is important in establishing the parameters and directions of actions, but it never determines the exact course of action; 2) Formal organisation structures are significant but not deterministic in their impact; 3) The programme's environment is a critical locus for transactions affecting implementation; environments are multiple, shifting and difficult to predict; 4) Judged by its impact on implementation, the process of policy formulation and programme design can be important as the product; 5) Implementer discretion is universal and inevitable; 6) In human service programmes, clients have a potent influence on the outcomes of implementation; 7) implementation is inherently dynamic and complex (ibid: 181-184).

bargained outcome, with the environment conflictual, a process characterised by diversity and constraint (Grindle and Thomas 1989, 1990). It emphasises negotiation, participatory design and implementation (Gordon et al, 1997), embedded within the wider socio-political and historical context (Grindle and Grindle, 1989). The contested nature of the policy process has been termed 'the politics of policy' (Grindle, 1977). Warwick (1982) states that the 'essence of implementation in the interactive model view lies in the coping with environmental diversity, uncertainty and hostility' (ibid:182). The interactive model is defined as politically contested in two ways: how actors (including the government) negotiate during the policy formulation and implementation stages; and how the actor's agenda is structured and manifested by particular discourses that impose meanings, thereby empowering and disempowering (Keeley and Scoones, 1999). The inter-active model aims to 'demythologise planned intervention' by public organisations (Long and van der Ploeg, 1989).

The interactive model focuses on the conflicts and reactions that a policy generates in implementation and the political and bureaucratic resources that policy makers need to mobilise to deal with the responses in order to sustain the policy (Grindle and Thomas, 1990:1163). 'Implementation is often the most crucial aspect of the policy process, and that outcomes of implementation are highly variable, ranging from success to failure, but also including an almost limitless number of potential outcomes and hence uncertainty' (ibid: 1164). Grindle and Thomas (1990) argue that 'implementation is an inter-active and on-going process of decision making by policy elites (political and bureaucratic officials who have decision making responsibilities and whose decisions become authoritative for society) and managers (implementers) in response to actual or anticipated reactions to reformist agendas' (ibid: 1165). Actors (government) are concerned with achieving politically, institutionally and economically viable outcomes, with the direction of such change significantly influenced by actors in strategic (e.g. government elite) locations (ibid). Central to the model is that characteristics of the policy being implemented will largely determine the reaction of individuals in strategic locations in the public or bureaucratic arenas, which in turn can favour, alter or reverse a policy at any stage of the policy process with numerous potential outcomes (ibid: 1163). This model problematises policy implementation as a political process involving a variety of policy actors in which a negotiation and accommodation of interests occur (Wester, 2008:97). The political nature of the policy process is encapsulated in the interactive model, defined negotiation and bargaining between multiple actors throughout the policy formulation and implementation stages structured by particular discourses that impose meanings, empower and disempower (Keeley and Scoones, 1999), with particular focus on public policy and institutional arrangements that mediate water control (Wester, 2008:23; Mollinga, 2003).

However, a key assumption of the interactive model is that the characteristics of a policy are determined before implementation phase, and these characteristics remain relatively constant during implementation (Grindle and Thomas, 1990:1167). Another key assumption is that decision makers and policy makers do not sufficiency anticipate the responses and reactions to the policy, and do not develop sufficient strategies to overcome opposition from other actors (ibid:1168). A similarity between the linear and interactive model has been highlighted as sharing the same basic assumption that policy formulation and implementation are discrete and sequential activities that are separated (from the public) by a politically and centrally enforced decision (Wester, 2008:97).

2.7.4 State centric policy process

An important characteristic of policy process is whether policy making is state or society centric (Grindle, 1999). In authoritarian systems policy processes tend to be highly state centric and confined to small circles of power within elite circles, with negligible influence of civil society. In democratic societies policy processes are more likely to be society centric, with recognised opportunities for different interest groups to influence policymaking and implementation (ibid). Many developing countries are characterised by state-centred policy processes, where such active public engagement is either absent or much less profiled, with policy being formulated within elite government circles (ibid; Mollinga, 2008). However, a lot depends on the institutions through which civil society involvement takes place (Merry et al, 2007). Grindle (1999) argues that most policy analysis frameworks in developed countries carry several biases by reflecting a society centred policy process, and as a result, they are not able to cope very well with state centred policy processes. Also the institutional setting of developing and transitional countries may be relatively unstable, and institutional and policy evolution a different process as a result. Another bias is the assumption in society-centred frameworks of the sovereignty of the voter in electoral processes, which does not apply in all situations. This means that frameworks of analysis need to be historically and geographically specific (Mollinga, 2008). But overall, the public policies are considered to embody the ambitions of government bureaucratic elites (Wester, 2008; Mollinga, 2005; Mosse, 2003).

In one of the few studies that examines public policy process in developing countries, a number of differences between developed and developing countries are identified (Horowitz, 1989). These include government legitimacy, with policies used to strengthening state legitimacy; the fact that in many developing countries the state structures are large and 'inordinately important' (ibid:197); capacity is often weak to implement the policy; there are often large groups of actors excluded from participation in the policy process; overtly significant weight given to 'expert knowledge'; and finally the importance of foreign models and dependence on foreign experts (ibid). Although cautioning against generalisations, it is claimed that within developing countries, it is not so much the level of development that makes a difference, but the extent to which there are democratic structures in place (ibid:197). It is possible 'to understand many policy phenomena in terms of concepts already embedded in the discourse on public policy in general (ibid:198). Overall, the state is found to be inordinately more influential in the policy formation stage than civil society, with the policy process characterised by contestation more at the policy implementation than at the policy formation stage (Mooji, 2003). This point reiterates that whilst in many developed countries the main area of policy contestation is in the process of policy formulation, in developing countries it is the process of policy implementation that witnesses most struggles and contestations (Grindle, 1999).

2.7.5 Policy window hypothesis

Kingdon (1984) developed the notion of the policy window hypothesis of opportunity, referring to the process by which adaptation actions – policy, regulatory change or otherwise – are facilitated and occur directly in response to a natural disasters, such as extreme weather-related events characterised by a flood or drought. The hypothesis states that immediately after a natural disaster, political will is generally conducive to economic, institutional, legal and social change that can begin to reduce society's structural vulnerabilities to a similar events happening in the future. The policy window hypothesis is based on three main assumptions in the wake of a natural disaster. Firstly, increased awareness of risks after a disaster leads to a broad consensus between the main stakeholders; secondly, development and humanitarian agencies are reminded of the risks and humanitarian implications of disasters; and thirdly and perhaps the most important of all, enhanced political will at the national and local level will more often than not lead to the release of extra resources and funds. Historical changes in water institutions have found to be spurred on by crisis or extreme events, for instance, by flooding or severe water scarcity (Merry et al, 2007; Saleth, 2004; Livingston, 1993; Wengert, 1985).

2.7.6 Political nature of water management

Politics is defined as 'the art and science of directing and administering states and other political units' (New Collins Concise English Dictionary, 1982). This general definition focuses on governance, however, politics can also be defined as 'the complex or aggregate of relationships of people in society, especially those relationships involving authority or power', 'any activity concerned with the acquisition of power' and 'manoeuvres or factors leading up to or influencing (something)' (ibid). Water management is conceptualised in this thesis as a politically contested[73] resource (Mollinga, 2008; Merry et al 2007; Mosse, 2003; Mehta, 2001). Contestation is an inherently political process through which politics is understood as the set of activities through which balances of power[74] that shape water resource use are re-negotiated (Mollinga, 2004: 241). In the last ten years especially, the rise of good water governance within the international forums and discourse (World Water Forum 2004 and the Stockholm Water Week 2006 and 2010) has highlighted the political dimensions of water managing (Mollinga, 2008; Jenkins, 2001).

[73] Contestation refers to water management approaches advocated by government and different actors aligning with particular interests. Politically contested highlights the political aspect to contestation and therefore to water control (Mollinga, 2008; Bolding and Mollinga, 2004).

[74] Power in the overall sense refers to the 'application of means to achieve something' (Giddens, 1976:110), including the 'the capacity or ability to direct or influence the behaviour of others or the course of events' (Oxford Dictionary, 2001). It is defined more specifically as 'power in the narrower, relational sense is a property of interaction, and may be defined as the capacity to secure outcomes where the realisation of these outcomes depends on the agency of others. It is in this sense that men have power over others: this power is domination' (Giddens, 1976:111).

Mollinga (2001) identifies the politics of water as existing in four discrete domains or arenas[75], through which relations of power are constituted and negotiated. These include everyday politics of water (Kerkvliet, 1990); the politics of water policy in the context of sovereign states (Grindle, 1977); inter-state hydro-politics (Elhance, 1999); and global politics of water (Conca, 2006). This thesis focuses on the politics of water policy in sovereign states, with public government policy being defined as a process through which different interest groups (primarily the government) negotiate the modalities of water governance[76] and consolidate this into institutional and organisational arrangement, projects, programmes and procedures' (Mollinga, 2008).
Based on the 'policy as politics' phrase coined by Grindle (1997) referring to the contested nature of water resources conceptualised by the interactive model, water policies can be considered to be negotiated and re-negotiated in all phases and at all levels (Mollinga, 2005). Within the context of this thesis, the politics of policy is considered to be the process of water public policy formulation and implementation by national and state governments. The majority of countries have sovereign water policies, detailing specific plans and targets; for instance, the creation of water infrastructure (irrigation systems and reservoirs) and investment programmes, project selection criteria, cost recovery policy, water pricing, user participation and privatisation, demand management strategies and institutional reform measures (Saleth, 2004).

In the approach conceptualised by the linear model, politics (contestation) is considered to occur only at the level of policy formulation (Grindle and Thomas, 1990; Warwick, 1982). For instance, contestation of actors involved in the policy formation process, or politicians working within a parliamentary or other framework make decisions on priorities and programmes based on scientific advice of natural scientists (Grindle and Thomas, 1990). Once the policy is formulated by government, it is considered as a 'policy statement of intent' (Saleth, 2004:12) or statements on desired water policy and outcomes (Shah, 2005; Mollinga, 2005; Iyer, 2003), regarded by government to automatically lead to implementation (Grindle and Thomas, 1990). As noted by Saleth (2004), water policy relates to the declared statements as well as the intended approaches of national and state governments for water resource planning, development, allocation, and management. However, regardless of how policy is decided, it remains largely symbolic without effective institutions and organisational capacity to transform it into practical reality (Merry et al, 2007).

As conceptualised by the inter-active model, both formulation and implementation of water policies are highly contested. Different interest groups attempt to influence and negotiate both the formulation and implementation stages, through various means. The nature, intensity and effects of this process differ from case to case. This political struggle or contestation takes place within government apparatuses, but also between the interactions of government institutions and other the non-government actors (e.g. civil society and water users) directly and indirectly affected by the policies. Policies are often transformed on their way

[75] The domains or arenas are distinguished on the fact that they have different space and time scales, are populated by different configurations of main actors, have different types of issues as their subject matter, involve different modes of contestation and take place within different sets of institutional arrangements (Mollinga, 2001, 2008).
[76] Governance is defined as 'the range of political, social, economic, and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different level of society' (Rogers and Hall 2003:7). Governance is therefore a broad term that encompasses policy, organisational and legal components of water institutions.

from formulation to implementation, if not made only in the implementation process (Rap, 2007). This field of inquiry could also be phrased as the investigation of actual governance practices regarding water management, with themes like democratisation, decentralisation, transparency, privatisation and public good functions (Mollinga, 2005).

2.7.7 Water control

The concept of water control is central when considering the politically contested nature of water management. Humans have been controlling the hydrological cycle for millennia, affecting the time and spatial characteristics of water availability and quality (Scarborough, 2003). Water control consists of three dimensions: technical control, focusing on the regulation of hydrological processes through technical devices or shaping the natural environment (Plusquellec et al, 1994); organisational control, in guiding human behaviour in water use particularly that of farmers (Hunt, 1990); and socio-political and economic control in which water management is embedded and that constitute conditions and constraints for management and regulation (Bolding and Mollinga, 2004; Bolding et al 1995; Boyce, 1987; Stone 1984). These three dimensions are considered inter-related and mutually constitutive of each other, with changes in one dimension translating to changes in the other two (Wester, 2008; Mollinga, 2001). As considered by Mollinga, management institutions and technical artefacts can be understood as embodiment of particular social relationship of power, and, the other way around, social and economic power in irrigation (and water supply strategies more generally) takes shape in particular forms of organisation and technologies' (adapted from Mollinga, 2003). The concept of water control is directly manifest by specific water management strategies within the wider socio-economic and political contexts (Suhardiman, 2008). Water control is crucial in understanding the hydraulic mission and the government's role in controlling water in space and time, particularly for surface water irrigation (Wester, 2008; Mollinga 2005). However, the concept of water control should not be interpreted as complete control in the literal sense, rather, the persistent endeavours and strategies of the government in attaining complete control. Furthermore, water control should not be considered as only political in nature, determining all other physical characteristics and inter-play; rather, the political aspect is considered as an important assumption and omnipresent factor (Mollinga, 2010).

2.7.8 Policy discourse

Central to this research is understanding how climate change is being integrated into government water policy processes. Discourses[77] are defined as 'ensembles of ideas, concepts, and categories through which meaning is given to phenomena. Discourses frame certain problems; that is to say, they distinguish some aspects of a situation rather than others' (Hajer, 1993: 45). Discourses are frames which define the world in certain ways, in the process excluding alternative interpretations (Grillo, 1997; Apthorpe and Gasper, 1996; Schram, 1993).

[77] Discourse is commonly understood as being synonymous with discussion or alternatively is seen as a shared meaning of a phenomenon (Adger et al 2001), as a sum of communication inter-actions (Sharpe and Richardson, 2001).

They are not the product of or controlled by individuals, but are social and political phenomena (Keeley and Scoones, 1999). The study of policy discourse includes the relationship between policy, knowledge and power (Shore and Wright, 1997). Discourses include ideas, concepts and categorisations that are expressions of power and knowledge, controlling human subjects by the definitions and categories imposed upon them (Foucault, 1991). Discourses aim to control thought processes, closing down the possibility of thinking of alternatives, although often discourses are contested (Mehta, 2001). Discourses have histories and reflect types of knowledge, empowering some institutions and individuals whose concerns and competencies they are associated with, and simultaneously marginalising others (Drysek, 1997).

Key ideas and concepts within discourse do not exist in a neutral and purely technical sense. Rather, Foucault considers discourses as political technologies: 'by taking what is essentially a political problem, removing it from the realm of political discourse, and recasting it in the neutral language of science' (Dreyfus and Rabinow 1982:196). Such ideology informed policies operating as political technologies mask the political agenda and the relations of power that it helps to reproduce (Foucault, 1991). Political technologies are enmeshed in relations of power between organisations, citizens, experts and political authorities (Burchell et al, 1991). In this way, water management strategies advocated by government or other actors discourse's as neutral solutions to manage water in a given context, essentially represent their particular underlying political agenda relating to expression of power and knowledge. Ferguson (1994) claims that the framing of development interventions in a technical policy discourse helps to explain why 'many projects fail in terms of their stated objective while being more successful in terms of unstated (e.g. political) agendas' (Apthorpe and Gasper, 1996:166).

Allan (2002) stresses the importance of the sanctioned discourse within water policy discourses, defined as the 'prevailing dominant opinion and views which have been legitimised by the discursive and political elite' (Jagerskog, 2002:18)[78]. It is argued that the sanctioned discourse sets the limits within which policies have to be pursued, indicating what avenues that may be politically feasible and legitimate, and 'constraining those who may wish to speak or think outside of the discursive hegemony' (Allan, 2002:182).

The inter-relationship between power[79] and knowledge is important when considering discourses. Francis Bacon was the first philosopher to note that 'knowledge is power' (Tovey, 1952). As stated by Foucault, power constantly generates knowledge, which in turn, continually brings about the effects of reinforcement of power (Foucault, 1980). Power cannot be exercised without knowledge, and knowledge engenders power (ibid). The amount of power an individual or organisation has is dependent on knowledge, along with other factors such

[78] Jagerskog (2002) draws on an earlier definition of sanctioned discourse by Feitelson (1999:438) as 'a normative delimitation separating the types of discourse perceived to be politically acceptable from those that are deemed politically unacceptable at a specific point in time'.

[79] Weber (1922) cited in Ziai (2009:185) considers power as 'denoting any chance to implement one's will in a social relation also against resistance'. Power is a concept that is unavoidably value-dependent, states Lukes (2005:30), as 'both its definition and any given use of it, once defined, are inextricably tied to a given set of (probably unacknowledged) value assumptions which predetermine the range of its empirical application'.

as economic, social and political capital. In the case of the GoI's water ministries and departments, the knowledge base including technical and engineering competencies in controlling surface water through infrastructure is unrivalled by other actors in the water policy arena. Furthermore, knowledge in terms of access to classified hydrological data and information technology, can be used in the application of power and hence control by the government within the discourse as the principal actor in water management.
How does policy discourse and the underlying expressions of power relate to the linear and interactive policy models? Shore and Wright (1997) is critical of the linear model approach, characterised by policy formulation as an instrument of benevolent governance, developed in a rational, non-political and unbiased manner by government. Rather, Shore and Wright (1997) considers the inter-active model is more relevant to understand how policy is formulated and implemented by government ideological considerations; operating as a political technologies (Foucault, 1991) and informed by technical knowledge and expertise, ultimately masking underlying expressions of power (ibid; Asthana, 2011).

2.7.9 The public policy process in India

The majority of existing literature on public policy models and process has emerged from developed country settings, where analyses of policy have a long tradition of enquiry, particularly in the USA (Hill, 1997). With notable exception of Horowitz (1989), there have been relatively fewer enquires on public policy in developing countries, despite the emphasis on policy reform initiatives within the development sector (Merry et al, 2007; Keeley and Scoones, 1999). The study of Indian public (government) policy process is relatively under-developed. In a literature review on the public policy process in India, Mooji (2003) claims that 'this is so despite the fact that many Indian social scientists are involved in policy relevant research and aim to contribute, through debate and research, to policy formulation and implementation. These debates are, however, almost entirely dominated by economists, and insights from other social sciences have hardly entered into them. There are very few political scientists, sociologists or anthropologists focusing on public policies. As a result, some aspects of policy studies are relatively well-developed (such as measuring policy effects), but others much less. The issues and questions, for instance, of why policies are formulated and designed in particular ways in the first place, and the political shaping of policies 'on the ground' (implementation), do not receive much attention' (ibid:5). Arora (2002) confirms the assessment of Mooji (2003), in so much as the discipline of political science in India has been neglected in public policy studies: 'political scientists have been engrossed in the study of political institutions and processes, which resulted in a sheer neglect of the systematic study of public policy' (ibid: 46). Arora considers that public policy studies encompasses more than the decision making, but should be seen as an on-going process including implementation (ibid: 46).

In an analysis of the Indian public water policy process, Mollinga (2005) notes the paradox in that water policy formulation is largely generated in elite government circles, despite the fact that India has a very active civil society. This is in part contrary to Grindle and Thomas's (1990) conclusion that in developing countries policy formulation is primarily state centric, at least partially owing to the absence of an active civil society sector. Grindle and Thomas (1990) also states that policy formulation in developing countries is state centric owing to the relative unstable nature of government; however, this is not the case in India where government is reactively stable since independence in 1947. Mollinga attributes these slight mis-matches with Grindle's perspective on public policy processes in developing countries to the fact that the model is primarily based on developed country experience, drawing on Europe and North America (Grindle and Thomas, 1990). Bolding and Mollinga (2004) notes that policy making and implementation in India is characterised by top-down, centralised and highly administrative procedures.

Recent research by Asthana (2011) utilised discourse analysis to understand how power and knowledge were used in the policy process with regards to the Delhi Water Reform Project launched in 2004. The government essentially adopted the approach of the international consultants (Price Waterhouse Coopers and the World Bank) through public-private partnership, investment in science and technology and strengthening an industrial network. The government echoed the rhetoric of the World Bank and the consultants, citing efficiency, quality of water, and 24/7 water supplies to the poor under the aegis of science, technology, and skills available through the private players. This thinking echoes the rhetoric of transnational institutions that have entered into the fray to provide the knowledge, technology, and skills necessary to manage the water sector. These discourses of power were built around the scientific knowledge and expertise brought by the so-called public–private partnership in water reform policy intending to improve the potability and access of water. The water reform discourses incorporated these claims, and solutions were presented in the politically neutral terms of a technical approach (ibid).

Mehta (2001) critically analysed narratives of scarcity in western India, finding that images of drought largely serve to legitimise the construction of the large-scale Sardar Sarovar reservoir and to manufacture dominant perceptions of increasing scarcity. Mehta claims that the manufacturing of scarcity in the region largely benefited powerful actors such as politicians, industrialists and large farmers. In conclusion, Mehta argued that scarcity is both a physical process as well as a powerful discursive construct, that of the 'real' and manufactured' scarcity, used by powerful actors to promote certain large-scale projects framed as 'there is no alternative' (ibid: 2001:2304).

In one of the rare studies on public policy process within Andhra Pradesh state in India focusing on health reform initiatives launched by the state government in the late 1990s, Mooji (2003) finds that policy formation is very much centralised and driven internally by state government. Limited debate and protest from civil society groups regarding policy formation was witnessed (e.g. the 'policy on paper'), with opposition weak and not able to develop an alternative viable scenario (Suri, 2005). However, policy implementation was vigorously contested, characterised by sabotage, manipulation and corruption in many different ways (Mooji, 2003). The significant majority of civil society organisations that were involved in the policy process served and functioned more as extensions of state political parties than independent civil society groups in their own right (ibid).

2.8 Conceptual framework

This section details the conceptual framework of this thesis, combining key theoretical concepts identified in this chapter with the research questions identified in Chapter 1. The interdisciplinary political ecological framework adopted for this thesis facilitates an examination of the overall research objective: how is climate change being integrated into government water policy and water management practices. A hydro-social[80] approach allows the policy and water practice response of the GoI to climate change to be examined within an inter-disciplinary framework. It facilitates an examination of both the GoI's water policy response to climate change, and the resulting choice of water resource management strategies set within the hydrological and political context of India and the case study state of AP. The particular choice of water management strategies advocated by the hydrocracy underlies an exertion of power through water control, set within the politically contested water management arena. Whilst at the same time, the water management strategies are examined within the hydrological (material) context of the river basin level in AP, in response to managing climate change impacts and also water demands. The inseparability of the physical and social within water management is stressed by Molle (2003), who states that 'the particular blend of water resource management responses selected by a society at a particular point in time to address water-resources problems (including climate change), must be understood within a framework that spans not only hydrological or physical; but also the distribution of agency and power among actors (including government), and their respective interests and strategies' (ibid:28).

The first and second research questions address the first half of the overall research objective: how is climate change being integrated into government water policy? In order to examine the first research question (what is the GoI's national water policy response to climate change?), an understanding of public policy formulation processes is required. Key theoretical concepts include the linear and interactive public policy models, state centric policy formation in developing countries, in addition to the policy window hypothesis. Considering the political nature of policy formulation as conceptualised by both the linear and interactive models, allows an understanding of internal government processes and under-lying issues and exertions of power, contested by non-government actors involved.

The second research question (what water management strategies does the national water policy response to climate change advocate, and why?) draws on the nature of the Indian hydrocracy with regards to its historic and present day role in water management within the context of the national hydraulic mission. This is

[80] As noted by Swyngedouw (2009), a hydro-social approach with theoretical roots in political ecology allows an interdisciplinary examination and understanding of the relationship between how changes in river basin hydrology through water management practices are related to social and political power of formal water institutions (e.g. government).

important to understand the contemporary water policy response to climate change. Discourse theory provides a grounding upon which the water policy response can be understood as representing exertions of power of the national government, through the water management strategies advocated that increase water control. Studying the characteristics of water supply and demand strategies allows an understanding of government water management practices set within the hydrological and political context of the water resource in India.

The third research question focuses on AP state government: what is AP state government's adoption of the NWM Goals through water management strategies, and is climate change linked to the choice of particular water management strategy? This question addresses the second half of the overall research objective: how is climate change being integrated into state government water management practices? The role of the AP state government, particularly the Irrigation Department, in the historical development of water management and the state hydraulic mission is again crucial in understanding the water management strategies adopted from the national water policy. The supply and demand strategies adopted by the state government communicated through discourse underlie concepts of water control and the political nature of water management. River basin trajectory theory allows an understanding of the multitude of factors influencing the state government's choice of water strategies, and the potential hydrological consequences at the river basin level. Strategies are hydrologically contextualised at the river basin level in the case study state of AP. State government discourse allows an understanding of power exertions through water control, and if and how strategies are linked to climate change responses.

The fourth research question focuses on policy implementation: what are the challenges to implementing the supply and demand strategies and institutional reform measures adopted by the AP Irrigation Department? Policy implementation is considered inherently political, contested by a variety of actors, as framed by the inter-active public policy model. Implementation of internal organisational reform measures and demand management strategies by the Irrigation Department, relating to operationalising the reflexive modernity paradigms of water management, are examined within the context of the state hydrocracy's historic focus on large-scale infrastructure supply interventions and resistance to change (reform). Implementation of supply and demand management strategies are also examined within the wider context of AP state at the river basin level, to understand political challenges to implementation, contested by different actors and on a variety of grounds. Conceptualising water management as a politically contested process allows an understanding of the wider political context in which the Indian hydrocracy operates, with other actors pursuing their vested interests through the promotion of particular water management strategies. Institutional reform provides a theoretical grounding to understand and identify possible points of leverage in negotiating the implementation challenges, generating insights into the nature and pace of water institutional reform in India.

The fifth research question focuses on overall findings and reflections of this thesis: what does the Indian water policy experience tell us about the use of water policy to respond to climate change? It draws upon the political ecology theoretical grounding of water policy and management adopted in this thesis, integrating the results and discussion of the four research questions to make overall findings and conclusions. Insights generated from the five research questions will inform the title of this thesis, whether there are times of change within the Indian hydrocracy.

3.0 Research design

3.1 Introduction

This chapter outlines the methodological foundations for the research in the following chapters. It begins by outlining the epistemological approach. It then presents the research methodology, detailing the data sources and methods of analysis. In order to address the hydro-social dimensions of this research, an interdisciplinary approach encompassing both qualitative and quantitative data is used to answer the research questions (McNabb, 2004). The research adopts a case study approach, taking the Indian national and state government to examine how climate change is being integrated into national policy and water management practices. The chapter concludes by discussing ethical issues and limitation to the research.

3.2 Epistemological approach

Epistemology is defined as the theory of knowledge (Blackburn 1994). It concerns the nature and grounds of experience, belief and knowledge (Lacey, 1991), referring to a stance on what should pass as acceptable knowledge (Bryman, 2004). It provides philosophical grounding which legitimises knowledge, upon which methodological frameworks can be based to gather valid results (Sumner and Tribe, 2004).

There exists a wide range of epistemological perspectives. At one end of the spectrum lies positivism, stating that scientific knowledge arises from positive affirmation of scientific theories, primarily by quantitative research enquires (Giddens, 1984). Sumner and Tribe (2004) claim that positivism allows reality and universal 'truths' to be measured and observed. The positivist approach is dominant in the field of natural sciences (Blaikie, 1995), although subjects with a significant social science slant such as economics and political science adopt similar quantitative-based investigative enquires in the quest for clarification and universal knowledge (Flyvberg, 2001). Positivists exclude the social, historical and cultural, including power relations, which are statistically and ideologically incompatible (Schoenberger, 2001).

At the other end of the epistemological spectrum lies constructivism. The constructivist approach is defined by the argument that multiple realities exist that are intangible and context specific in nature (Summer and Tribe, 2004). Social constructivism considers that knowledge is created and placed within the social context of the observer, at an individual or collective societal level. Many factors influence the social context of perception, including education, identity, culture, history, politics, psychology, general awareness and so on. Stereotypically constructivists can be typified as relativists[81] and post-modern.

[81] Relativism is termed as the 'permanently tempting doctrine that in some areas at least, truth itself is relative to the standpoint of the judging subject' (Blackburn, 1994:326).

Realism is situated in the middle of the epistemological spectrum, between positivism and constructivism. Realism is grounded in an ontological stance claiming that physical reality exists independently of human cognition, or in other words, what you know about a physical object exists independently of your mind (Bhaskar, 1997). Realists claim that whilst the study of the natural environment is inherently socially constructed, certain facets of the physical environment inherently lead themselves to be more socially constructed than others. Realist knowledge is thus invariably a social construct. However, it is also an approach that seeks to explain the physical reality of the environment in quantifiable terms (Blaikie, 1994). Scientific realism acknowledges an objective reality independent of the human senses, and is therefore measurable in quantifiable terms via appropriate research enquires and theoretical speculation (Bryman, 2004).

This research takes a critical realist approach to examine the hydro-social[82] dimensions of the GoI's water policy and management practices in response to climate change. Critical realism is defined as a philosophical approach that defends the critical rational of scientific enquiry against both positivist and postmodern (constructivist) challenges (Bhaskar, 1997). It seeks to describe and understand the interface between the natural and social worlds (ibid). Though critical realism may rely on empirical evidence, it also accepts sensory data not amenable to measurement and therefore usually discarded by the logical positivist (Mikkelsen 2005). Positioned in the middle ground between positivism and constructivism, this research draws on both to examine the water management strategies advocated by government as manifesting social and power relations set within the hydrological (physical) context of the river basin. From the constructivist perspective, limited discourse analysis is employed to examine underlying social processes, particularly those of power through water control that certain water management strategies allow, advocated by the government through policy text and speech. From the positivist perspective, hydrological data as well as climate change projections of changes in rainfall and temperature, are utilised to understand the physical dimensions of water resources at the river basin level, in which the water management strategies are contextualised and hydrologically understood.

The research approach is interdisciplinary in nature. Klein and Newall (1996) offer a definition of interdisciplinary studies as 'a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession.' (ibid:393). This research examines elements of discourse as underlying issues of social power of the government hydrocracy, the politically contested nature of the water policy process and its implementation, the implications for institutional reform, together with the physical impacts of climate change on water resources and management at the river basin level.

[82] Swyngedouw (2004) defines a hydro-social approach within a broad political ecology framework as one that 'fuses the circulation (movement) of water as a combined physical and social process, as a hybridised socio-natural flow that fuses together nature and society in inseparable manners' (ibid:110).

3.3 Research methodology

3.3.1 Selection of case study country, host organisation and fieldwork timetable

Case study approaches have been described as an empirical enquiry that investigates a contemporary phenomenon within a real-life context, particularly relevant for addressing 'how' and 'why' questions (Yin, 2003), as identified in the research questions detailed in Chapter 1. Having previously carried out postgraduate research in India, I knew the water management sector fairly well. Based on this and with the knowledge that at the beginning of my PhD the national government was developing a new water policy in response to climate change – the National Water Mission (NWM) - I decided to make India a case study for my research.

The International Water Management Institute (IWMI) hosted me for the duration of my fieldwork. IWMI is an international organisation focusing on various aspects of water management, part of the global Consultative Group on International Agricultural Research group. They have offices in New Delhi and Hyderabad, the state capital of AP. IWMI provided intellectual support, logistical arrangements and personal introductions to key informants both within government and with other relevant organisations and individuals.

Examining government policy development and water management practices requires an understanding of both national and state government institutional processes. National policy analysis requires one to work in the capital, New Delhi, where decision makers are based in relevant national ministries. Being based at the IWMI New Delhi office facilitated introductions and access to senior water policy makers and managers in the Ministry of Water Resources (MWR), Central Water Commission (CWC), the Planning Commission (PC) and other relevant government organisations. Water management is an independent issue for state government under the legal constitution of India. Therefore it was appropriate to choose a case study state in which to examine how the NWM is being interpreted and implemented at state level. I chose AP for a number of reasons. Firstly, the IWMI office in Hyderabad, the state capital of AP, made a practical choice. Staff at the IWMI Hyderabad office have well developed connections with senior government personnel in the AP state Irrigation department, and other relevant government departments and organisations. I gained access to senior state government personnel, particularly the irrigation department, to carry out interviews and to access relevant hydrological data. IWMI Hyderabad had also carried out research projects in the Krishna river basin (KRB), including the Lower Krishna River Basin (LKRB), located in AP state. Being based at their office allowed access to relevant secondary information and hydrological data.

My fieldwork in India consisted of two separate trips. From November 2008 to May 2009, and from June to December 2010. During the first fieldwork period, I was based primarily at the IWMI office in New Delhi. The NWM policy was being developed at that time by the MWR, and I was able to interview key government water policy advisors, including the lead author of the policy. During the second fieldwork period, I was based at IWMI's office in Hyderabad, AP. The final draft of the NWM policy had been developed, and my enquires focused on how this policy and climate change more generally were being interpreted by senior managers in the state government Irrigation department and the subsequent choice of water management strategies.

3.3.2 Methods of data collection

Methods of data collection focused on both qualitative and quantitative sources to answer the research questions. Bryman (2004) considers combining qualitative and quantitative research as a 'multi-strategy research', with both forms of research complementing each other in an interdisciplinary approach (Klien and Newell, 1996). Table 3.1 summarises the data sources and methods of analysis for each of the research questions. A diverse range of primary and secondary data were collected from a variety of sources during the two fieldwork periods.

Table 3.1: Data sources and methods of analysis to answer the research questions (see list of acronyms)

Overall research objective: **How is climate change being integrated into national government policy and water management practices?**		
	Data source	**Methods of analysis**
National level		
Q1: What is the GoI's national water policy response to climate change?	1.1 Key informant interviews a) National government policy makers and managers (MWR, CWC, PC) b) Non-government (retired government officials, NGO, civil society, international and Indian academia, international organisations and donors, consultants) 1.2 NWM policy a) NWM policy document (86 pages) b) NWM supporting document (471 pages) 1.3 Observations At interviews, workshops, conferences and meetings	1.1 Discourse analysis (speech) MS Word and Access (data reduction, coding, display and verification). Triangulation 1.2 Discourse analysis (text) MS Word and Access (data reduction, coding, display and verification). Triangulation 1.3 Interpretation MS Word
Q2: What water management strategies does the national water policy response to climate change advocate, and why?	2.1 NWM policy a) NWM policy document (86 pages) b) NWM supporting document (471 pages) 2.2 Key informant interviews a) National government water policy makers and managers (MWR, CWC, PC) b) Non-government (NGOs, civil society, Indian and international academia, international organisations, Indian research organisations, international donors, private sector, retired Indian government officials, consultants) 2.3 Observations At interviews, workshops, conferences and meetings 2.4 National government policy documents and reports a) NWP 2002 and 1987 b) Reports (technical, feasibility, annual, legal acts). 2.5 Secondary documents	2.1 Discourse analysis (text) MS Word and Access (data reduction, coding, display and verification). Triangulation 2.2 Discourse analysis (speech) MS Word and Access (data reduction, coding, display and verification). Triangulation 2.3 Interpretation MS Word 2.4 Discourse analysis (text) (data reduction, coding, display and verification). Triangulation 2.5 Textual analysis (reduction, coding, display and

	a) research reports and papers from international organisations and academia, media articles, website information, books, opinion pieces 2.6 Hydrological, agricultural (irrigation) and meteorological (climate change) data a) From government (MEF, MWR, CWC, GWB, MoA) b) Non-government (IWMI, IITD, IITM, FAO AquaStat, IPCC)	verification). Triangulation 2.6 MS Excel (data reduction, calculation, display)
State level (AP)		
Q3: What is the state government water management adoption of the NWM objectives, and is climate change linked to the choice of particular water management strategy?	3.1 Key informant interviews a) Senior water managers at AP state government (ICAD, APGW, APHRD). b) Non-government (NGO, civil society, international organisations, state-level research organisations, retired state government officials, international and Indian academia, consultants) 3.2 Observations At interviews, workshops, conferences, meetings 3.3 Government policy documents a) NWM policy b) AP State water policy 2008 c) Relevant GoAP water and NRM policy documents and reports 3.4 Hydrological, agricultural (irrigation) and meteorological (climate change) data at river basin level in KRB and AP a) State government (ICAD, APGW). National government (MEF) b) Non-government (IWMI, IITD, IITM, ICRISAT, IPCC) 3.5 Secondary documents Research reports and papers from international organisations and academia, NGOs, media articles, website information, books, newsletters, opinion pieces.	3.1 Discourse analysis (speech) MS Word and Access (data reduction, coding, display and verification). Triangulation 3.2 Interpretation MS Word 3.3 Discourse analysis (text) (data reduction, coding, display and verification). Triangulation. 3.4 MS Excel (data reduction, calculation, display) 3.5 Textual analysis (reduction, coding, display and verification)
Q4: What are the barriers in implementing the demand, supply and institutional reform measures adopted from the NWM?	4.1 Key informant interviews a) Senior water managers at AP state government (ICAD, APGW, APHRD). b) Non-government (NGO, civil society, international organisations, state-level research organisations, retired state government officials, international and Indian academia, consultants) 4.2 Hydrological and agricultural (irrigation) data a) AP Irrigation department b) IWMI and other relevant state-level organisations 4.3 Secondary literature a) research reports and papers from international organisations and academia, NGOs, media articles, newsletters, brochures, website information, books, opinion pieces.	4.1 Discourse analysis (speech) MS Word and Access (data reduction, coding, display and verification). Triangulation 4.2 MS Word and Excel (data reduction, calculation, display) 4.3 Textual analysis (reduction, coding, display and verification). Triangulation
Q5: What does the Indian water policy experience tell about the use of water policy to respond to climate change?	No direct data sources. This question draws on the results and discussion of four previous research questions.	N/a

3.3.2.1 Policy documents and reports

National and state government water policy documents

The NWM policy response to climate change developed by the MWR was made publically available on their website from December 2008 onwards, consisting of early drafts before being finalised in April 2011. The NWM consists of the policy document (86 pages) and a supporting document providing a detailed account of the government approaches (471 pages). The two documents provided a significant amount of information and data upon which initial data collection and analysis was undertaken, and provided an insight to structure my interviews around. Other national and state government water policy documents (National Water Policy 2002 and AP State Water Policy 2008) were also downloaded prior to fieldwork. All of these policy documents were in English.

Other relevant national and state government reports and documents (annual reports, feasibility reports, technical reports, project reports, hydrological data reports, legal acts, river basin dispute tribunal reports) were obtained via government websites, through personal requests during meetings, from IWMI's offices, and via personnel connections in India. These documents were obtained in both paper and electronic format, written in English.

More general literature containing qualitative and quantitative data was obtained from a variety of sources, including international and national research organisations (IWMI New Delhi and Hyderabad offices), NGOs, media websites, and relevant organisations and academic websites. This literature consisted of media articles, academic papers and reports, newsletters, opinion articles and books. In order to assess the quality of secondary data, a criterion of authenticity and credibility was employed (Darlington and Scott, 2002). Authenticity was checked with regards to the origin of the data, particularly whether it was from a reliable source. The majority of secondary data was collected directly from relevant organisations, in paper format or electronically, which helped to confirm authenticity. Credibility of data was checked with the source, whether it was from a relatively respected and established organisation[83], which was the case with the majority of the data. When there were questions over credibility, attempts were made to check the data with the organisations or authors of the data or report. Triangulation was an important method to check the accuracy and creditability of secondary data (Section 3.3.3).

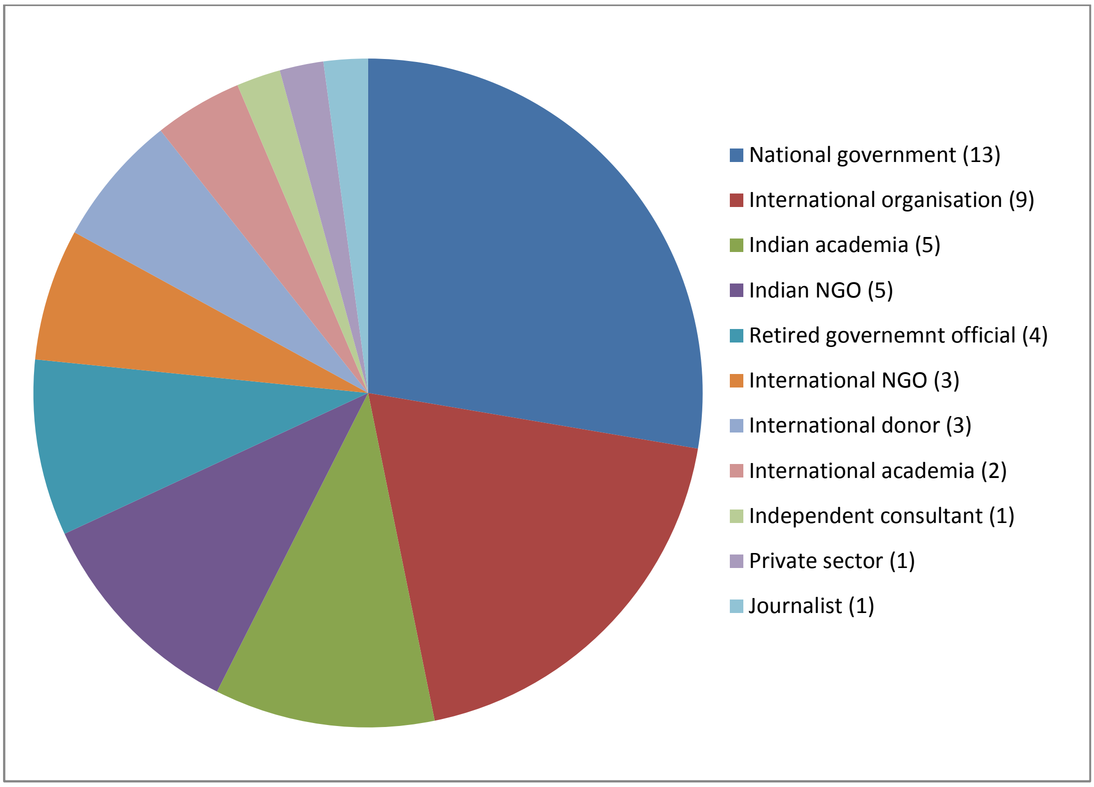
[83] The general criteria for assessing the organisations (international and Indian) was based upon informal feedback from international and Indian-national water experts, the quality of reports and publications (with their research outputs being cited by other organisations or academic journals and related literature), being part of a wider group of organisations, staff specialisation and organisational focus, and the partnerships with similar organisations and funders.

3.3.2.2 Interviews

Key informant interviews were extremely useful in confirming certain aspects of the NWM policy and recommended water management strategies, providing insights and nuances into government process and strategic water management approaches. The term key informant is used in this sense to describe respondents interviewed owing to their specialist knowledge or expertise of the phenomena being observed due to their privileged position (Corbetta, 2003). Insights from the interviews highlighted further lines of enquiry whilst in the field, emerging from the fieldwork research process itself (Durrheim, 2006; Bryman, 2004).

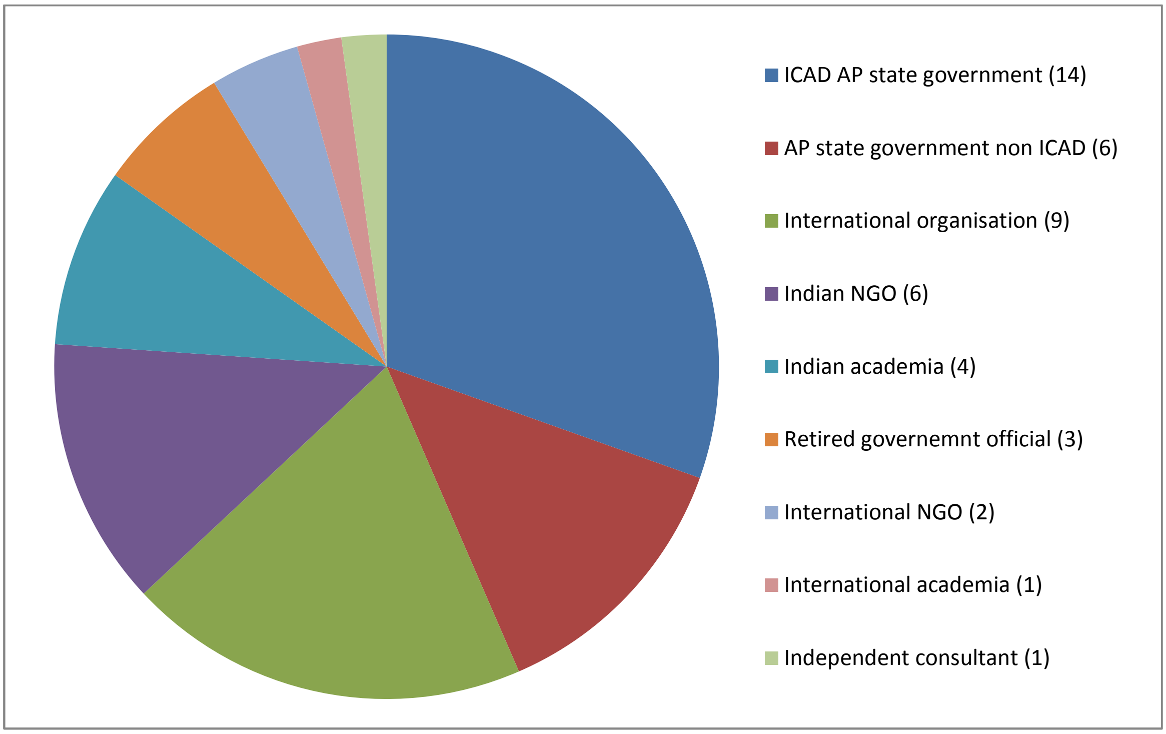
A wide range of key informants were interviewed at national level, including government and non-government personnel from different organisations and backgrounds (Figure 3.1 and Appendix 2). Key informants within national government (MWR and CWC) were chosen owing to their involvement in the NWM development process, including the lead author of the NWM. Non-government informants were chosen on the basis of their involvement in the NWM policy development process, in addition to their expertise in the Indian water sector and experience of dealing directly with government. In total, 47 key informants were interviewed, 13 of which were national government personnel at the MWR and CWC (Figure 3.1).

Figure 3.1: Key informant interviews at national level (number of respondents in brackets; total number of respondent was 47)



At AP state level, a wide range of key informants were interviewed from state government and other organisations (Figure 3.2 and Appendix 2). In total 46 key informants were interviewed, 20 of which were state government personnel, of which 14 were with the Irrigation department. Key informants at the Irrigation department (ICAD) were selected and interviewed on the basis of their senior position, and owing to their direct authority and involvement in providing strategic direction to the WRM strategies employed at state level. Personnel from the top-level of the Irrigation department at the Secretary for Irrigation, Commissioner and Chief Engineer levels were interviewed (Appendix 3 for staff organisational hierarchy of the Irrigation Department).

Figure 3.2: Key informant interviews at AP state level (number of respondents in brackets; total number of respondents was 46)



Speaking to non-government informants at national and state level provided a valuable insight into government processes and strategic water management approaches, being relatively free to communicate potentially sensitive issues that government personnel were generally less inclined to divulge. Retired government officials at national and state level were particularly helpful in being able to read between the lines of policy documents and elaborating on underlying agendas and sensitive issues.

Interviews were semi-structured, with open-ended questions posed to allow insights into the complexity of the situation (Robson, 2002). Corbetta (2003) describes a semi-structured interview as a conversation between an interviewer and an informant, where the interviewer has a general outline of the topics to be covered but has considerable freedom to conduct the conversation in his or her own style. Semi-structured interviews are widely used in flexible research designs and frequently combined with other methods (Robson 2002). All the interviews were carried out in English, being the official language of the GoI. The vast majority of senior government personnel are relatively well educated[84], and well versed in English. Non-government key informant interviews were also carried out in English.

The questions and topics prepared prior to interviews were context specific to the position of each key informant, dependent on their role in the policy process and their position in government. In this manner, key respondents, especially senior government personnel, can reconstruct and uncover previously unknown or under-emphasised elements of policy documents and speech (Tansey, 2007). Questions to non-government key informants were also prepared prior to interview depending on the expertise and background of the informant. This is in line with what is termed 'elite interviewing', where the interviewer does not set standardised or controlled questions to obtain data, but takes into account the position, experience and knowledge of the key informant in shaping and conducting the interviews (Dexter 2006:19). No generic set of questions were posed to all of the informants, apart from enquiring as to their understanding of climate change impacts in AP. However, depending on the position and background of the key respondent, questions were structured around the four research questions at national and state level, with the NWM providing substantial grounding upon which questions were orientated in order to gain further insights.

During interviews, discussion was encouraged to flow freely, often deviating from the original question into issues previously unconsidered or under recognised. I employed probing methods such as rephrasing questions and previous comments to check for accuracy (Corbeta, 2003:278). Interviews were generally informal in nature, particularly with non-government informants or government personnel with whom a good relationship was built during consecutive interviews. The majority of the interviews were recorded by a digital audio device, with full consent of the respondent prior to the interview, in line with research ethics detailed in Section 3.4 (Bryman, 2004). Audio recording aided the interview to be free flowing in nature, without the need to take significant amounts of notes during the interview. The interviews were played back soon after, upon which notes were taken and further questions arose. The majority of the interviews lasted for around one hour in duration. Some respondents were interviewed once, whereas others were interviewed on a handful of occasions over the two fieldwork trips. Non-government interviews were conducted primarily in the offices of the organisations in which respondent was based, although some interviews were carried out at conferences, workshops or at local restaurants.

3.3.2.3 Observations

Observations are a commonly employed method to gain further insights in policy orientated research involving different actors (McNabb, 2004). Observations throughout the fieldwork provided a useful insight into

[84] A significant number of senior government personnel are Indian Administrative Service (IAS) officers. The process of IAS officer selection is considered academically challenging and rigorous, with entry leading to prestigious and high level government civil service positions.

interactions and opinions of those involved. For instance, at a workshop organised by the MWR in New Delhi to present and discuss a draft version of the NWM attended by a variety of non-government actors, I was able to observe verbal and physical (body language, tone of voice) interactions between those present (Appendix 4 for list of events attended).

3.3.2.4 Hydrological, agricultural (irrigation), and climate change data

Hydrological data at the national and state level in India can be a sensitive subject, particularly relating to water sharing between riparian countries and states. Certain data are classified as sensitive, restricting dissemination both outside of government circles and internally even between ministries and departments[85]. However, some hydrological and agricultural (irrigation) data at the India country and river basin level are generally available. Such national-level data were collected via national government and international organisations websites, in hard copy and report format following national interviews, and from the IWMI New Delhi office's electronic and report records. In AP, some relevant hydrological data at the river basin level to contextualise the water strategies of the Irrigation department were obtained from various sources. Researchers at IWMI's office in Hyderabad had been conducting extensive research in the KRB over the last decade, accumulating a significant amount of hydrological data for the entire KRB. This data were made readily available on personal request. Up-to-date hydrological and agricultural data, including project data relating to the on-going Jalayagnam irrigation project, were made available from the Irrigation department in electronic and paper format on personal request. Climate change data relating to projected changes in precipitation and temperature, and the impacts on water resources at the national and regional level, was obtained from international publications (IPCC), Indian publications (MEF) and from relevant research organisations in India on personal request.

3.3.2.5 Field visits

Field visits were conducted in numerous locations in the KRB during the second fieldwork period. As part of a small IWMI group, I participated in a three-day field visit to the Nagarjuna Sagar reservoir and left bank canal irrigation system (Figure 4.10 for location in KRB). The chief engineer conducted this field tour explaining the technical and physical characteristics of the infrastructure, as well as an overview of irrigation within AP including the fertile lower Krishna river delta region. A field visit was also conducted in the semi-arid Mahabubnagar region of Telegana to understand rainfed agriculture and watershed development programmes. Furthermore, a field visit was conducted in the Upper Bhima basin in Maharashtra state to understand the hydrology of the Upper KRB (Appendix 5 for more details on field visits). Although no primary data were collected on such field visits, they were particularly useful to gain an understanding of the hydrology of the KRB, its topography, agricultural practices, the infrastructure involved in large scale irrigation and the crops cultivated by farmers in the distributary canal systems.

[85] National hydrological data at the river basin level is also politically sensitive with regards to riparian South Asian countries, particularly with Pakistan, Nepal and Bangladesh. At state level, total reservoir storage capacity in AP, along with other riparian states in the KRB, is not in the public domain owing to the politically sensitive nature of the on-going Krishna Water Disputes Tribunal.

3.3.2.6 Informal discussion

Informal discussions took place during the entire duration of both fieldwork periods. Staff at the IWMI New Delhi and Hyderabad offices, familiar with government policy processes and water management issues, provided an invaluable sounding board upon which I discussed my research and ideas. Informal discussion also took place with a variety of water sector international and Indian national experts, many of whom I met in the IWMI offices, at workshops, conferences and meetings. Although not a primary data source in its own right, informal discussions were valuable in fine tuning my ideas.

3.3.3 Methods of data analysis

3.3.3.1 Discourse analysis

Discourse analysis helps reveal how speech act interlocutors (e.g. hydrocracy and other actors) construct a specific ensemble of ideas, concepts, and categorisations that are produced, reproduced and transformed in a particular set of practices and through which meaning is given to physical and social realities (Hajer 1997:44). Discourse analysis is subject to a diverse number of interpretations (ibid). Different approaches are adopted for a variety of purposes, with none claiming general veracity (Brown and Doulton, 2009; Adger et al, 2001). However, two general approaches to discourse analysis are identified by Fairclough (2003). The first approach is 'Foucauldian' which plays relatively less attention to linguist features of a text and engages in under-lying social theoretical issues of power and knowledge (Section 2.7.8). And the second approach is critical discourse analysis, which specifically focuses on the linguistic analysis of texts (Van Dijk, 2005), including the use of tropes[86] and other stylistics linguistic devices such as specific language style and particular arrangements of words (ibid; Apthorpe and Gasper, 1996). This research adopts the former approach, analysing discourse as 'text and utterances' (ibid:116), in the form of policy documents, statements, observations and what is verbally communicated during interviews. Underlying the themes and ideas expressed in discourse are social relations and expressions of power and knowledge (Shore and Wright, 1997; Foucault, 1991).

Discourse analysis was employed with regards to policy texts and reports, interviews and observations (Hastings, 1998), as the sum of government's communication (Sharpe and Richardson, 2001). Textual discourse analysis of the NWM, particularly the water management strategies advocated by national government, aids in understanding how texts are deployed as part of a persuasive strategy to convince readers of the appropriateness of policy objectives (Marston, 2000; Hastings, 1998). Production of written texts is a crucial means by which policy makers establish the parameters of debate and policy endeavours (Asthana, 2011; Hastings, 1998), and in doing so, establish and sustain the sanctioned water discourse (Allan, 2003). Early in the first fieldwork period, the NWM was printed off and read very carefully, with substantial notes taken. Key text (words, phrases and sentences) relating to water management were searched for via the pdf version. This analysis provided the grounding upon which questions were generally structured during interviews with key informants, to confirm and expand on certain issues (Marston, 2000). Textual analysis was

[86] A trope is a figurative or metaphorical use of a word or expression (Oxford Dictionary, 2011).

also carried out for other relevant government policy documents, selecting quotes and data to provide background, which was then triangulated with the NWM and key informant interviews (Figure 3.3) (Hastings, 2000).

Interviews with key informants provided primary qualitative data upon which discourse analysis was conducted, expanding on the NWM in providing further insights into government water strategies. Speech as discourse analysis revealed how verbal communication of government key informants constructed a 'specific ensemble of ideas, concepts, and categorisations that are produced, reproduced and transformed in a particular set of practices and through which meaning is given to physical and social realities' (Hajer 1995:44). In this interpretation of discourse, power relations are central, with discourse as an entity of repeated linguistic articulation, material practices, social and power rationality configurations (ibid; Shore and Wright 1997).

Qualitative data analysis was carried out in line with the template approach, that of data reduction, data display, conclusions and verification (Robson, 2002). All interviews were carefully transcribed immediately after being conducted. The majority of the interviews were recorded, being played back on numerous occasions to capture points and nuances of responses. The qualitative data was then entered into a Microsoft Access and Word tables to perform data reduction. Quotes were selected and coded in terms of the relevance to the research questions, to related issues and to provide further insights (ibid). A diverse range of quotes were selected on the basis of the complex nature of water management issues in India, integrated into relevant results chapter sections (Yin, 2003). Interview responses were coded with regards to questions posed to ICAD key informants, for instance, regarding their understanding of climate change impacts in AP. This data was entered into Microsoft Excel to analyse responses and present findings in appropriate graphic form (Bryman, 2004). The coding process was time consuming, as it involved listening back to many hours of interviews and categorising responses along the parameters of the research questions. A detailed field log-book was kept throughout both fieldwork periods containing reflections and ideas. Reading this whilst transcribing and coding interviews helped for clarity and in drawing conclusions. Finally, the data were displayed as direct quotations in the text and tables in relevant results chapter sections. Analysis of observation data during interviews, workshop, meetings and conferences was based around interpreting the specific nature of observation (McNabb, 1998). For instance, tone of voice and body language interpretation often ran alongside what was being communicated, in terms of the respondent stressing the importance of his or her point, or the open or guarded manners and tone in which responses were given.

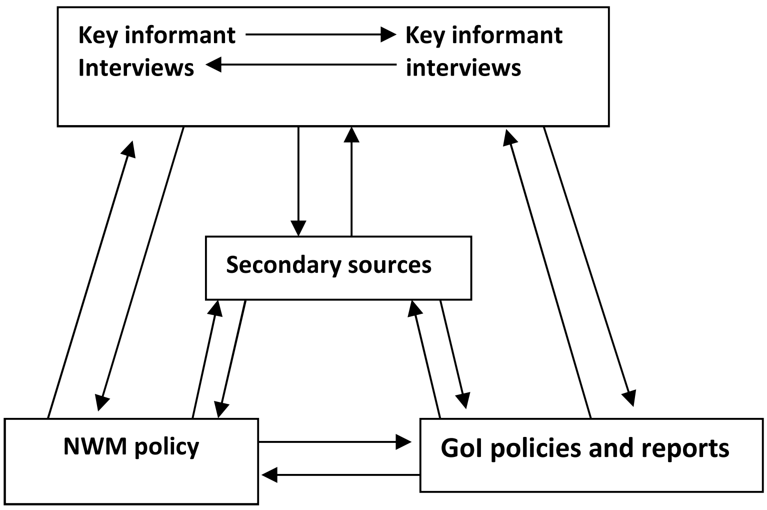
3.3.3.2 Hydrological, agricultural (irrigation) and climate change data analysis

Hydrological and agricultural (irrigation) data were analysed at the national and river basin level in AP to provide a physical context to the water management strategies advocated by government. This data were entered and analysed with MS Excel, presented in graphic form to illustrate trends and relationships (Bryman, 2004). Data on projected changes in rainfall and temperature under climate change projections and the impact on water resources, were selected from relevant data sources, analysed and presented in graphical form to convey physical implications at the river basin level.

3.3.3 Triangulation

Triangulation is an important method of data analysis verification (Robson, 2002), particularly useful for qualitative and quantitative methods (Jick, 1979). It facilitates the verification of findings through convergence, corroboration and correspondence of results from different data sources and methods (Darlington and Scott, 2002:121). Triangulation was applied to data, including data collection and analysis methods. Figure 3.3 represents how and what was triangulated.

Figure 3.3: Triangulation of data (adapted from Davies, 2001:78)



Triangulation was conducted between different primary data sources, including key informant interviews, the NWM, and other GoI policies and reports. Key informant government interviews were triangulated in relation to each other to check consistency of responses. The NWM provided substantial primary data for textual analysis, triangulated with key government informant interviews to confirm government approaches. Previous GoI water policies and reports offered substantial data to triangulate and contextualise the data generated from the NWM and key informant interviews. Secondary data was triangulated with primary data to check for consistency, to contextualise government approaches and to provide further insights. Some secondary data sources were triangulated with other secondary data sources to check validity and accuracy.

3.4 Data sources and ethical considerations

Interviewing senior government personnel has its limitations. It places the emphasis on the unique responses of the key informant, with potential for biases that should be considered. Key informants are under no obligation to be truthful or objective (Berry, 2002). As the responses were not moderated during the interviews, spontaneous decisions were made when to intervene or probe with further questions or clarification on certain issues. Although hydrological and agricultural (irrigation) data were collected from IWMI's offices and on request from government, the sensitive nature of hydrological data severely limits data availability within the public domain. This limitation is not specific to data collection for this research, it is an endemic issue throughout the KRB and India more generally. Minutes of internal meetings within the MWR are not published within the public domain[87]. Insights into the internal policy development process were gathered from interviews with key informants, along with attending and observing public consultation workshops and meetings. The exact nature of internal discussions behind closed doors within the MWR is unknown.

The ethics policy of the School of International Development, University of East Anglia, requires researchers to present the purpose of their presence and data collection activities to relevant parties. My fieldwork host organisation was made fully aware of my research purpose and activities in India prior to accepting to host me. Once in India for fieldwork, when I contacted potential key interview informants, relevant organisations or government departments for data, I made it explicitly clear from the onset what my purpose was for being in contact. Key informant interviews were on a purely voluntary basis. Prior to interviews, all key informants were informed as to the purpose of my research, either by way of a short introductory letter or verbally (Appendix 6 for consent form and Appendix 29 for ethics consent application and approval). Informants were informed that any response given by them would be treated in the upmost confidentiality, with the data being used to inform my PhD research, with the potential for insights gained from interviews to be included in relevant academic papers and presented at conferences and workshops. Key informants were asked prior to the interview whether they consented to the use of an audio recording device, the majority of which agreed. Complete anonymity was guaranteed at the onset regarding the identity of each informant, and this has been maintained throughout the chapters of this thesis. Informants were also informed that it was not compulsory to answer questions if they did not wish to do so, and that they could withdraw from the interview at any point in time with relevant data destroyed (permanently deleted) in such circumstances. A high level of confidentiality was kept to avoid disclosure. All electronic qualitative and quantitative data, papers, reports and field notebooks were stored in a secure and safe manner throughout the fieldwork periods. The University of East Anglia's Health and Safety guidelines were adhered to during the duration of both fieldwork periods.

The next chapter sets the scene by introducing the institutional arrangement for water management at the national and state government level in AP. The water resources of India and AP state are also detailed.

[87] SANDRP, an NGO based in New Delhi, have repeatedly called on national government to make available internal meeting notes regarding policy formulation and discussion, but as yet (mid 2012), this information has not been made available to the public.

4.0 Setting the scene

4.1 Introduction

The chapter begins by introducing the institutional arrangements for water management at the national and Andhra Pradesh (AP) state government level (Section 4.2). It then moves on to detail the physical water resources status of India and AP, including the relevant river basins within AP (Section 4.3). An overview of the hydraulic missions in India and AP state is presented in Section 4.4.

4.2 Government institutional arrangements

This section details the institutional arrangement of the national and AP state government for water management. It consists of organisational, policy and legal components, known as the 'three pillars' of formal institutions[88] (Shah, 2006; Saleth, 2004; North, 1990; Ostrom, 1990).

4.2.1 National government water organisations

National government water organisations include the numerous ministries responsible for various elements of water management, based in New Delhi. Ten national ministries are involved, each with unique but overlapping organisational responsibilities, due to the cross-cutting nature of water management as an inter-disciplinary challenge (Table 4.1).

Table 4.1: National ministries responsible for all aspects of water management (GoI, 2012b; Saleth, 2004)

Ministry	Organisational responsibilities
Ministry of Water Resources	National water policy formulation and development; assessment of water resource status; strategic national planning for major and minor irrigation projects; groundwater and flood management.
Planning Commission	Strategic planning for human and economic development in India by the efficient mobilisation of relevant human and financial resources. Development of Five Year Plans for national development, including water resources. Provide funding approval for medium/major infrastructure through the Accelerated Irrigation Benefit Programme.
Ministry of Agriculture	Water planning for agriculture and crop productivity, watershed development projects, micro irrigation, drought management plans.
Ministry of Drinking Water and Sanitation	Provision and maintenance of rural drinking water and sanitation facilities. Policy development, project design and implementation.
Ministry of Urban Development	Provision and maintenance urban drinking water supplies and sanitation facilities, including project design, monitoring and implementation.
Ministry of Urban development, and Ministry of Commerce and Industry	Provision of water for industrial purposes, policy development and planning.
Ministry of Power	Hydropower policy development, planning and projects
Ministry of Shipping, Road Transport and Highways	Inland navigation planning for internal water bodies.
Ministry of Environment and Forests	Mandated by Prime Minister's Office to oversee the development of the PM's Action Plan on Climate Change, consisting of the eight missions, including the National Water Mission.

[88] Water institutions (government) consist of three components: policy, organisations and law (Saleth, 2004; North, 1990). Saleth (2004) refers to government institutions as 'entities defined by a configuration of policy, legal and organisational rules, conventions and practises that are structurally linked and operationally embedded in a specified environment '(ibid:3). The identification of these three components originates from the Institutional Analysis and Development Framework developed by Ostrom (1990), drawing on new institutional economic theory (North, 1990; Williamson, 1975).

	Development of environmental impact assessments, habitat conservation in aquatic environments, monitoring and regulation for water pollution control.
Ministry of Agriculture, Ministry of Environment and Forests, Ministry of Rural Development	Watershed development and drought management programmes.
Ministry of Home Affairs and National Institute of Disaster Management	Management of water related disasters, including floods and droughts.

Ministry of Water Resources

The Ministry of Water Resources (MWR) has overall responsibility for formulating national water policy, guidelines and programmes for the development and regulation of India's water resources (GoI, 2012b). Specific functions include technical guidance, project scrutiny and flood management. The MWR provides strategic direction for major and medium irrigation projects throughout the country, including technical clearance and monitoring of projects under the Accelerated Irrigation Benefit Programme (AIBP). Policy development, planning and guidance for minor irrigation and command area development as well as for groundwater, are also the responsibility of the MWR. Financial responsibilities include assisting specific projects and obtaining external funds where necessary, from the Planning Commission or from non-national sources such as the World Bank or other international donors. The MWR also facilitates riparian state disputes over shared waters within India, and at the international level between riparian countries bordering India.

The MWR's organisational evolution lies primarily in the development of irrigation. It has been at the forefront of developing India's national hydraulic mission (Section 4.4). After Indian independence, the Ministry of Irrigation and Power was established in 1952. In 1969, the Irrigation Commission was established to accelerate irrigation infrastructure development across the country, along with command area[89] development projects. In 1985, the Ministry of Irrigation and Power was split, resulting in the creation of the department of Irrigation under the Ministry of Agriculture, which was subsequently re-constituted into the MWR, mandated as the nodal ministry responsible for policy development and planning of India's water resources.

The MWR has a number of organisations under its responsibility, detailed in the following paragraphs. The organisations relevant to this research include the Central Water Commission, the Central Groundwater Board and the National Water Development Agency. Programmes currently being implemented by the MWR include the AIBP, flood management schemes, irrigation command area development, dam rehabilitation and improvement, and renovation of existing water bodies (Appendix 7 for a complete list of organisations under the MWR and programmes).

[89] The command area is the area that is served by surface water from a canal irrigation system for agricultural purposes. Major irrigation projects serve a command area of over 10,000ha; medium projects from 10,000 to 2,500ha; and minor project under 2,500ha (GoAP, 2012).

The Central Water Commission (CWC) provides technical engineering and scientific input as well as monitoring the MWR's programmes, for major and medium irrigation projects, reservoir development, flood management and multi-purpose projects. Created in 1952 under the Ministry of Irrigation and Power and later re-structured in 1985 under the newly established MWR, the CWC constitutes three major operations: design and research, river management, and water planning and projects (GoI, 2009a). The CWC's central office is located in New Delhi, with 13 regional offices located throughout India providing technical input for on-going projects. The CWC has a separate Human Resource Management Unit, with the National Water Academy in Pune providing staff training. The Central Groundwater Board (GCWB) is a subordinate office of the MWR since 1985, providing scientific input for the exploration, monitoring, assessment, augmentation, regulation and management of groundwater resource throughout the country. It was established in 1970. The National Water Development Agency's primary role is to develop plans for the National River Linking Project (NRLP). Specific activity includes technical feasibility studies and technical reports for potential reservoir sites and inter-basin links for the Peninsular and Himalayan rivers development components of the NRLP. The Planning Commission (PC) was established in 1950 to pursue national government objectives to promote a rise in living standards throughout the country by efficient and effective exploitation and management of relevant resources. Since 1951, the PC has developed national-level Five Year Plans (FYP), detailing future objectives, priorities and plans for a wide range of development sectors, including water resources (GoI, 2012c). All major and medium irrigation projects under the AIBP, as well as other infrastructure projects under the NRLP, have to be approved by the PC before the Ministry of Finance releases relevant funds to state governments. The 12th FYP (2012-2017) is currently (late 2012) being developed by the PC. In preparation for this, the Working Group on Water Resources was established in October 2010, constituting non-government water experts in India, along with representatives of national (including the MWR) and state government[90].

4.2.2 National water policy

The MWR is the nodal national ministry mandated to develop national water policy (NWP). The first NWP was developed and passed by the National Water Resources Council[91] in 1987, following a severe nationwide drought the same year. The central tenents of this policy included irrigation development, conjunctive use of ground and surface waters, increasing reservoir storage capacity, water conservation and efficient use of water for agriculture (GoI, 1987) (Section 5.2 for an examination of NWP formation process).

The MWR revised the NWP in 2002, primarily in response to increasing water scarcity and competition between water user sectors. The policy detailed sectoral prioritisation for the provision of water in the order of drinking water, irrigation, hydropower, ecology, industrial and navigation respectively (GoI, 2002). The

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[90] The composition of the Working Group on Water Resources has varied with each of their meetings since formation in 2010. At least half of the Group are national and state government personnel from the MWR and state irrigation departments, at the senior level of Secretary and Commissioner. Non-government representation consists of water experts (mainly Indian nationals) from international organisations, academia, NGO and civil society groups, along with independent consultants (GoI, 2012c).

[91] The National Water Resources Council was established in 1983. The apex-body is chaired by the Prime Minister of India, and includes the Union Minister of Water Resources and Chief Ministers of all state governments in India. It is an important policy organisation within the Indian water sector. National water policy requires the approval of this council before it is legislatively passed by national government (GoI, 2012b; Saleth, 2004).

objectives and content were near identical to the 1987 policy. However, the policy contained two notable inclusions. Firstly, the explicit promotion of private sector involvement in the planning, development and management of water resource. And secondly, recommending a paradigm shift, from water resources development to management and performance improvement (GoI, 2002:6-8).

Under the legal constitution of India, the NWP is not a legally binding document that state governments have to follow. Rather, it represents recommendations by national government for state government to consider and implement (Cullet, 2007). State governments are encouraged to develop their own state water policies, in line with the recommendations made by the NWP. Numerous state governments have developed their own state water policies in recent years, including Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Kerala, Gujarat, Orissa, Uttarakhand, Himachal Pradesh, Uttar Pradesh and Rajasthan (Appendix B for state map of India). However, a number of less progressive states have not, particularly those in the north-east region of India.

4.2.3 National water law

India lacks an umbrella framework to regulate water resources in all its dimensions. The existing water law framework is characterised by the co-existence of a number of different principles, rules and acts adopted over many decades. Existing laws include common law principles and irrigation acts from the British colonial period; as well as more recent regulation of water quality and the judicial recognition of a human right to water. In terms of statutory development, irrigation laws constitute historically the most developed part of water law. This is in large part due to the fact that the British colonial government saw the promotion of large-scale irrigation works as central to its mission (Cullet, 2007). Many of the laws date back to colonial times and in the period immediately after Indian independence, passed when water was more abundant in river basins with lower populations and sectoral demand. Many of the current acts are somewhat outdated with regard to new water challenges of the 21^{st} century (ibid; Saleth, 2004).

The legal provision of inter-governmental responsibility for water resources is derived from the overall constitutional division of power between national and state governments, as declared by the Indian Constitution of 1952. As per Entry 17 in the State List under the Seventh Schedule of the Constitution, the states have legal jurisdiction over water resources within their administrative borders (GoI, 1952). However, legal powers of the states are subject to Entry 56 in the Union List that allows the national government (MWR) to regulate and develop inter-state rivers when it is declared by parliament to be a matter of public interest (ibid).

The national government (MWR) also has a role in resolving inter-state water disputes under Article 262 of the Constitution. The Inter State Water Disputes Act of 1956 established a number of tribunals to facilitate the resolution of water disputes among riparian states. However, ultimate legislative powers lie with state government under the Constitution. Water laws and policy can only be passed by, and with the support of, the state government legislature.

4.2.4 AP government water organisations

State government water organisations include the numerous water departments responsible for different aspects of water management in AP. Eleven government departments are involved with water management, each with their own unique organisational responsibilities (Table 4.2) (Appendix 9 for district map of AP, and Figure 4.4 for location of AP state in India).

Table 4.2: AP state government departments involved with water management (GoAP, 2012, 2010a)

Department	Brief description of organisational responsibilities
Irrigation and Command Area Development (ICAD)	Construction of major, medium and minor surface water irrigation canals; reservoir design, planning and construction; state water policy development and implementation; operation and maintenance of irrigation structures; GIS and remote sensing; water efficiency programmes; Participatory Irrigation Management, Water User Association and water audits; flood management; groundwater management.
Rural Development	Watershed development programmes; groundwater management including recharge and community participation; rural development; drought management programmes.
Groundwater	Monitoring and assessing groundwater status throughout the state. Investigation of selection sites for wells, recharge structure and exploratory drilling.
Agriculture	Implementing national agriculture policies; management of programmes to promote agriculture growth through land, water, soil and plant resources. Agricultural production, marketing products, horticulture, sericulture.
Metropolitan Water Supply and Sewerage Board	Provision of urban drinking water and sanitation services
Energy	Policy formation of energy sector within the state; manage functioning of electricity, coal and boiler sectors. Hydropower development. Oversee the functioning of electricity, coal and boiler sectors.
Transmission Corporation of AP Limited (partially privatised)	Electricity development and distribution throughout the state (established 1999). Provision of electricity for groundwater pumping.
Industry	Plans and implements schemes for industrial development in the State, from large to small scale industrial activity.
Environment, Forests, Science and Technology	Proposals relating to forest lands, mining leases, encroachments on forest lands, forest Conservation Act 1980, use of forest land for non-forest purposes, soil conservation Issues
Rain-shadow Area Development	Focused on rain-shadow districts of AP: Ananthpur, Chittoor, Kadapa, Kurnool, Mehboobnagar, Rangareddy, Nalgonda, Medak, Prakasham, Nellore Programmes (Appendix 9 for district map of AP). Programes include cloud seeding, lift Irrigation, micro irrigation, watershed development.
Finance	Allocation of finances to the Irrigation department construction of major and medium irrigation projects, including other infrastructure projects (reservoirs).
Revenue	At the district and mandal[92] level, collection of charges for groundwater withdrawal (Revenue Officer)

Irrigation and Command Area Development department

The Irrigation and Command Area Development (ICAD) department is the largest and most influential state government department involved in water management. The ICAD is responsible for the construction, operation and maintenance of all irrigation works (surface flow systems) from the head works to the piped outlets (GoAP, 2010a). It employs over 7000 staff throughout the state, and has the largest financial budget of the state departments involved in water management standing at $3.06 billion US dollars[93] for the financial year 2011-2011 (GoAP, 2012). Created in 1956, the department has focused primarily on the construction and

[92] Mandal (or Tehsil as it is known in other states of India) is an administrative division and term used for towns in India. It is the second of three tiers of administrative divisions at state government in AP. Above is the district level and below is the village or panchayat raj administrative tier.
[93] Equivalent to 15,000 Crore Rupees.

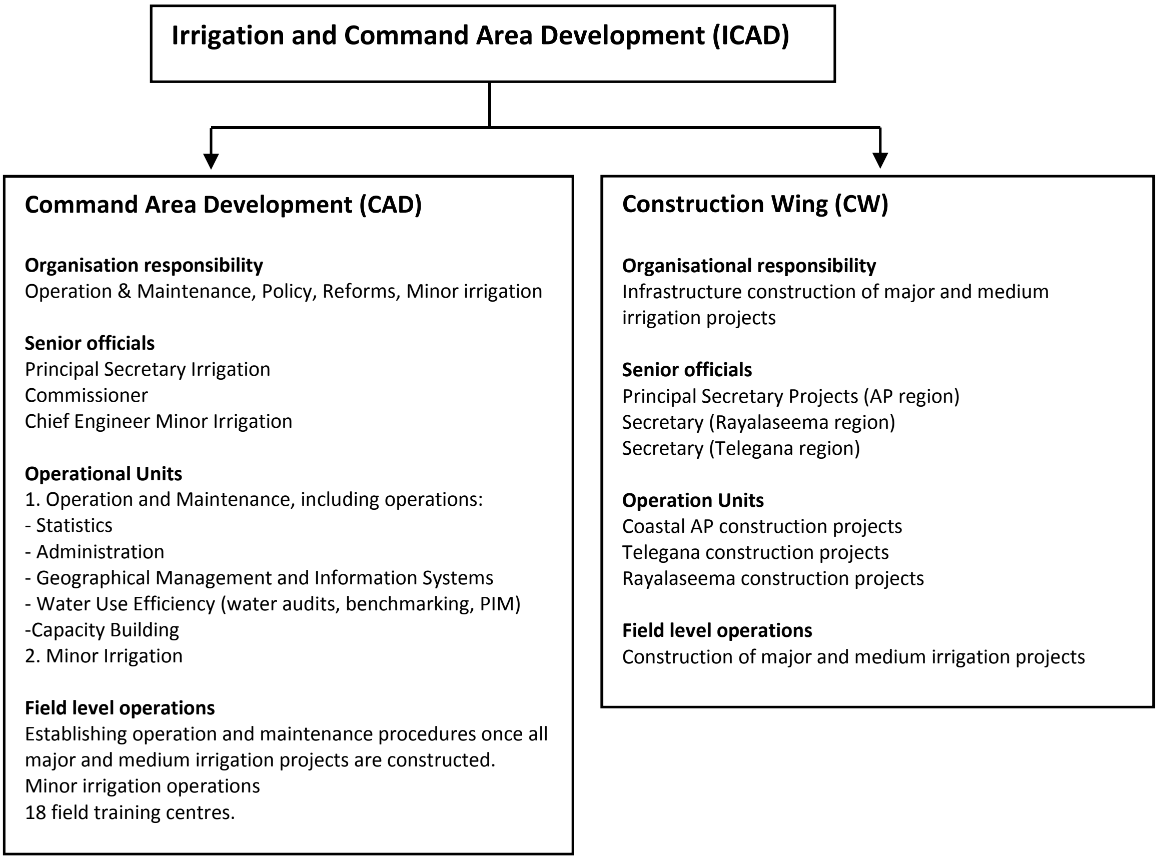
development of reservoir and canal infrastructure to increase water storage capacity and expand the area under irrigation throughout AP (Section 4.4.2 for overview of AP state hydraulic mission).

The ICAD is divided into two distinct but complementary organisational components: the Command Area Development (CAD) and the Construction Wing (CW) (Figure 4.1). The CW is exclusively focused on the construction of major and medium irrigation infrastructure throughout the state, including canals, embankments, reservoirs, dam, weirs and other related infrastructure. The CW is headed by the Principal Secretary for Projects and AP coastal region, along with two Secretaries responsible for project construction in Rayalaseema and Telegana regions of AP (Appendix 10 for regional map of AP). The Principal Secretary for Projects reports directly to the incumbent Minister of Major and Medium Irrigation in AP state government (ibid). The CW has 6700 staff working on various activities related to construction of major and medium irrigation projects (ibid).

In 1973 the Irrigation Commission (national government) instructed state Irrigation Departments to establish Command Area Development Authorities for irrigation schemes, in acknowledging the under-utilisation of large irrigation systems and to promote better management through inter-disciplinary approaches[94]. The CAD was established through the enactment of the AP Irrigation Utilisations and Command Area Development Act in 1984. The CAD's primary objective is to implement demand management initiatives, in addition to policy and reform measures (Gupta, 2010). The CAD consists of two units with 300 staff manning various positions (AP1; GoAP, 2010a). The Operation and Maintenance (O&M) unit focuses on improving efficiency and performance of all existing irrigation projects (major, medium and minor); and the Minor Irrigation unit focuses on the creation and revival of minor irrigation projects under 2,500ha in command area[95] (ibid). In 2005 under an organisational reform initiative, various programmes were established within the O&M unit to examine cross thematic areas of irrigation and water management, in addition to efforts to staff them with multi-disciplinary teams (ibid). The CAD is headed by the Principal Secretary for Irrigation, who reports directly to the Minister of Minor Irrigation and to the Minister of Major and Medium Irrigation (Appendix 11 for further operations of the CAD and CW).

[94] The Irrigation Commission considered that 'the Command Area Development Authority would be responsible for water utilisation and integrated area development in the irrigation command area, including modernisation of the distribution systems, the provision of drainage and the maintenance of both the distribution and drainage systems' (GoI, 1984:20).
[95] Irrigation projects are classified by the command area that they cover. Major projects serve an area of over 10,000ha; medium projects from 10,000 to 2,500ha; and minor project under 2,500ha (GoAP, 2012)

Figure 4.1: ICAD organisational components (GoAP, 2010a)



Water Management Committee

The Water Management Committee (WMC) is a state-level apex body for decision making on water related issues, promoting inter-disciplinary coordination amongst state departments on water projects. It was established in 2007, to replace the previous Water Charges Review Committee within the ICAD, as part of the on-going reform measures initiated in 2005. The WMC's functions include policy development and reform, regulation, performance, convergence and coordination within the ICAD department and amongst the various state government departments (Gupta, 2010). The WMC represents one of the first attempts to establish an integrated and multidisciplinary framework for cooperation of all departments involved in water management at state government level in India (GoAP, 2010a).

The WMC is chaired by the Chief Secretary of AP, with the Principal Irrigation Secretary and CAD Commissioner conveners of the committee. It also includes Principal Secretaries of the state departments listed in Table 4.2. There exists a significant weighting towards ICAD personnel on the WMC, with further ICAD representation including the three Secretaries of the CW, numerous Chief Engineers of major, medium and minor irrigation works. In total, ICAD staff make-up between a third and half of the all representation on the WMC. The ICAD acts as a secretariat for the WMC.

AP Water Resources Regulatory Commission

In August 2009, the AP state government passed an Act to form the AP Water Resources Regulatory Commission (APWRRC). The role of the APWRRC is to determine and regulate water requirements and use between different sectors, promote irrigation efficiency measures, and help implement state water policy (GoAP, 2010a:34). The APWRRC consists of a chairperson and ICAD staff, including representation from various state departments listed in Table 4.2 (Gupta, 2010). It is an independent body, not officially part of the state government bureaucracy. Although the APWRRC Act was passed by state government in August 2009, it is still in the process of formation and operationalisation (as of late 2012).

Organisations providing capacity building and technical input for ICAD

Established in 1982 under a programme initiated by the World Bank, the Water and Land Management Training and Research Institute (WALAMTARI) provides training in administrative, financial and technical irrigation issues to the field training centres and farmer organisations throughout AP, including Participatory Irrigation Management and Water Users Associations. The Centre for Climate Change and Environment Advisory (CCCEA), established in 2010 and housed within the Human Resource Development Institute of AP, provides climate change awareness and inter-disciplinary training to ICAD staff. AP Satellite Remote Application Centre based in Hyderabad, provides remote sensing support for irrigated area assessment of cropping seasons, digitising canal networks and for flood monitoring purposes (GoAP, 2010a).

4.2.5 Andhra Pradesh water policy

The overall objective of the Andhra Pradesh State Water Policy (APSWP) 2008 is to 'ensure the comprehensive multi-sectoral planning, development and management of the state's water resources; and effective, efficient, equitable and sustainable service deliveries for various water uses' (GoAP, 2008:6). The policy declares the provision of drinking water and irrigation as the two top priorities, number one and two respectively; followed by hydropower, ecology, agro-industries and non-agricultural industries, navigation and other uses. This sectoral prioritisation is identical to the National Water Policy (GoI, 2002). The APSWP identifies four main objectives:

1) To achieve water security for the state by providing sufficient water to all users, particularly for drinking purposes and agriculture. In achieving water security, existing threats to water resources from extreme weather events (drought and floods) and other development pressures both in terms of water quantity (future demand outstripping supply by 2025) and water quality are acknowledged. Although the policy does not use the term 'climate change', it does make a number of references to 'climate risks' in terms of managing the impacts of extreme events, particularly droughts and floods, in reference to natural climate variability, and not anthropogenic climate change.

2) The improvement of water management and efficiency, with particular focus on the institutional response. In this regard, the policy calls for reform, in so much as 'making systematic transition from the water resource

development mode to an integrated water resource management mode, with appropriate reforms in water sector' (GoAP, 2008:4). This is the first time the concept of IWRM has entered AP water policy. Such institutional reform measures include the establishment of the Water Management Committee, the AP Water Resources Regulatory Commission, re-organising the ICAD department and the strengthening of WUA. The policy calls for all concerned organisations to develop a policy framework for planning water resources, augmenting them (and hence supporting the organisational remit of the Construction Wing), and putting them to productive use. Also of note is the call for the use of effective modern technology approaches in water planning, including the development of a knowledge base, monitoring and communication systems, applied research, and improving information and data flow between departments and with the public (supporting the organisational remit of the CAD).

3) Improvement in the availability and efficiency of irrigation water. Specifically to close the gap between the irrigation area created and utilised[96]In this regard, the policy calls for modernisation and rehabilitation of existing irrigation infrastructure, and the development of appropriate information analysis systems with bench marking and water audits. The policy does not call for a revision of irrigation water tariffs as a mechanism to improve efficiency; however, the ICAD is carrying out efficiency incentives with the target of complete devolution of water taxes to WUA. The promotion of sustainable groundwater use is also highlighted.

4) The sustainable ecological balance by conserving and protecting water bodies and wetlands through regulation and enforcement of standards, including regulating industrial waste (GoAP, 2008)

4.2.6 Andhra Pradesh water law

There is no overall legal framework for water law in AP. A number of legislative acts cover various aspects of water management, the first dating back to 1884 (Appendix 12 for complete list Acts in AP). Recently passed Acts that aim to promote institutional reform include the 1997 AP Farmers Management Irrigation Act, recommending the establishment of Participatory Irrigation Management and Water User Associations (GoAP, 1997). The AP Water, Land and Tree Act 2002, calls for water conservation measures, abatement of pollution of surface water bodies, an increase in tree cover over the state, and significantly, for the regulation of groundwater abstraction (GoAP, 2002). The AP Water Resources Regulatory Act, 2009, calls for the establishment of a state level regulatory authority, to facilitate the efficient, sustainable and scientific management of water resources of the state for drinking, agriculture, industrial and other purposes (GoAP, 2010a).

[96] Section 5.3.2.1 for explanation on irrigation gap.

4.3 Water resource status

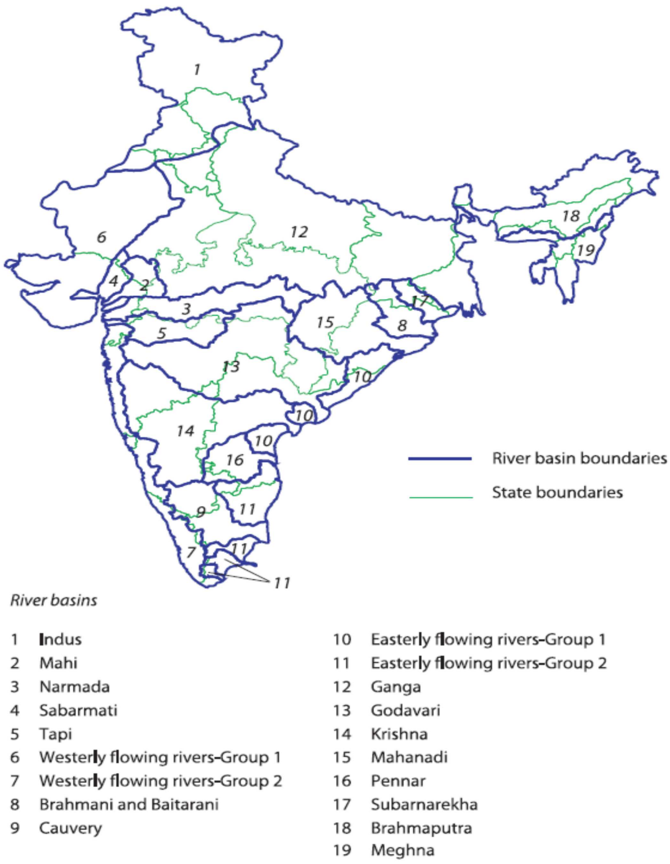
This section details the physical water resources of India and Andhra Pradesh state.

4.3.1 National water resources

India covers an area of 3,287,263km^2, sustaining a population of over 1.21 billion people (GoI, 2012b). India is a physiologically diverse country, with the Himalaya mountains defining the northern border, the northern fertile Gangetic river plains, the Thar desert in the north-west, the peninsular semi-arid Deccan plateau in the central south region, and tropical southern India.

India's internal renewable water resources are estimated at 1287BCM[97]: 690BCM from surface water and 433 BCM from groundwater (CWC, 2005; Amarasinghe et al, 2005). There are 19 major river basins[98], the majority of which flow eastwards draining into the Bay of Bengal (Figure 4.2). The climate is tropical monsoon in nature, with an average 75% of precipitation being delivered during the south-west and north-east monsoon seasons, from June to November (Kumar et al, 2011). River flows are highly seasonal, with peak discharges occurring during and immediately after monsoon precipitation (Amarasinghe et al, 2005).

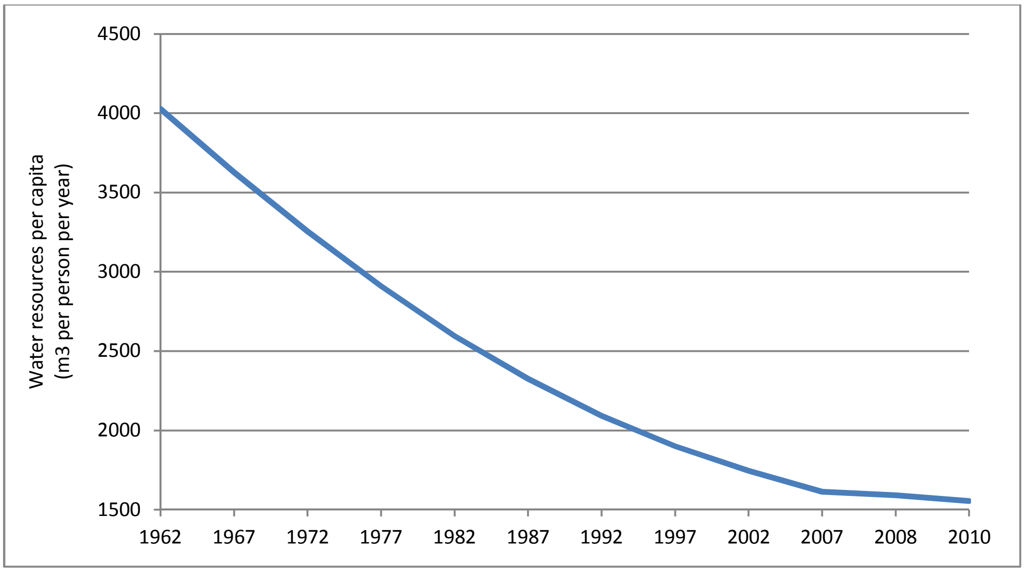
Figure 4.2: Major river basin of India with state administrative boundaries (Amarasinghe et al, 2005)



[97] India's total renewable water resources are estimated at 1887BCM, the sum of the internal renewable water resources (1287BCM) and the water flow generated outside of India's national borders (600BCM).
[98] Appendix 13 for water resources statistics of each of the 19 major river basins .

Water resources per capita have declined sharply since 1962, from 4090^3 to $1560m^3$ in 2010, defined by Falkenmark et al (1989) as experiencing occasional or regular water stress[99] (Figure 4.3). Irrigation accounts for an estimated 90.4% of water withdrawn in India, followed by domestic (7.3%), industrial (2.3%) (FAO, 2012). The withdrawal of groundwater for irrigation, domestic and industrial needs has dramatically increased since the late 1960s with the advent of groundwater pumps and borewells (Shah, 2009). Agriculture engages an estimated 58% of the Indian workforce[100], contributing 19% of GDP (GoI, 2011b). It is estimated that irrigation[101] supplies 45% of agricultural production[102], with rainfed agriculture the remaining 55%[103] (GoI, 2012b).

Figure 4.3: Declining per capita water resources in India since 1962 (FAO, 2012)



Future projections[104] for 2025 and 2050 estimate that total sectoral demand will increase by 153BCM and 220BCM, respectively, from the 2000 level of 680BCM (Shah et al, 2007); on the account of population growth, changing consumption habits and economic development (ibid) (Appendix 14 for demand projections for each sector). Per capita water resources are estimated to be in the region of $1400m^3$ per person by 2025 (Gupta and Deshpande, 2004).

[99] Water resources per capita per year below $1700m^3$ is termed as experiencing 'water stress'; below $1000m^3$ is termed 'severely water scarce' (Falkenmark et al, 1989).
[100] Agriculture in India is characterised by small and marginal operational holdings. About 85% of total cultivated land has been fragmented into less than 10 hectare land plots. About 60% of farmland is less than 4 hectare in size (FAO, 2012).
[101] Irrigation water from both surface sources via canal systems and groundwater sources.
[102] Principal crops in India include rice, wheat, barley, sorghum, millet, sugarcane, oilseeds, cotton, jowar, bajra, tea, coffee, coconut, cashew, rubber, spices, pulses, potatoes, cauliflower, onion, tomatoes, cabbage, mango, banana, sapota and lime (FAO, 2012).
[103] The exact percentage of rainfed and irrigated land in India is disputed, with some claiming rainfed and irrigated land is 60% and 40% respectively (Shah et al, 2007).
[104] The demand projections are calculated by the PodiumSim model under a Business as Usual storyline, developed by the International Water Management Institute (Shah et al, 2007).

4.3.2 Andhra Pradesh water resources

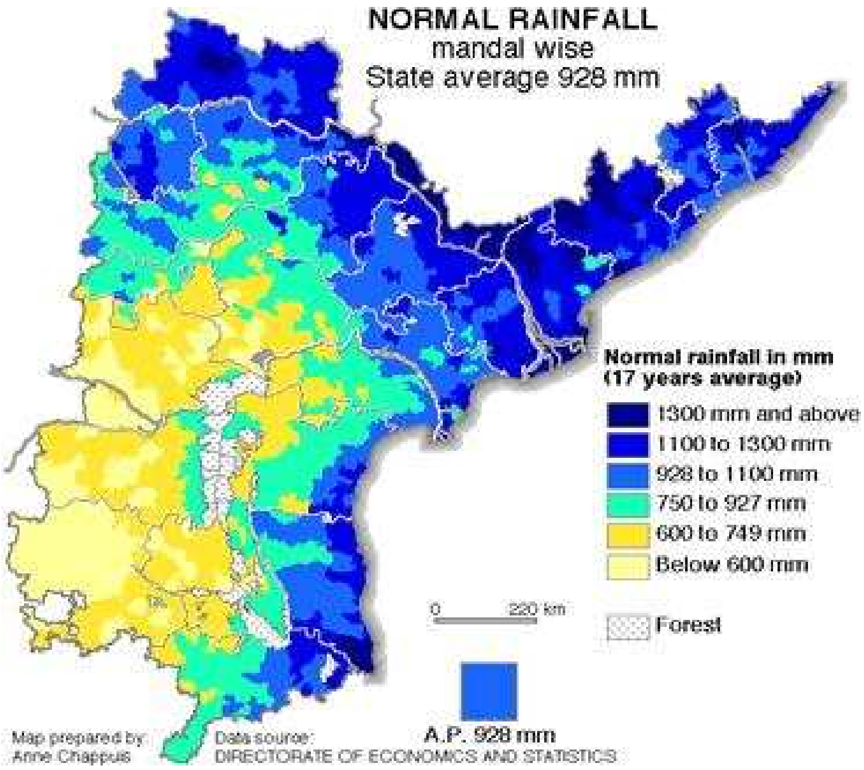
AP covers an area of 275,045km^2, with a population of 84.6 million people (GoAP, 2012), located in south central India (Figure 4.4). Over three quarters (76%) of the population live in rural areas with agriculture the principal livelihood activity[105], engaging 60% of AP's workforce and the largest sectoral contributor to Gross State Domestic Product (GSDP) at 30% (GoAP, 2010c). The state consists of three principal regions: Rayalaseema, Telegana and Coastal Andhra Pradesh (Appendix 10). Hyderabad is the state capital.

Figure 4.4: Location of Andhra Pradesh state within India (shaded in red)

AP is predominately semi-arid, receiving on average 928mm of precipitation annually, 75% of which is delivered during the summer monsoon season (June to September) (GoAP, 2009). There exists considerable spatial variability in precipitation, with the south-west Rayalaseema region receiving less than 600mm and the northern areas over 1300mm (Figure 4.5). The south-west monsoon delivers on average 550mm from early June to late September, whilst the weaker north-east monsoon delivers on average 120mm (GoAP, 2010a). The state experiences periodic droughts every 15 years on average since 1871, with the last drought occurring from 2001-2004, characterised by a 13% reduction in average precipitation (Venot et al, 2007). The state also suffers periodic flooding, particularly during and immediately after the south-west monsoon, inundating low lying delta regions. The last major flood was in October 2009 (Section 6.2.4.1).

[105] The major crops grown in AP include: rice (61% of total irrigated area), groundnut (4.7%), maize (4.5%), pearl millet (4.1%), cotton (3.5%), pulses (3.3%), sugarcane (3.2%), chillies (3.0%), fruits and vegetables (2.5%), cereals (2.3%), sorghum (2.1%) and numerous other crops (5.8%) (GoAP, 2009).

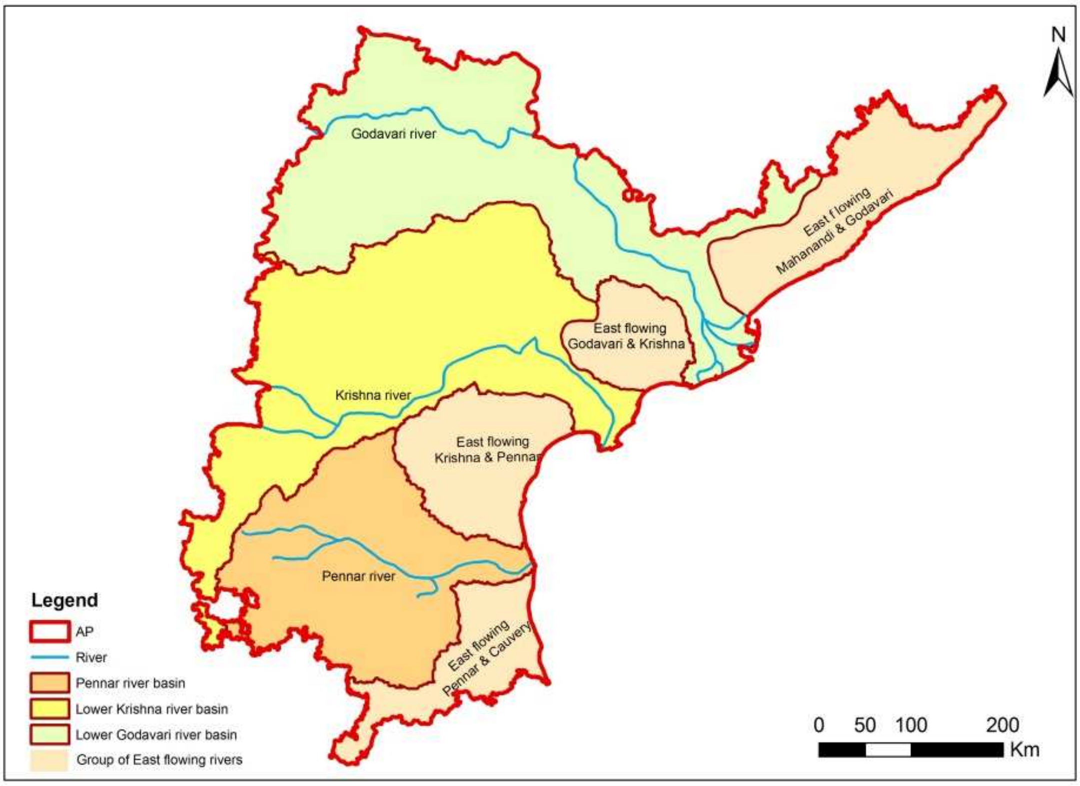
Figure 4.5: Precipitation variation across Andhra Pradesh state (GoAP, 2012)



The total renewable water resources of AP are estimated to be 108.6BCM, with surface and groundwater accounting for 78.5BCM and 30.1BCM, respectively (ICAD, 2010). 65BCM are currently utilised, 60% of the total renewable water resources of the state. Irrigation accounts for 64BCM of water withdrawn (98.4%), with the remaining withdrawn for drinking water 0.6BCM (1%), industry 0.3BCM (0.5%) and power generation 0.003BCM (0.003%). Per capita water available is estimated to be in the region of 1400m^3 (Gupta, 2010), defined as water stressed (Falkenmark et al, 1989).

There are three major river basins in the state, along with four groups of easterly flowing rivers and sub-basins (Figure 4.6). The Lower Krishna, Lower Godavari and the Pennar basin, in addition to the Group of Easterly Flowing Rivers consists of 37 medium and minor rivers and catchments located along coastal region of AP (GoAP, 2010a).

Figure 4.6: Major river basins of Andhra Pradesh (GoAP, 2012)



The Godavari and Krishna rivers have the highest water yields[106] within the state (Table 4.3). The water resources of the Krishna and Pennar basins are fully utilised, having been closed basins for the last decade (Gupta, 2010; Venot et al, 2008, 2007). The Godavari is estimated to have 21.5BCM of available water annually, according to state government statistics (GoAP, 2012). The rivers are highly seasonal in nature, with peak flow occurring during and immediate after the summer monsoon season (Appendix 15 for historical annual hydrograph of the Krishna River). Irrigation accounts for over 90% utilisation of AP's surface waters with 49.1BCM withdrawn for canal irrigation, (GoAP, 2012). Agriculture employs 60% of the state workforce contributing 30% of GSDP (GoAP, 2010c). Future water demand projections for the state estimate that an additional 47.8BCM of water resources will be required to sustain sector demands by 2025, of which agriculture will account for 91.6% (GoAP, 2012) (Appendix 16 for sector demand projections for 2025). By 2020 with an increasing population projected at 90 million, water availability per capita is estimated to be 1150m^3 (Palanisami et al, 2010), edging closer to severely water scarce status (Falkenmark et al, 1998).

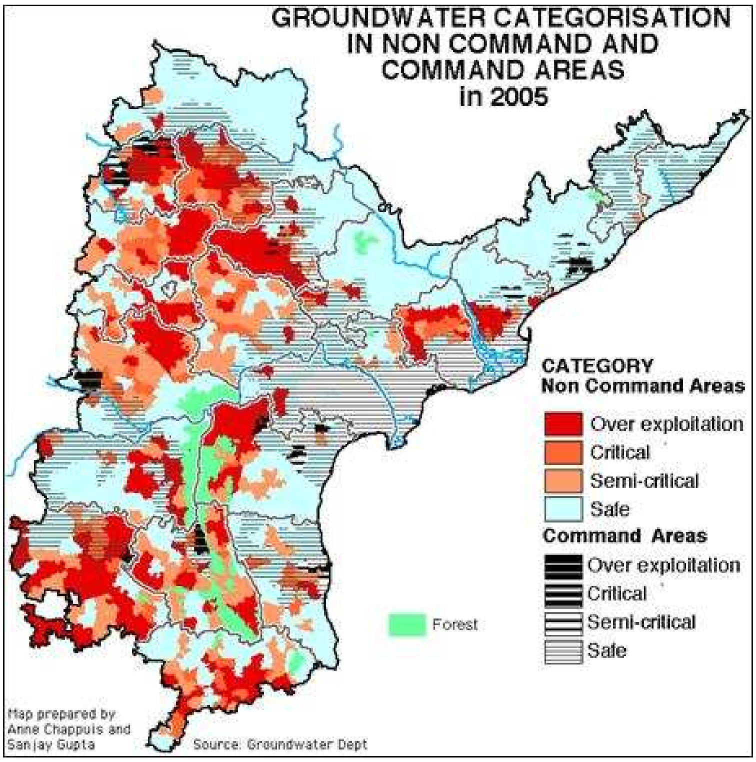
[106] Assuming annual river discharge being calculated at 75% mean annual flow probability.

Table 4.3: Total renewable surface water resources of Andhra Pradesh river basins (GoAP, 2012)

River basin	Catchment area (km)	Total renewable surface water (BCM)	Total renewable groundwater (BCM)	Total renewable water resources
Godavari	73,201	41.9	9.9	51.8
Krishna	74,382	22.9	11.3	34.2
Pennar	47,111	2.8	4.0	6.8
Group of Easterly Flowing Rivers (GEFR)	52,461	10.9	4.9	15.8
Total	**247,155**	**78.5**	**30.1**	**108.6**

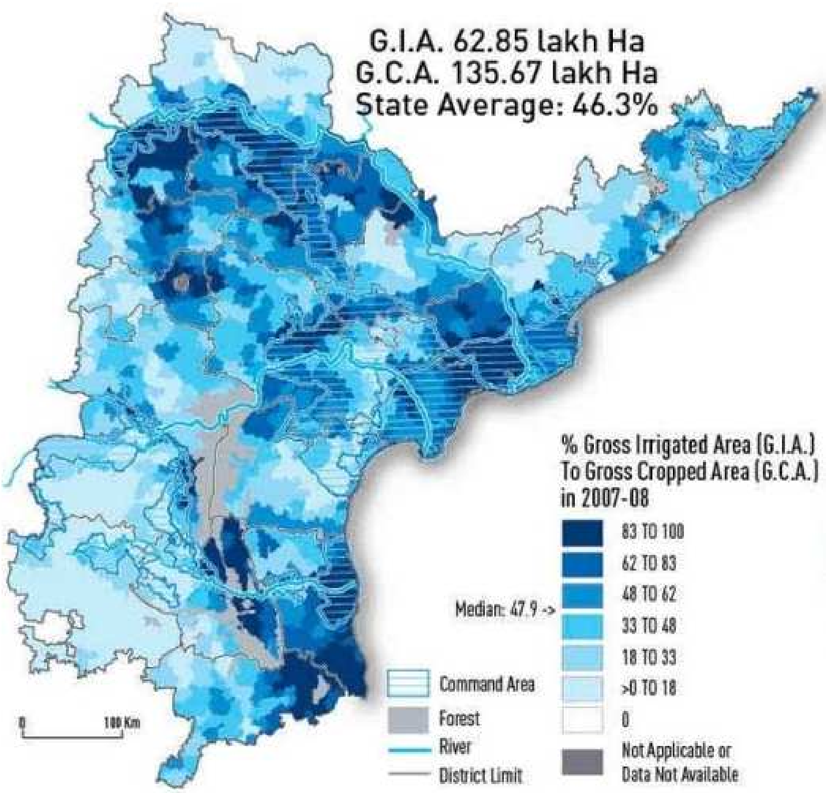
The State Groundwater department estimated that AP has 30.1BCM of replenishable groundwater annually (GoAP, 2012). Over 85% of the state lies on crystalline and basaltic rocks characterised by hard rock aquifers, with low groundwater potential (Venot et al, 2007). The development of deep groundwater bore holes from the mid-1970s onwards has accelerated the level of extraction in recent decades, with an estimated 26 million individual extraction points, the vast majority of which are unregulated. The level of withdrawal and exploitation varies significantly across the state (Figure 4.7). Levels of exploitation are higher in the interior western-half of the state, in areas generally not served by surface water canal irrigation. 18BCM of groundwater is utilised by agriculture, domestic and industrial needs (GoAP, 2012). Withdrawal for irrigation accounts of 14.9BCM, with domestic and industrial needs accounting for the remainder (ibid). Of the remaining 13BCM within the state, only 3.5BCM is potentially available for utilisation owing to the remaining existing in deep aquifers and generally inaccessible (ibid; Venot et al, 2008, 2007).

Figure 4.7: Groundwater exploitation status in non-irrigation and irrigation command areas (GoAP, 2012)



An estimated 46% of AP gross cropped area[107] is irrigated by surface water form canal systems and groundwater, with canal systems concentrated in the coastal region of AP[108] (Figure 4.8). The remaining 54% of the gross cropped area is rainfed, concentrated inland in the Telegana and Rayalaseema regions (GoAP, 2010c) (Appendix 10 for regional map of AP). The area under canal irrigation contributes 60% of the states total agricultural production (Gupta, 2010).

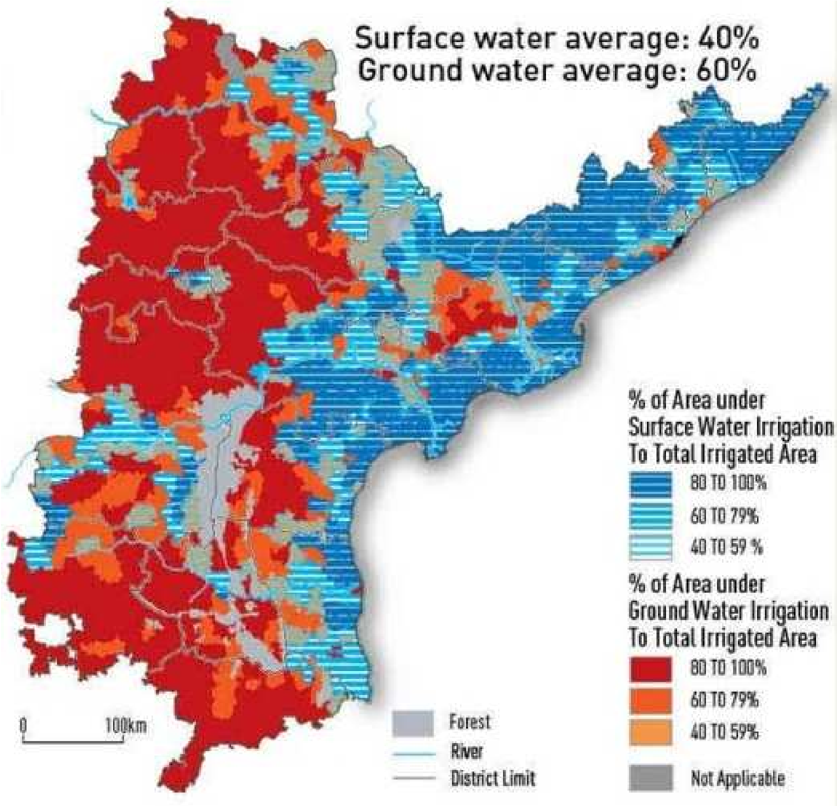
Figure 4.8: Irrigated area to gross cropped (rainfed) area in AP (GoAP, 2012)



Of the total net irrigated area[109] in AP, surface water from canal systems provides 33% of water for irrigation (GoAP, 2010c). Canal surface water irrigation is concentrated in the delta regions of the Krishna, Godavari and Pennar rivers; and the coastal region (Figure 4.9) (Appendix 17 and 18 for map of major and medium irrigation projects in AP). Groundwater irrigation dominates the interior region of the state, in areas relatively less well served by canal irrigation, accounting for 55% of total irrigated area in the state[110] (ibid).

[107] Gross cropped area refers to the total area sown for crop cultivation at least once per year, including both irrigated and rainfed areas (FAO, 2012).
[108] Canal irrigation accounts for 75.2% of total net irrigated area of the Coastal region, 16.4% in Telegana and 8.3% in Rayalaseema. Tank and well irrigation is dominant in Rayalaseema and Telegana region, with the regions relatively less served by canal irrigation than Coastal AP.
[109] Net irrigation area refers to the total area that is irrigated at least once per year in India (GoI,2012c), similar to the FAO's term 'area actually irrigated' (FAO, 2012). It includes the areas both within the command area of an irrigation system and rainfed areas not served by canal irrigation.
[110] Tank irrigated accounts of the remaining 7% of total irrigated area in AP (GoAP, 2010c).

Figure 4.9: Surface and groundwater irrigation in AP (GoAP, 2012)



4.3.3 Riparian basins of Andhra Pradesh

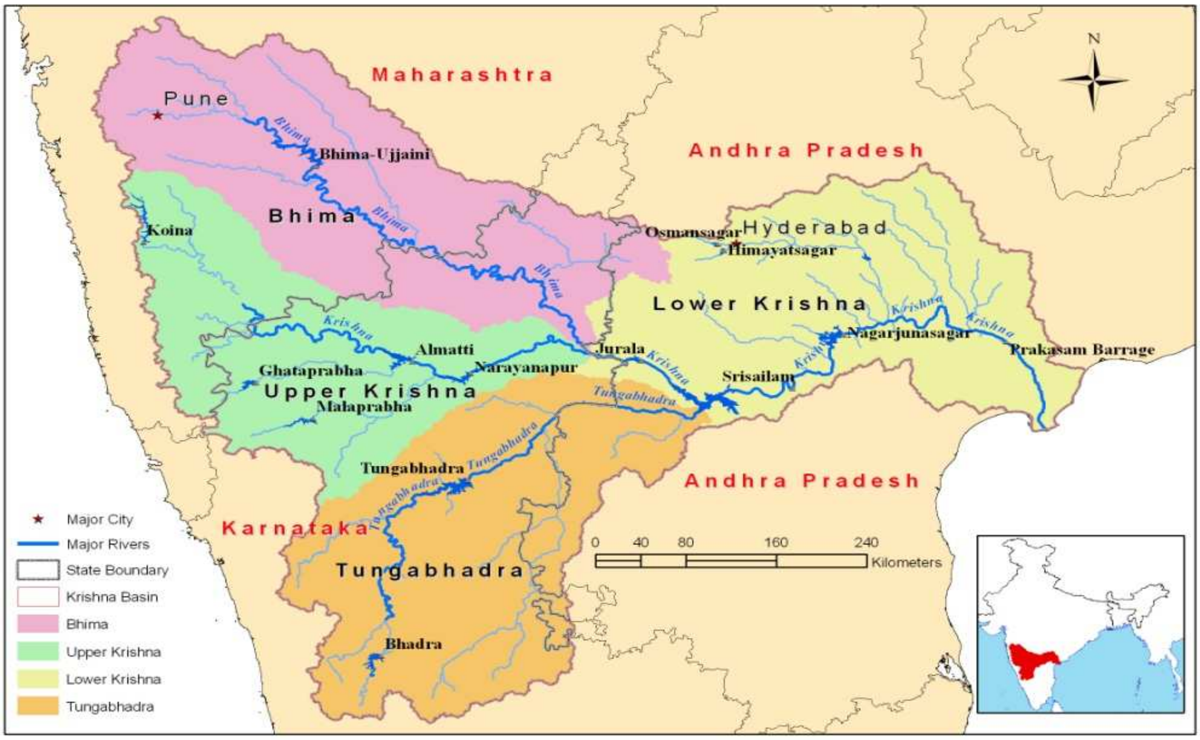
In order to provide a wider context to understand the water resource status of AP, it is necessary to provide a brief overview of the riparian basins shared by the state. Both the Krishna and Godavari river basins are shared with other states.

4.3.3.1 Krishna river basin

The Krishna River Bain (KRB) is the fifth largest basin in India by surface area (258,948 km^2), and the fourth in terms of annual discharge (Venot et al, 2007). The Krishna River originates in the Western Ghat mountains in Maharashtra, flowing easterly draining the semi-arid Deccan plateau before discharging into the Bay of Bengal (Appendix 19 for physical map of the basin). The climate is predominately semi-arid, with the basin receives on average 840mm of precipitation, 85% of which is delivered during the south-west and north-east monsoon periods (GoAP, 2009; Venot et al, 2007). Large spatial variation in precipitation exists throughout the basin, with the Western Ghats receiving over 3000mm and parts of the lower Krishna basin receiving less than 500mm of precipitation. The KRB is a closed river basin (Molden et al, 2005), with all of the flow withdrawn and committed between states characterised by minimal to zero outflow to the ocean within the last decade (Gaur et al, 2008; Venot et al, 2007, 2008) (Appendix 15 for historical outflow to the ocean). Historically and to this day, water resource development within AP has focused in the Lower Krishna River Basin (LKRB) (Figure 4.8). The fertile Krishna river delta region has extensive canal irrigation systems, with the basin sustaining a high proportion of the state's population, including the capital city, Hyderabad. The LKRB is particularly prone to water shortages, experiencing a drought every 10-15 years on average since 1887, the last of which was from 2001-2004. The KRB sustains a population of 74 million inhabitants, over 65% of which live in rural areas relying on agriculture for livelihood activities (GoAP, 2009).

The KRB covers three states: Karnataka (44% by area), Andhra Pradesh (29%) and Maharashtra (27%) (GoAP, 2009; Venot et al, 2007) (Figure 4.10). Owing to disagreements over water sharing between the riparian states, the national government of India established the Krishna Water Disputes Tribunal in 1969 under the Inter-state Water Disputes Act of 1956, with legal authority under the Supreme Court. After considering the water resource status and requirements of each state, the KWDT came to a decision in 1976 to allocate each state a representative proportion of the basins water resources[111]. Disagreements continued in following years with legal contestation by each state within the Supreme Court. In December 2010, the KWDT made a second allocative decision, awarding Maharashtra 25.5BCM, Karnataka 33.5BCM and Andhra Pradesh 36.8 BCM[112] (GoI, 2010b). Disagreements regarding allocative rights between the riparian states have continued after this second decision, with legal contestation on-going within the Supreme Court. The next formal decision by the KWDT is scheduled for 2050.

Figure 4.10: Krishna river basin shared by three riparian states (Venot et al, 2007)



[111] The first KWDT award in 1976 allocated Maharashtra 20.5BCM, Karnataka 25.7BCM and Andhra Pradesh 29.4 BCM based on 75% river flow dependency (Venot et al, 2007).

[112] The sum of the second KWDT award is 18.2 BCM higher than the first, allocating all of the KRB waters between riparian states, with zero flow to the ocean, as is the case with a closed river basin.

4.3.3.2 Godavari River Basin

The Godavari River Basin (GRB) is the fourth largest in India by area (312,812km^2). The basin is semi-arid, with precipitation ranging from 300 to 650mm annually, 80% of which is delivered during the south-west and north-east monsoon periods (Appendix 20 for physical map). The GRB is an open basin, with the easterly flowing Godavari River discharging into the Bay of Bengal (Appendix 21 for annual discharge into the ocean from 1968). The GRB sustains a population of 76.7 million people, 85% live in rural areas with agriculture the primary livelihood activity (Amarasinghe et al, 2005). The basin is shared by six states: Maharashtra (48 % by area), Andhra Pradesh (23.5%), Chhattisgarh (13%), Madhya Pradesh (8.5%), Orissa (5.5%) and Karnataka (1.5%) (GoAP, 2012) (Figure 4.11).

Figure 4.11: Godavari River Basin shared by six riparian states (GoAP, 2012)

The national government constituted the Godavari Water Disputes Tribunal (GWDT) in 1969, with direct legal authority under the Supreme Court. Unlike the KWDT which awards allocation at the state-level between riparians on 75% dependency of river flow, in 1980, the GWDT awarded water allocation between states at the basin and sub-basin level, linked to irrigation and other relevant water projects (GoI, 1980). AP was awarded an allocation of to divert 2.9BCM of water from the Godavari River for the Polavaram irrigation project. Similar project-based awards exist between other riparian states. As the GRB is open basin with surplus river outflow to the Bay of Bengal, there is generally less tension between riparian states regarding water sharing as water is more available, unlike the KRB characterised by a high level of infrastructure development and utilisation.

Although there are on-going ah-hoc legal disputes regarding project-based allocations between riparian states, at the time of writing, there are no plans to change the 1980 agreement.

4.4 India's hydraulic mission

This section introduces the historical development of the national and AP state hydraulic missions, and the role of the hydrocracy (Section 2.5.2 for hydraulic mission theory).

4.4.1 National hydraulic mission

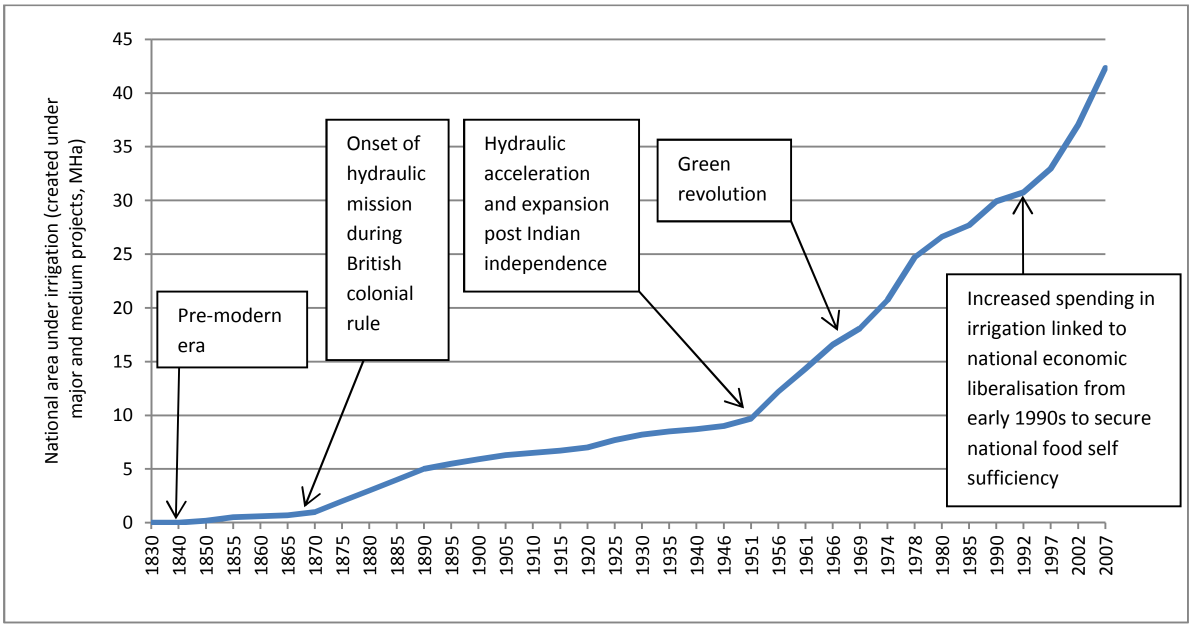
Water management for farming in ancient and medieval India was centred on village communities at a small scale. Although some modest (medium-scale) canal structures were built during the Mauryan kingdom[113] - including the earliest canal systems in Cauvery river delta in south India, during the reign of Firoz Shah Tughlak[114] in north India and the Vijayanagar kingdom[115] in south India - it is unlikely that at any point in time these were significantly present in a typical India rural household (Randhawa, 1982). Farming was organised as a family enterprise, with water mobilised and distributed at the community level at the small scale (Aggarwal and Narain, 1997). Water management techniques included tanks, inundation canals, temporary bunds to trap drainage, wells and water-wheels made up the ensemble of water harvesting and water storage structures. These techniques were essentially directed towards either impounding precipitation, tapping river inundations or retrieving groundwater recharge (ibid). By the turn of the 19th century, it is estimated that water was being applied to six million hectares of agricultural land throughout India, with only 300 hectares centrally controlled by the government (Habib, 1999). As Habib considers 'sufficient evidence does not exist to warrant the belief that the state's construction and control of irrigation works was a prominent factor in the agrarian life of Mughal India'[116] (ibid:297).

The 1830s heralded a dramatic change in water resource management in India, a paradigm shift in irrigation and water development practice (Shah, 2009). The British controlled much of India as the colonial power, and began to show interest in the significant commercial potential of irrigation expansion (Whitcombe, 2005). In the following decades, perennial canal irrigation, weirs and barrages were constructed to control surface water flows, dramatically increasing the volume of water stored through medium and large scale reservoirs (Stone, 1984; Whitcombe, 1972). Several large canal irrigation schemes were built by the mid-19th century, including the Ganges canal, the Godavari and the Krishna delta systems (D'Souza, 2006). Controlling rivers and reshaping river basins were considered as goals befitting the British empire, with grandiosity and state building at the heart of the colonial irrigation ideology, described as 'constructive imperialism' (Saul, 1957). The new ideology, the 'advent of the modern irrigation era in India' (D'Souza, 2003:3786) featured hydraulic works of such 'bold and magnificent conception' (Whitcombe, 2005:683), manifested itself in creating centralised state

[113] The Mauryan kingdom endured from 321 to 185 BC across the majority of modern India.
[114] Tughlak kingdom was centred in Delhi, north India, in the mid-14th century.
[115] Vijayanagar kingdom was centred in south India, in the 15th century.
[116] The historical time period of Mughal India is from the early 16th to early 19th century.

bureaucracies for constructing and managing large irrigation systems on commercial lines, often to grow cash crops for export exploiting hydraulic opportunity for intensive irrigated agriculture (Shah, 2009). The hydraulic mission can be considered to have begun at this time, from the mid-19th century onwards (Figure 4.12). By the end of the 19th century, 5.9 million hectares of land was irrigated throughout India under the management of the government (GoI, 2012c). The commercial viability of large-scale canal irrigation had been firmly established by the British (Whitcomb, 2005). However, enthusiasm for new irrigation projects waned somewhat in the late 1920s owing to the global depression and the rise of the Indian independence movement, with the British wary of significant financial investments and long gestation periods of project financial recovery. However, further momentum for hydraulic control emerged in the mid-1930s, drawing on the Tennessee Valley Authority blueprint for multi-purpose storage schemes, with the prospect of complete control of surface water within the command area and river basin (D'Souza, 2006).

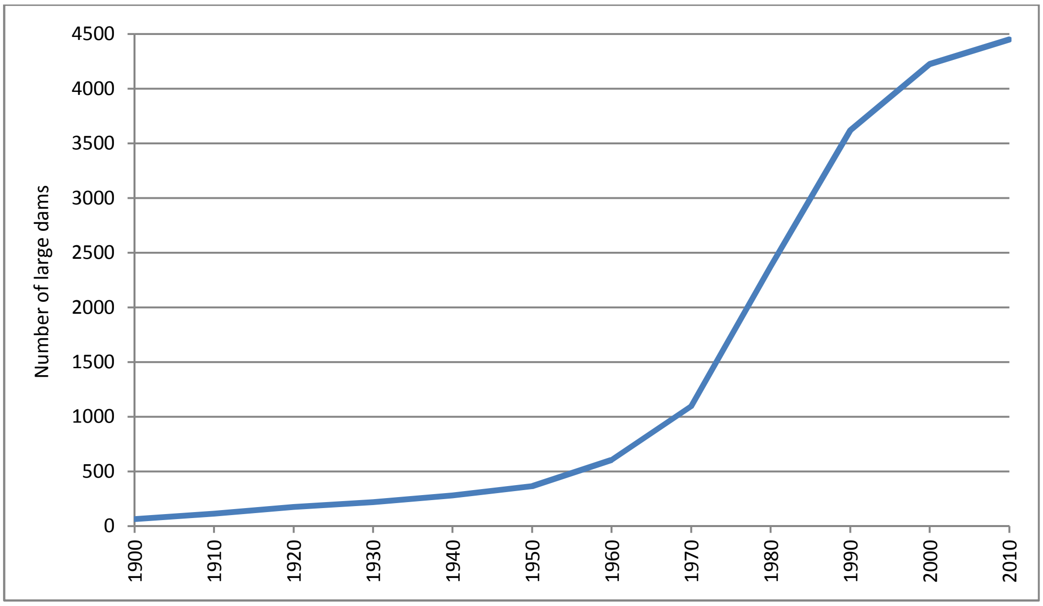
Figure 4.12: National irrigation area created from 1830 to 2007, as an indicator of India's national hydraulic mission (FAO, 2012; Shah, 2009)



The British colonial rule had created a strong civil engineering profession that dominated postcolonial thinking about irrigation (Shah, 2009). The British had established a civil engineering college in northern India (Thomason College of Civil Engineering) in 1854, and a laboratory in Lahore University in 1930 to examine applied irrigation research techniques in the field. Newly trained engineers (British and Indian) felt 'a new sense of professional mission, and one linked intimately to colonialism and state building' (Gilmartin, 2003:5058). The engineering professionalism became more professional, 'the progress of science had outrun the rule of thumb methods', with scientific research and investigations needed to replace 'engineering judgement based on experience' (GoI, 1992:57). Civil engineering and applied research concentrated on the engineering of river basin in order to control surface waters, through weirs, barrages, surface water hydraulics, canal structure, distribution, dam and reservoir construction, and reclamation of waterlogged and saline soil (Shah, 2009).

From Indian independence in 1947, the 'colonial irrigation ideology' (Shah, 2009:22) was the official doctrine of the newly formed government, which duly established the Department of Public Works, empowered to carry this approach forward (ibid). Providing political backing, the first Prime Minister of India, Jawaharlal Nehru, famously described the Bhakra dam in the foothills of the Himalaya as a 'temple of modern India' (D'Sozua, 2003). Thus in the following years after independence, India continued and accelerated along its hydraulic mission, into an era of industrial or high modernity, defined by large-scale infrastructure-based supply-side water management approaches. The mid to late 1960s heralded an up-shift in gear as India accelerated along its hydraulic mission (Figure 4.12). The hierarchical and centrally organised government hydrocracy (the national MWR and state irrigation department) increased their physical (and political) control of water in river basins throughout India by enhancing storage and extending irrigation command areas (D'Souza, 2003)[117]. At independence, 9.7Mha of irrigation area had been constructed under medium and major projects, rising to 42.5Mha by 2007 (FAO, 2012). The number of large dams constructed has dramatically increased since independence, from less than 500 in 1947 to over 4400 in 2010 (Figure 4.13); within the period 1960s to late 1980s, over half of all of India's existing large dams were constructed (FAO, 2012).

Figure 4.13: Number of large dams in India (FAO, 2012; GoI, 2012b)



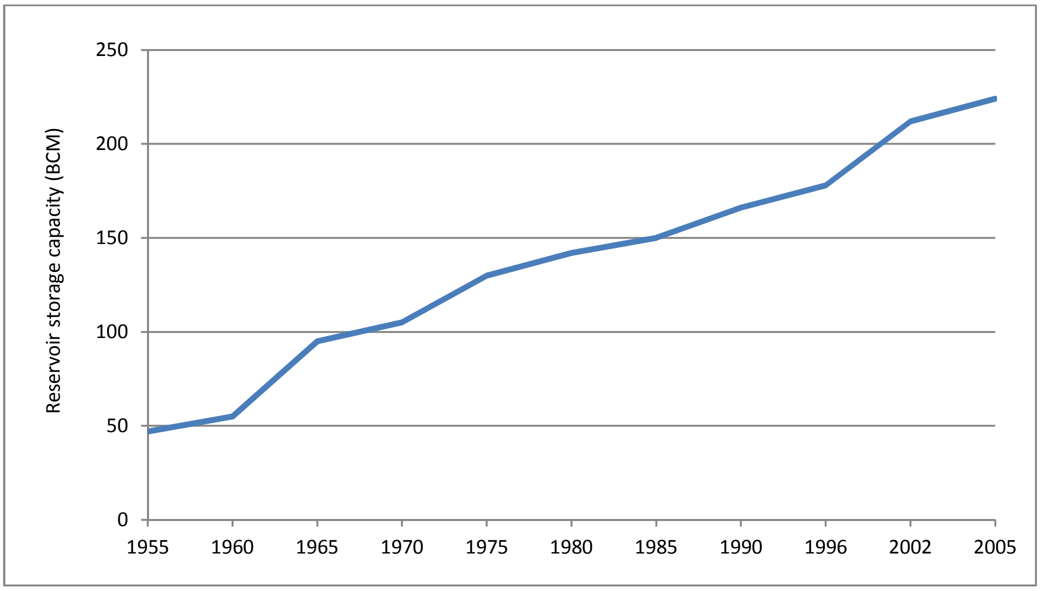
Sufficient funding was made available in pursuit of the hydraulic mission. From the Indian government, more than 90% of public investment in agriculture during the first 40 years of independence was allocated to the construction of reservoirs, dams and canal systems (Kishore, 2002). And from the World Bank too, funding numerous large-scale irrigation projects from the 1960s to mid-1980s, with an estimated $20 billion lent to India from the period 1970 to 1985 (Briscoe and Malik 2006). However, by 1960, the once profitable irrigation sector under the British colonial rule had turned into a less than profitable endeavour. Irrigation charges

[117] The colonial irrigation ideology was largely considered 'at odds' with native water-harvesting practises that had dominated water management at a local scale before the mid-19th century (D'Souza, 2006:624).

remained uncollected, the maintenance system was continually deferred, and vote-block rural politics took their toll (Ebrahim, 2004). The constructive imperialists ethos of 'build, manage, generate surpluses and maintain', had given way to the 'build, neglect, rebuild' syndrome (Shah, 2009:25).

The onset of the green revolution[118] in India from the mid to late 1960s onwards led to further construction of large scale irrigation systems and reservoirs to meet national food production targets, leading India to become food self-sufficient as a nation in 1971[119]. The sanctioned 'water for food' discourse had firmly been established with national government during this time, with significant political importance attached to India being food self-sufficient as a nation (Shah, et al, 2007; Iyer, 2003; Allan, 2002). Cumulative reservoir capacity rose from 47 BCM in 1951 to 224 BCM in 2005 (Figure 4.14) (GoI, 2009a). Although it is noted that the proliferation of groundwater boreholes and pumps was as much, if not more, responsible for supplying localised water for farmers to increase production in helping meet national food demands (Shah, 2009; Repetto, 1994).

Figure 4.14: Cumulative national reservoir storage capacity (FAO, 2012)



As can be witnessed since Indian independence from 1947, the national hydraulic mission has remained strong and enduring, relentlessly pushed by the hydrocracy, with the sanctioned 'water for food' discourse setting the limits within which policies and projects are pursued, indicating what avenues are politically feasible and legitimate (Allan, 2002). In contemporary times, the hydrocracy's support for the National River Interlinking Project (NRLP) is a continuation of this approach. The NRLP is an ambitious pan-India major infrastructure project, aiming to transfer water from surplus river basins in the north-east and east to water deficit basins in

[118] Prior to the mid 1960s, India relied on imports and food aid to meet domestic requirements. However, two years of sever drought in 1965 and 1966 led to agricultural policy reform focusing on food self sufficiency. This led to the Green Revolution in which superior yielding, disease resistant wheat varieties in commination of better farming practices dramatically increased yields. In 1948, the average wheat yield per hectare was 0.8 tonnes, rising to 4.7 tonnes in 1975, and up to 6 tonnes per hectare in 2000 in some particularly productive areas such as the state of Punjab (FAO, 2012).

[119] Along with high yielding seed variety and the widespread use of chemical fertilisers that helped increase India's national food production level during the green revolution (Iyer, 2003). Crop yield per hectare in some areas of India is estimated to have increased as much as 400% during the decades following the green revolution (Swaminathan, 2006).

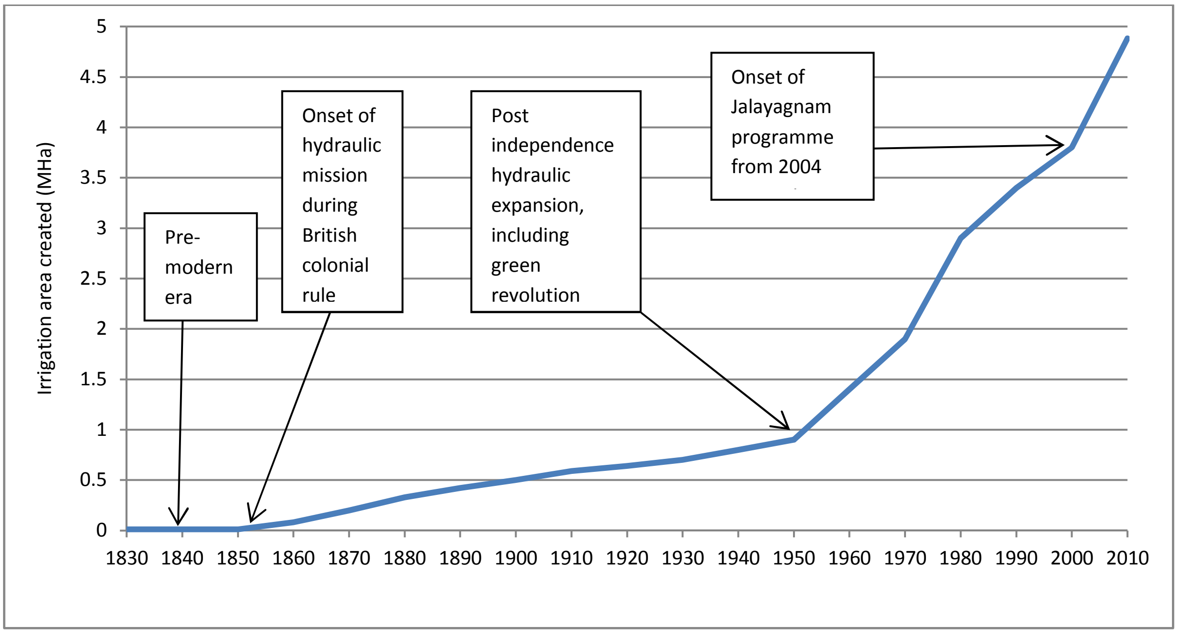
central and peninsular southern India (Smakhtin et al, 2007). It consists of linking 37 rivers throughout India, through the construction of 30 canal links and 36 major dams (Appendix 22 and 23 for maps of the Himalaya and Peninsular components of the NRLP).

Particularly targeted are the surplus water of the Brahmaputra and Ganga river basins, estimated to account for 32% and 28% of India's total utilisable water resources (1869BCM). It is claimed that the project will utilise an additional 220BCM of water, generating 34,000 MW of hydropower, supply drinking water to 101 districts and five cities, and irrigating an additional 34 Mha (GoI, 2012b). The total cost of the project is estimated to be in the region of $150 billion US dollars (Amarasinghe et al, 2009). The concept of a national river inter-linking project is not new. It was first proposed by Sir Arthur Cotton, a British engineer in the 1850s, primarily to aid inland navigation and transportation in preference over railways (D'Souza, 2003). However, owing to significant financial costs, the plans were shelved. After Indian independence, the project gained political traction in the 1960s, with plans re-worked in 1970s in the form of a national river grid, based on the notion of transferring surplus water from the Ganga and Brahmaputra rivers in the north, to central and southern states. Discussion has rumbled on throughout the last few decades, with criticism from civil society groups. However, owing to the huge financial costs and criticism by many of India's water experts the project has repeatedly been shelved, but the concept has never entirely been dropped by the hydrocracy (ibid). In 2002, the Supreme Court recommended that the government (including the hydrocracy) implement the NRLP, which led to the start of construction of the Ken-Betwar (Madhya Pradesh) and Polavaram (Krishna-Godavari basin) inter-basin links. However, owing to inter-state legal disputes over land submergence in riparian basins, relocating displaced populations, continuing environmental impact assessment disputes and funding constraints, the links are still (mid 2012) not fully constructed and operational. However, in February 2012, the Supreme Court judge again officially recommended the NRLP implementation, stating that central and the state governments should participate for the effective implementation of the river-linking project, 'in a time-bound manner' (BBC, 2012). Such legal and political backing of the NRLP is more than likely to embolden the hydrocracy, particularly the MWR and its subsidiary arm, the NWDA, which manages the project.

4.4.2 AP state hydraulic mission

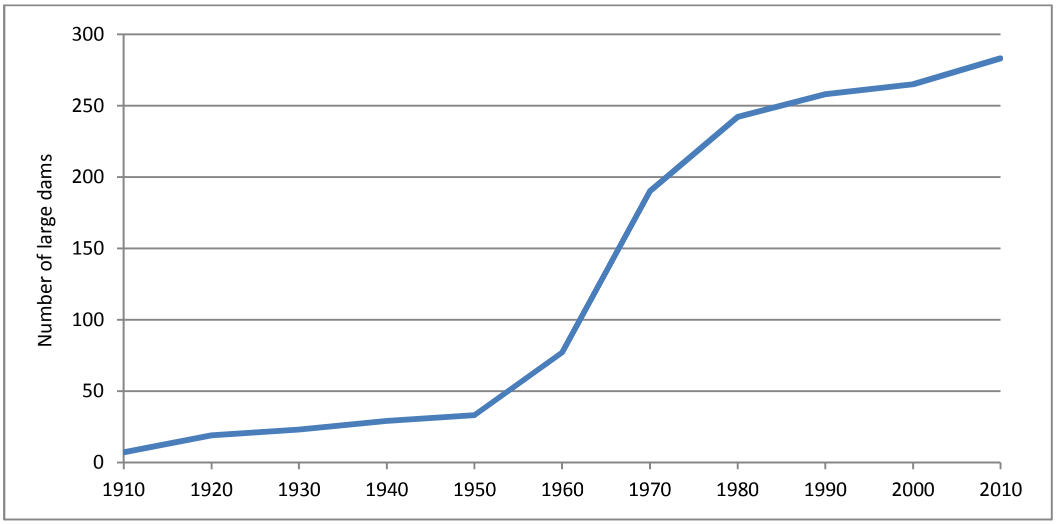
AP's hydraulic mission has developed along a similar time-bound fashion and characteristics to that of the national hydraulic mission (and contributed to it collectively along with other states). Until the late 1850s, water management was at a local level with water diverted from small streams and stored in tanks (Venot et al, 2007; Wallach, 1985). However, from the late 1850s onwards, under the colonial rule of the British, large hydraulic infrastructure began to be constructed, under the engineering direction of Sir Arthur Cotton (D'Souza, 2006). Many of the initial irrigation canals and reservoirs were constructed in the Krishna and Godavari river deltas, low lying fertile land (Figure 4.6), the largest being the Prakasam barrage completed in 1855; and later in the semi-arid regions of the Deccan plateau (Venot et al, 2007). From the early 1960s with the onset of the green revolution and the increasing political importance of securing state level food self-sufficiency, the state government embarked on numerous large scale infrastructure projects, particularly from the early 1960s to mid-1980s. The sanctioned 'water for food' discourse within AP government and particularly the Irrigation Departments legitimised large-scale infrastructure irrigation projects as politically necessary to secure state food production (Allan, 2002). During this time, under the direction and management of the centralised state hydrocracy the large reservoirs such of Nagarjuna Sagar (1967), Srisailam (1983) and the Tatipudi were constructed, primarily for irrigation purposes (Gupta, 2010). The area under irrigation dramatically rose from 1.5Mha in 1960 to 3.8Mha in 2000 (Figure 4.15).

Figure 4.15: AP hydraulic mission (GoAP, 2012; FAO, 2012; Shah, 2009)



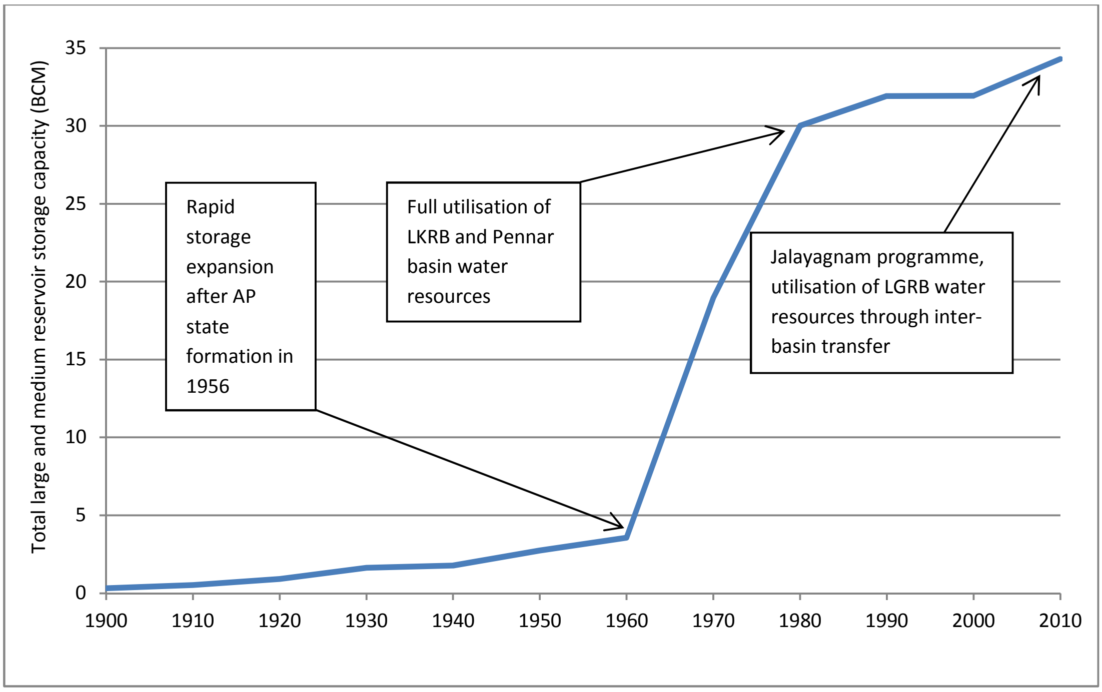
However, by the mid-1980s, the majority of the suitable sites for large dams had been exhausted, in addition to the full utilisation of the Lower Krishna River Basins (LKRB) waters. This slowed the pace of large scale reservoir construction, with efforts focused on improving the management and performance of existing irrigation systems (Figure 4.16).

Figure 4.16: Cumulative number of large dams in AP (FAO, 2012; GoAP, 2010a, GoI, 2009a).



As illustrated in Figure 4.17, the gross storage capacity dramatically rose from the early 1960s onwards, the peak period of the hydraulic mission, levelling off from the early 1980s, owing to the full utilisation of the LKRB water resources. However, under the Jalayagnam project initiated in 2004, storage capacity is starting to slowly increase once more, primarily through the capture and control of the Lower Godavari River Basin (LGRB) water resources. The Jalayagnam project with its emphasis on increasing reservoir storage and the area under irrigation, as well as inter-basin transfer, is considered as a renewed effort by the state hydrocracy to continue the hydraulic mission in AP (Section 6.2.1 for further details on the Jalayagnam programme).

Figure 4.17: Cumulative gross large and medium-scale reservoir storage capacity in AP (FAO, 2012; GoAP, 2010a, GoI, 2009a)



4.5 Conclusion

India's water resources are under increasing pressure to sustain a growing population and increased sectoral demand. Per capita water availability has been declining since Independence. Climate change non-stationarity heralds a new hydro-meteorological challenge for the government in developing an appropriate policy and water management responses. The MWR's institutional arrangement is rooted in post-independence government structures and approaches, historically focused on large-scale infrastructure based supply-side strategies in a continuation of the hydraulic mission. The next chapter examines the MWR's water policy response to climate change, particularly the policy formation process and the strategic direction of the water management strategies advocated by the MWR.

5.0 The National Water Mission policy

5.1 Introduction

This chapter examines the Government of India's (GoI) water policy response to climate change. It focuses on the two research questions at national government level introduced in Chapter 1.

Section 5.2 addresses the first research question: what is the GoI's national water policy response to climate change? It begins by discussing climate change awareness within national government that led to the formation of the Prime Minister's Advisory Council and National Action Plan on Climate Change in June 2008. It moves onto examine the national water policy formation process led by the MWR that resulted in the National Water Mission (NWM) policy, and the opinions of non-government actors on that process. Insights from this process are discussed in the context of policy formation theory within India and developing countries. Section 5.2 finishes with a discussion on the significance of the NWM within the wider context of water policy in India.

Section 5.3 presents evidence in examining the second research question: what water management strategies does the national water policy response to climate change advocate, and why? It focuses on the strategies advocated by the MWR in the NWM, consisting of supply and demand approaches, flood management, as well as institutional reform measures. Each strategy is examined in the hydrological context of India, how climate change relates to the MWR's discourse concerning each strategy, and how the NWM targets relate to existing or similar policy targets by the MWR. It draws on textual analysis of the NWM policy and other water policy documents, as well as interviews with senior MWR officials who contributed to the policy. The section concludes by briefly discussing whether the water strategies are autonomous or specific adaptations.

Section 5.4 draws on the evidence presented in section 5.3 to discuss insights from the GoI's (MWR) water policy response to climate change. It also presents opinions from non-government actors regarding the strategic outlook of the NWM. The section draws heavily on theory presented in Chapter 2, particularly regarding the MWR's resistance to fundamentally change its primary focus on supply-side approaches, water discourses, the contested and political nature of water management in India, policy formulation and implementation, and the process of institutional reform. It concludes by summing up key findings that are addressed in Chapter 6, taking Andhra Pradesh state as a case study to examine how the NWM is interpreted, and Chapter 7, that examines challenges to implementation and the wider political context in India.

5.2 The national government policy response to climate change

This section draws on textual analysis of the water policy response to climate change (the National Water Mission), other relevant government documents, and interviews with senior MWR officials and non-government respondents.

5.2.1 Climate change awareness within national government

In fulfilment of international obligations, the national government's first official international response to climate change was the signing of the Kyoto Protocol in 1997. Lead by a small team consisting of Ministry of Environment and Forests (MEF) officials, the negotiations and eventual signing of the Kyoto Protocol, increased awareness and sensitised national government to the issue of climate change (ND5, ND6, ND12, ND13)[120]. Prior to this date, awareness in government had been relatively low (ND12, ND13), with climate change orientated research being carried out by a small number of specialist organisations in India, such as the Indian Institute of Tropical Meteorology (IITM), that had been developing climate change scenarios since the 1980s (ND13, ND23, ND24).

In 2004, based on over five years of research by specialist research organisations, the MEF, in fulfilment of Article 42 of the UNFCCC convention under the Kyoto Protocol, released the National Communication on Climate Change (NatCom) report[121] (GoI, 2004). This first comprehensive report published by the national government provided an initial overview of impacts across sectors in India, including water resources, agriculture, human health, forestry, ecosystems, coastal areas, energy and infrastructure (ibid). The preparation and release of this report increased awareness and the profile of climate change within the MEF and related ministries, including the MWR (ND1, ND12, ND13). The report also raised climate change awareness and research activity within relevant organisations throughout India who were involved in its development (ND6, ND12, ND13, ND23, ND24).

The IPCC Fourth Assessment Report, launched in April 2007, significantly increased climate change awareness within national government (ND12, ND13). The launch of this report and particularly the award of the Nobel Peace Prize to the IPCC headed by Al Gore and Rajendra Pauchuri, the latter an Indian national and also the IPCC chair, received widespread media attention throughout India (The Hindu, 2007; ND12, ND13, ND22, ND23). It highlighted potential climate change impacts in India, a number of Indian scientists contributed to the IPCC reports, building on previous research published in the first NatCom (ND35; GoI, 2004).

Owing to the high level of media coverage throughout the nation in 2007, the political profile of climate change within the national government increased, particularly within the Prime Minister's Office (PMO) the MEF and also related ministries, including the MWR (ND1, ND5, ND12, ND13). The increased awareness and high political profile of climate change created sufficient policy initiative within national government, which led the Prime Minister's Office (PMO) to take the lead in developing a policy response (ND1, ND5, ND12, ND16).

[120] Interview respondents at the national level are coded with the acronym ND (New Delhi). Section 3.3.2.2 and Appendix 2.
[121] The second NATCOM report was launched in January 2012 by the MEF (GoI, 2012a).

5.2.2 Prime Minister's Advisory Council and National Action Plan on Climate Change

In June 2007, the PMO established a high-level advisory group on climate change, the Prime Minister's Advisory Council on Climate Change (PMACCC). The primary objective was to 'coordinate national action plans for assessment, adaptation and mitigation of climate change', and to 'advise the government on pro-active measures that can be taken by India to deal with the challenge of climate change' (Mehra, 2008; GoI, 2008). The PMACCC consists of a multi-stakeholder membership of representatives from a cross-section of ministries within national government, as well as research and academia organisations, civil society, business and industry.

The Prime Minster of India, Dr Manmohan Singh, officially launched the National Action Plan on Climate Change (NAPCC) in June 2008, under the guidance of the Prime Ministers Advisory Council on Climate Change (PMACCC). The NAPCC sets out the national government's plan to 'achieve a sustainable development path that simultaneously advances economic and environmental objectives' (GoI, 2008:2). The NAPCC consists of eight individual national missions. These missions represent 'a multi-pronged, long-term and integrated strategic approach for achieving key goals in the context of climate change' (ibid:3). The national missions include: solar mission; enhanced energy efficiency; sustainable habitat; water mission; sustaining Himalayan ecosystems; green India; agriculture; and strategic knowledge for climate change. The PMACCC mandated the Ministry of Environment and Forests (MEF) to oversee the overall development of the NAPCC.

5.2.3 National Water Mission policy formation process

The PMACCC mandated the MWR as the nodal government ministry to develop the National Water Mission (NWM) policy in July 2008. The MWR established a High Level Steering Committee of senior MWR officials, consisting of six sub-committees examining different thematic water issues[122]. The Six Sub-Committee Reports were written primarily by current and former MoWR officials[123]. A small number of sector specialists from the private and NGO sectors, as well as independent consultants, wrote specific sections of the six sub-committee reports[124]. The Six Sub-Committee Reports constitute the supporting document to the NWM policy, consisting of 471 pages (GoI, 2009b). The first draft of the NWM policy detailed the objectives and strategic water management approach of the MWR, totalling 55 pages. The MWR published the first draft of the NWM policy, along with the Six Sub-Committee Reports, in December 2008 on their website.

The MWR convened a half-day workshop in March 2009 in New Delhi to solicit feedback from a wide variety of water professionals. This included representatives of the MWR, state government irrigation departments, NGO and civil society, academia, activists and international organisations. The objectives and strategies of the draft NWM policy were presented by a senior MWR official, inviting questions and comments from those present. Over a year later in May 2010, the MWR released the revised draft of the NWM, modified in light of

[122] The six sub-committees focused on: policy and institutional framework; surface water management; groundwater management; domestic and industrial water management; efficient use of water for various purposes; and basin level planning and management (GoI, 2009b).
[123] Forty five MWR officials were named in the Six Sub-Committee Reports as contributing authors.
[124] Ten non-government experts were named as contributing to the Six Sub-Committee Reports.

the March 2009 workshop and further internal discussion within the MWR. The MWR convened another half-day workshop in October 2010 to present the revised draft, to a similar diverse range of individuals as present at the March 2009 workshop. Again, a MWR official presented the revised draft and opened the floor for comments and discussion. Feedback was taken on board by attending MWR officials. Based on the workshop feedback and further internal discussion within the MWR, the revised draft was modified and passed to the National Water Resources Council (NWRC) for further discussion and clearance. The NWM policy (GoI, 2011a) was finally approved by the PMO in April 2011 at a High Level Steering committee meeting, chaired by the Prime Minister of India. The entire policy formation process took two and a half years.

The NWM policy formation process was overwhelmingly an internal government affair, with the MWR taking a leading role. Although non-government water experts wrote sections of the Six Sub-Committee Reports, they were in a minority to the contributors from the MWR[125]. The Six Sub-Committee Reports are not policy documents themselves, rather an overview of issues and strategies used to inform the NWM policy development. The MWR selected a single author to write the NWM policy, drawing on the Six Sub-Committee Reports and his own technical knowledge and experience[126]. The individual appointed was a former chairman of the Central Water Commission (CWC), with a professional background spanning over 40 years in irrigation engineering with the government.

By including non-government actors as contributing authors to the sub-committee reports and the two consultation workshops, MWR officials claim that the policy formation process was inclusive of other actors and their views (ND1, ND3, ND4, ND44). Furthermore, MWR officials claim that as mandated by the Prime Ministers Office and in line with the MWR's responsibility to develop water policy, it is primarily the MWR's role to take the lead in policy formation and development (ND1, ND3, ND4, ND44).

However, numerous NGO, civil society, activist and academic actors contest and oppose the policy formation process on a number of grounds, claiming it was non-transparent and lacked meaningful participation of non-government actors (ND6, ND7, ND16, ND31, ND39, ND45, ND47; Thakkar, 2009). They consider that the minority representation of non-government contributors to the sub-committee reports, accounting for 18% of the named authors, allowed limited influence in providing strategic direction to that of government (ND7, ND10, ND16, ND17, ND22, ND27, ND35, ND45, ND47). And that those non-government authors were chosen by the MWR from the private sector and organisations that closely aligned with the MWR's approach (ND10, ND16, ND22, ND27). NGO actors claim that non-government actors participation in the formation processes was very limited, restricted to two half-day consultation workshops organised by the MWR, which did not allow sufficient time to discuss the multitude of issues at hand (ND7, ND16, ND22, ND45, ND47). Many of the issues that they raised, both in opposition to the strategic direction of the draft versions and suggested additions to the policy, were not sufficiently integrated and included in the final draft (ND7, ND16, ND45) (Section 5.4.3 for further discussion on non-government actors view of strategic direction of the NWM).

[125] The Six Sub-Committee Reports named 55 authors in total, 45 (82%) of which were MWR officials, 10 (18%) of which were non-government contributors (GoI, 2009b).
[126] The NWM lead author was also the principal author for the Sub-Committee Report on Policy and Institutional Framework.

Examination of the draft, revised draft and final draft of the NWM highlights that the policy content did not change fundamentally through the two and a half year consultation process. The objectives and strategic direction, as well as ambitious national irrigation and reservoir storage targets, remained consistent in each version, even with opposition from numerous non-government actors present at the two consultation workshops. Furthermore, non-government actors also claimed that the unknown criteria for selection and composition of individuals on the High Level Steering Committee and the MWR officials contributing the Six Sub-Committee Reports was non-transparent and non-participatory (ND5, ND7, ND16, ND39, ND45). Non-government actors consider that the MWR, by selecting a former CWC chairman and professional irrigation engineer as the lead author, automatically biased the strategic direction of the policy, defaulting it to the agenda of the government (ND7, ND16, ND22, ND31, ND47). They were critical that policy formation process was primarily an internal MWR affair, with limited transparency of internal processes, for example, with minutes of internal MWR meetings not published in the public domain (ND7, ND22, ND31, ND45).

When considering the politically contested nature of water management (Mollinga, 2008; Merry et al, 2007; Mosse, 2003; Mehta, 2001) within the 'politics of water policy in sovereign states' domain (Grindle, 1977), as conceptualised by this research, relations of power are constituted and negotiated by different actors throughout the policy process, including the policy formation process (Mollinga, 2005). Contestation[127] by non-government actors manifests their interests and exertions of power within the policy formation discourse. The relatively closed nature of the policy formation process within elite government circles is interpreted as a deliberate approach by the MWR to pursue it's own interests primarily, and ultimately the exertion of power (Foucault, 1991; Shore and Wright, 1997). And likewise, contestation of the policy process on above mentioned grounds by non-government actors, particularly the NGO and civil society, is interpreted as manifesting their particular interests and agendas. The politically contested nature of the NWM policy formation process is consistent with both the linear and interactive models, that conceptualise the policy formation process as contested by those actors involved (Grindle and Thomas, 1990; Warwick, 1982).

The NWM formation process confirms earlier observations by Mollinga (2005), regarding the nature of policy formation in India. Although there was some non-government consultation, the NWM was primary developed by a small group of senior MWR officials, with internal discussions to finalise the NWM occurring behind closed doors of government. The NWM policy formation process was predominately state-centric despite the active and vociferous NGO and civil society in India, as found earlier by Mollinga (2005) when analysing the National Water Policy process in 2002. The NWM formation process also confirms Horowitz's (1989) findings, that the government is inordinately more influential in the policy formation process than civil society in developing countries. However, findings are contrary to Grindle and Thomas' (1990) conclusion that in developing countries policy formation is largely state-centric owing to the absence of an active civil society sector, which is not the case in India which has an active civil society and NGO sector. The internal nature of the NWM policy

[127] Contestation is an inherently political process through which politics is understood as the set of activities through which balances of power that shape water resource use are re-negotiated (Bolding and Mollinga, 2004:241).

formation process characterised the MWR's resistance to change its consultation process and inclusion procedures (Molle et al, 2009), largely deflecting criticism and alternative approaches proposed by non-government actors. The public policy development model developed by Grindle is shown to have some short-comings when applied to developing countries, primarily owing to the fact that the model was based on developing country experience, developed over two decades ago.

5.2.4 Water policy formation and the significance of the National Water Mission

Water policy discourse within India has historically focused around a number of issues. After independence in 1947, the primary concern of the MWR was the construction of large reservoirs and the expansion of canal irrigation systems, reaching its peak during the peak of the green revolution to provide water for agriculture expansion in achieving and sustaining national food self-sufficiency (Section 4.4.1). In the last 15 years as the economic growth rate has increased in India, water demand from industry and growing urban centres has grown exponentially, especially in the mega-cities. Groundwater has played a crucial role in helping to meet India's growing water demand, especially in the last two decades as groundwater pump ownership has proliferated (Shah, 2009). Future projections estimate an increase in demand by 153BCM and 220BCM for 2025 and 2050, respectively (Shah et al, 2007). It is estimated that food production will have to double from 2010 levels to meet rising demand by 2050 (ibid).

In light of such contemporary challenges, the NWM states that a new water management response is required: 'in the future, demands for water would increase considerably both on account of rising population and their rising food and domestic water needs, and also on account of larger industrialisation and changing standards of living. Even without climate change, many basins will be water stressed leading to a major constraint on development. Changes in water policy which stress on new strategies of water management and on meticulous accounting of water situation would be necessary' (GoI, 2009a:35). It was noted by a senior MWR policy advisor that climate change has created an 'opportunity' and sufficient 'policy space' through the NAPCC and the resulting NWM policy for a re-examination of water management practices in India (ND1). In considering whether climate change has created sufficient policy space, it is useful to briefly contextualise the historical development of national water policy in India. India suffered a severe drought in 1986-87, with widespread negative repercussions on agricultural productivity and livelihood activities. A few months after the drought, in 1987, the MWR formulated India's first national water policy (NWP) (Saleth, 2004; GoI, 1987). It is widely acknowledged that the drought acted as a catalyst for the development of the NWP, with significant political pressure on government at the time to act accordingly (ND5, ND7, ND8, ND11, ND26, ND31, ND38, ND42; Saleth, 2004; Iyer, 2003). This is in line with the 'policy window hypothesis', in reference to how extreme natural catastrophes create sufficient (political) space leading to appropriate policy development (Kingdom, 1984). The 1987 NWP was updated in 2002[128], primarily owing to the significant political pressure due to rising water scarcity and increased competition between water user sectors, as population continued to

[128] The objectives and content of the NWP 1987 and 2002 are near identical, apart from the latter including two notable additions. First, the explicit promoting private sector participation in the planning, development and management of water resource, and second, recommending a paradigm shift from water resources development to performance improvement (GoI, 2002:6-8).

grow along with economic development (ND1, ND5, ND7, ND8, ND32, ND44; NWP, 2002; Saleth, 2004). In a similar fashion to the political pressure resulting in the 1987 NWP formation and revision in 2002, the significant political importance and awareness of climate change risks within national government, particularly from 2007 onwards, led the national government to initiate the policy process resulting in the NWM policy (ND5, ND12).

The NWM policy represents the most comprehensive government-led examination of water management in India to date. This can be gauged in terms of the significant number of MWR officials who contributed to the Six Sub-Committee Reports[129]; the two and a half year formation process[130]; the input a senior MWR policy advisor who claimed to have spent 'significant time, energy and thought' (ND1) on the policy; the level, detail and content of the Six Sub-Committee Reports that fed into the policy[131] (GoI, 2009b); the broader non-government consultation through the two half-day workshops and non-government actors input into the sub-committee reports; and finally the process of circulating the two draft versions before being finalised by the National Water Resources Council and the Prime Minister's Office. Unfortunately, owing to the MWR's relative lack of transparency, it is not known exactly how many formal or informal meetings took place internally within the MWR, or to estimate the number of hours spent developing this policy by MWR officials. However, based on the above mentioned factors, it can be assumed that significant time and energy was spent on this policy by the MWR. The NWPs of 1987 and 2002 did not receive the same level of input during their respective formation processes (ND1, ND5, ND7, ND16, ND22, ND27, ND31, ND37, ND38, ND42, ND44). And neither of these two national water policies were accompanied by a detailed supporting document; they did not have the same number of MWR personnel providing input (ND1, ND5, ND44); they did not have the level of non-government consultation through the website and workshops (ND1, ND5, ND22, ND31); and both policies were developed in half of the time it took to develop the NWM. Therefore, the NWM policy provides an invaluable insight to understand the MWR's contemporary thinking through the direction of the water management strategies advocated to manage climate change and to meet increasing demand for water. The following section (5.3) examines the strategic direction of the WRM strategies advocated by the MWR in the NWM policy (GoI, 2011a, 2009b).

[129] Forty five MWR officials are named as contributing to the Six Sub-Committee Reports, although it can be expected that numerous MWR officials offered informal guidance and opinion to the named authors during the writing process.
[130] Although the time of policy formation cannot be used as a definitive indicator of the extent of the process, it does at least suggest that the process was more thoughtful and involved than previous water policies.
[131] Totalling 471 pages (GoI, 2009b).

5.3 Strategic water management direction of the National Water Mission

This section examines the second research question at national government level: what water management strategies does the national water policy response to climate change advocate, and why? The section is structured around supply and demand strategies, institutional reform, and climate change and hydrological data approaches advocated in the NWM (5.3.1 to 5.3.4). The final sub-section (5.3.5) briefly discusses their adaptation to projected climate change impacts in India.

The NWM consists of five Goals, advocating a number of water supply and demand management strategies, as well as institutional reform measures (Appendix 24 for complete list of NWM strategies). The overall objective of the NWM is the 'conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within states through integrated water resources development and management' (GoI, 2011a:iii).

5.3.1 Water supply management

Since independence, the MWR has historically concentrated on water supply management (WSM) as its primary concern, focusing on the construction of large-scale reservoirs and canal irrigation infrastructure, to increase national reservoir storage capacity and the area under irrigation (Section 4.4.1). It is particularly relevant to examine the WSM strategies advocated within the NWM to understand the contemporary approaches of the MWR, to examine if anything has changed or not. The WSM strategies detailed in this section (5.3.1) are considered as 'top priority' by MWR officials (ND1, ND2, ND3, ND4, ND5, ND7, ND31, ND38, ND44).

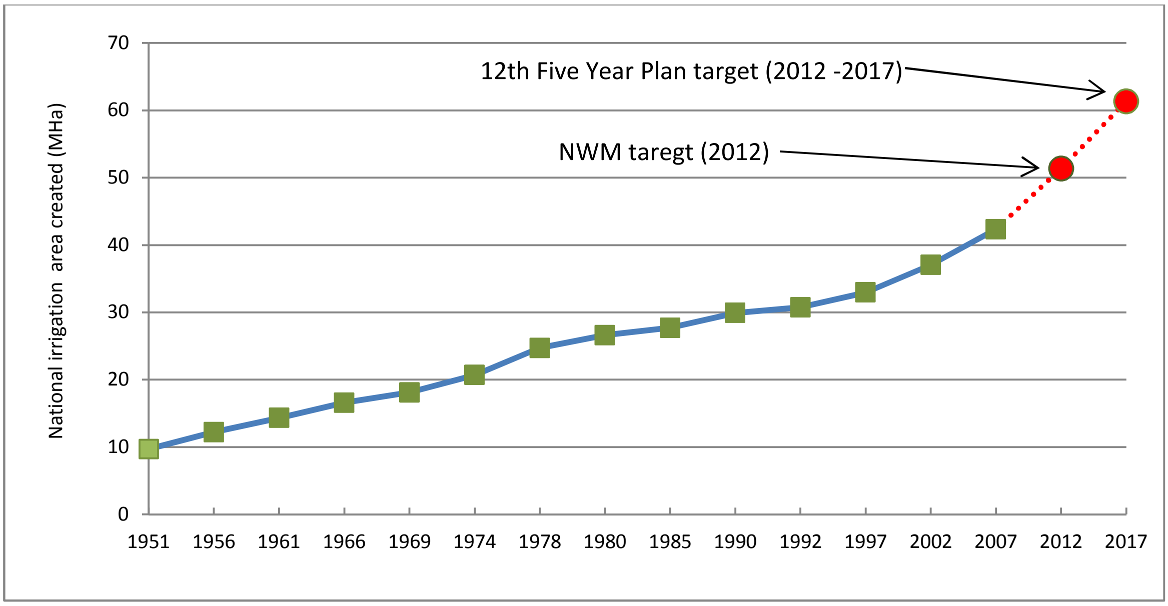
5.3.1.1 Irrigation expansion

The NWM policy sets an ambitious target of creating of an additional 9Mha through the expansion of major and medium (M&M) irrigation projects by the end of the 11th Five Year Plan (FYP) in 2012 (Figure 5.1)[132]. The NWM calls for 'the expeditious completion of 205 major and medium irrigation projects throughout India' (GoI, 2011a:65). This target is not a new target specifically for the NWM or climate change, rather it is a continuation of existing national targets on irrigation expansion. The target for the 10th FYP (2002-2007) of an additional 9.9Mha by the year 2007 (GoI, 2003) is largely in line with the NWM target. Moreover, the target of 10Mha for 2009 under the Bharat Nirman Rural Infrastructure Development Programme[133] (2005-2009) is also in line with the NWM target (GoI, 2005). The policy text of the Bharat Nirman and the NWM are identical, both calling for 'expeditious implementation of major and medium irrigation projects' (GoI 2005:16; GoI, 2011a:64). The provisional target of the 12th FYP (2012-2017) for irrigation expansion is set at 10Mha through the creation of 8Mha of additional irrigated area and the restoration of 2Mha (GoI, 2011c).

[132] India's total irrigation area created stood at 41.5Mha by 2007,(GoI, 2011c).
[133] The Bharat Nirman Rural Infrastructure Development Programme, launched in 2005 by the Ministry of Rural Development, targets rural areas for the construction and development of irrigation area, housing, water supply, electrification and telecommunication connectivity.

It can be seen that previous and existing national irrigation expansion targets are being adopted by the MWR for the NWM to provide further policy support and time-bound targets. The NWM irrigation expansion target is highlighted as a 'priority strategy', singled out for immediate action (GoI, 2011a:36). Although the NWP 2002 does not set a specific date target for irrigation expansion, it does call for 'further development of irrigation of a substantial order is necessary if the food and fibre needs of the growing population are to be met' (GoI, 2002:1). With policy 'as a statement of intent' (Saleth, 2004; Iyer, 2003), it is clear from the repeated emphasis on irrigation expansion within existing policy, reiterated by the NWM, that it is a primary objective of the MWR. This was confirmed by interviews with MWR officials (ND5, ND8, ND15, ND20, ND31). Figure 5.1 illustrates the increase in national canal irrigated area created from 1951 to 2007, including the NWM and the 12th FYP targets for 2012 and 2017 respectively. The NWM target is clearly in line with the MWR's ambitions to continue increasing the area under irrigation, in line with India's national hydraulic mission (Section 4.4.1).

Figure 5.1: National canal irrigation area created since 1951, including NWM and 12 FYP targets (FAO, 2012; GoI, 2011a)



An interview with a senior MWR policy advisor stated that: 'it is imperative to increase national food production to meet national targets in dealing with growing population and changing consumption habits, and also to meet changes in monsoon and long term precipitation and temperature because of climate change' (ND1). Interviews with other MWR officials supported the importance of the national irrigation expansion target (ND1, ND2, ND4, ND44), considering it important to provide sufficient water to secure national food production to meet a growing population and increasing demands for food. This sanctioned discourse of 'water for food' is dominant and prevalent throughout the MWR (ND5, ND8, ND11, ND14, ND15, ND19, ND20, ND31), legitimising which strategies can be pursued in a given political context (Allan, 2002; Jagerskog, 2002). It is estimated that India's current (2010) food production levels will have to be doubled to sustain the projected population of 1.6 billion people by 2050 (Shah et al, 2007). Climate change, as a risk in terms of changing summer monsoon precipitation patterns and long term precipitation and temperature change, is considered as an 'additional reason' (ND1) to further increase national irrigation area to secure food production (ND1, ND2, ND3, ND19, ND20). In this manner, climate change can be seen to be entering the MWR discourse as additional justification for irrigation expansion, with the primarily justification cited in securing water for food production (ND1, ND2, ND3, ND4, ND44).

5.3.1.2 Increasing reservoir storage capacity

The NMW policy targets a 64BCM increase in reservoir storage through the completion of 205 on-going M&M irrigation projects during the 11th FYP, 2007-2012 (GoI, 2011a:65). As is the case with the irrigation expansion target, the NWM storage target is an adoption of an already existing national target, namely, the policy target of the 11th Five Year Plan (2007-2012) (GoI, 2007). This storage target (currently 'under construction' according to the 11th FYP, GoI, 2007) existed before the advent of the NWM policy and can be seen as being adopted by the MRW for inclusion within the NWM policy to provide further national policy support (ND1, ND5).

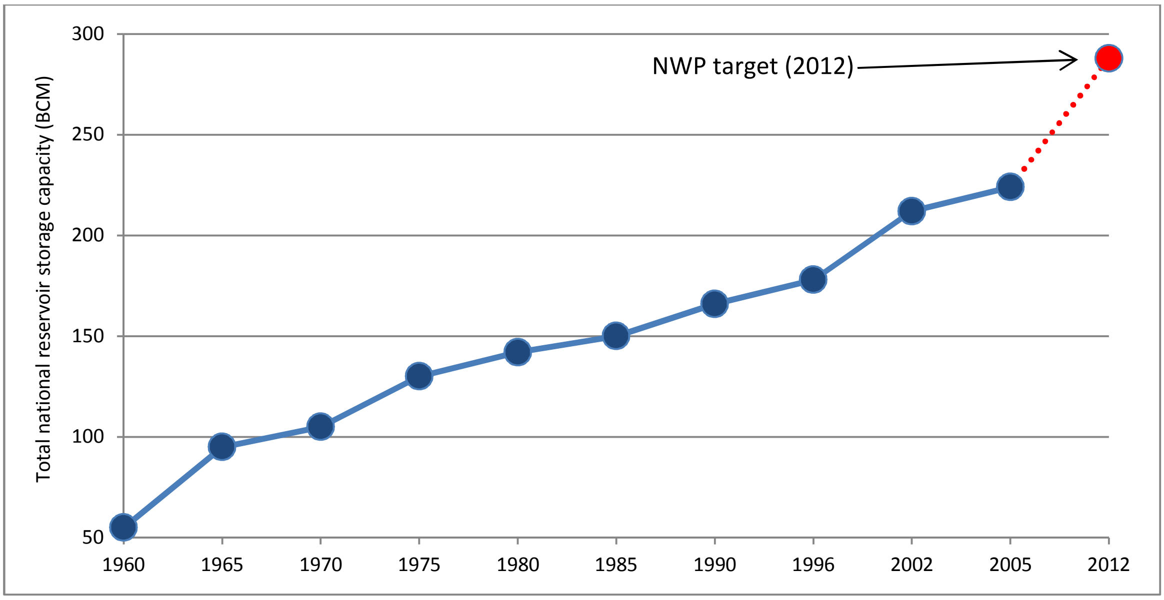
The NWM policy explicitly states the priority of augmenting utilisable water resources (increasing reservoir storage) in response to climate change impacts: 'the studies in respect of impact of climate on water resources indicate that various components of the hydrological cycle would be affected resulting in further intensification of temporal and spatial vitiations of the water availability. It is necessary to take immediate steps for augmentation of the utilisable water resources' (GoI, 2011a:10). Interviews with a senior MWR official stated that the organisational approach of the MWR is to 'increase surface water reservoir storage capacity in response to potential climate change' (ND2). Increasing reservoir storage at all scales is seen as a top priority of a senior MWR policy advisor in response to climate change: 'storages should be increased at all levels (major, medium, minor) to manage possible climate change' (ND1). MWR officials stated that even without climate change, additional reservoir storage is required to meet India's growing water demands through rapid urbanisation, industrial growth and agricultural expansion and intensification to provide food security (ND2, ND3). Meeting such water demand drivers and in line with the MWR 'water for food' sanctioned discourse, climate change can be seen to be entering the discourse as additional justification for increasing storage, as a risk in terms of changing monsoon precipitation patterns and long term temperature and precipitation change (ND1, ND2, ND3, ND4). Climate change can be seen to be entering the government discourse as a reason to secure more funds for increasing storage: 'climate change has provided a good reason to continue this approach (increasing reservoir storage), by additional funding that would otherwise have not been made available' (ND2). Climate change can be seen to have been appropriated[134] by the MWR through the NWM to continue the existing plans to increase water storage in line with their objective of increasing water storage capacity. A report commonly cited by national government in justification for increasing reservoir storage capacity is the Briscoe report (ND1, ND5). This strongly advocates increasing surface water storage capacity, particularly large reservoirs, to aid economic development and agricultural production. The

[134] The Oxford dictionary (2001) defines appropriation as 'the action of taking something for one's own use'.

report stresses 'there is every indication that the need for storage will grow because global climate change is going to have major impacts in India' (Briscoe and Malik, 2006:1).

India's total reservoir storage capacity stands at 225BCM in 2005 (GoI, 2009a). An additional 64 BCM of reservoir storage is under construction at the national level, as planned in the 11th Five Year Plan (2007-2012) (GoI, 2007) and reiterated by the NWM policy (GoI, 2011a). A further 108 BCM of storage is under 'consideration' (GoI, 2009a). If the NWM storage target of 64BCM is achieved, it would raise the total reservoir capacity to 289 BCM by 2012, an increase of 30% from the capacity in 2005 (Figure 5.2). This is considered as a top priority of MWR officials (ND1, ND2, ND3, ND4).

Figure 5.2: Historical development of reservoir storage capacity in India since 1960, with NWM target for 2012 (FAO, 2012; GoI, 2011a)

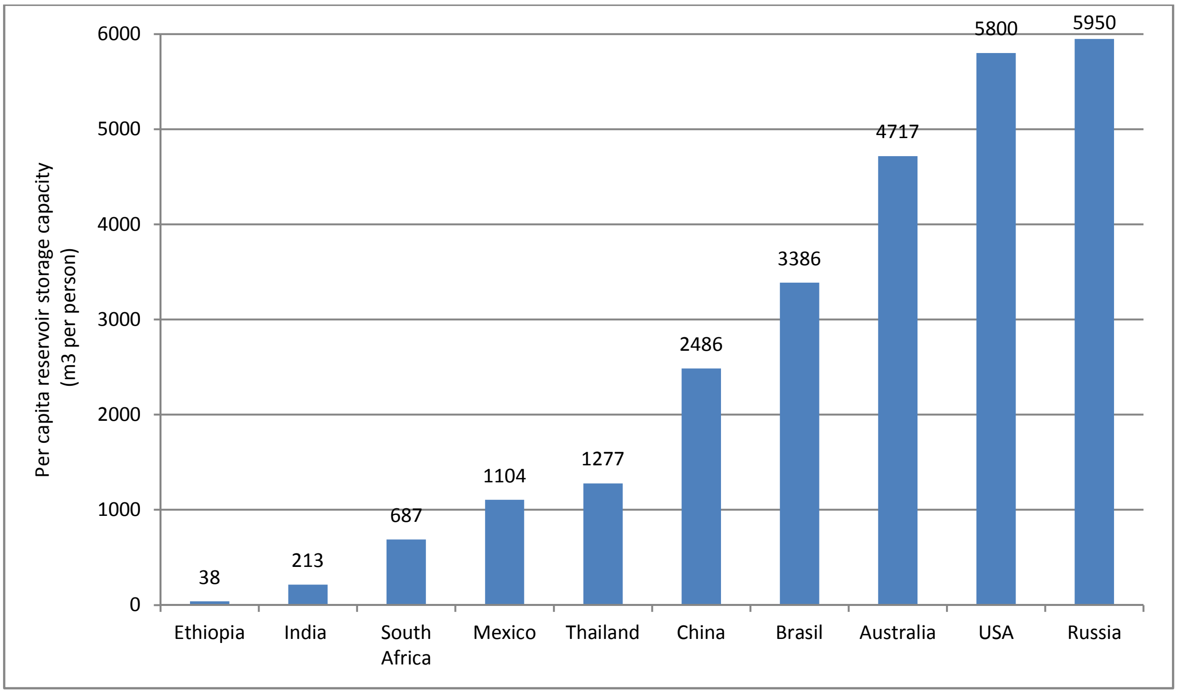


Per capita reservoir storage capacity in India was 213 m^3 in 2005 (GoI, 2009a) (Figure 5.3). MWR officials consider it imperative to raise this figure in future years, primarily to meet growing urban, industrial and agricultural demands (ND1, ND2). If the additional 64BCM of storage under construction and the further 108BCM under consideration are completed, this figure would rise to roughly 400m^3 (ibid). In the long term, MWR officials consider raising India's per capita reservoir storage capacity to around the region of China (2486m^3 per person), with a similar population to India, as important to achieved long term national water security (ND3). Achieving such a figure would require drastically increasing storage. Many of the most suitable topographic sites for large reservoirs have been developed in India. The remaining areas are technically[135] more challenging for the construction of large scale reservoirs[136] (ND1, ND5). Furthermore, water flow availability is also a constraining factor in future reservoir development, particularly downstream as flows are

[135] And often politically volatile as well, particularly in the north-east region of India, making government and private sector actors wary of making long-term financial investments in infrastructure.
[136] Ideal topographic terrain for large scale (valley) reservoir construction is characterised by topography that provides a natural basin for the reservoir. Dams are typically constructed at the narrow part of the topography (or valley), both to provide strength to the structure and lowest practical cost of construction (WCD, 2000).

depleted and allocated between users, as is the case with closing or closed river basin in India[137] (ND1, ND5, ND7). Such hydro and physical constraints clearly offer significant challenges to the MWR in future supply-side infrastructure development. The north-east region of India, particularly the Brahmaputra river having an estimated 34% of total renewable water resources in India (ibid), has been earmarked for future infrastructure development by the MWR, both large scale reservoirs and inter-basin transfer through the National River Linking Project (ND1, ND3, ND5, ND7). (Appendix 22 and 23 for maps of the NRLP).

Figure 5.3: India's reservoir storage capacity per capita in comparison with other countries (Sadoff and Grey, 2007)



5.3.1.3 Carry-over storage

The NWM recommends 'the expeditious implementation of water resource projects particularly the multipurpose projects with carry-over storage benefiting drought prone areas in rain deficient areas' (GoI, 2011a, Goal 3.1). Carry-over storage is the amount of water stored in a reservoir throughout the year, the residual volume that is retained just before at the onset of the summer monsoon in June[138]. The recommendation of carry-over storage is a new policy development included in the NWM, neither the NWP 2002 or the 11th FYP made explicit statements promoting carry-over storage (GoI, 2002, 2007). As the NWM

[137] Appendix 13 for water resource status of India's 19 major river basins.

[138] Carry over storage reservoirs do exist in India, such as the large reservoirs of Bhakra in the Punjab, Rihand in Uttar Pradesh, Narmada Sagar in Gujarat, and the Srisailam-Nagarjuna Sagar in Andhra Pradesh. However, the vast majority of medium and large reservoirs are 'within the year' storage, with the remaining amount of water is released just before the onset of the summer monsoon. The NWM states that carry over has not been developed because the policy of '75% dependability of water flow was misinterpreted as one discouraging carry-over storage' (GoI, 2009b:33).

states: ‘if and when the entire actual variability of flows increases (with climate change), carry-over storages, which utilise the waters available in a good year by storing them for a long period and use these in a bad year, would become very attractive’ (GoI, 2009b:33). Furthermore, ‘larger storage and larger carry-over storage becomes essential to increase water use. In view of the larger water stresses attributed to climate change and increased water demands, a programme of increases in the capacities of existing dams needs to be taken up (ibid:42).

A senior MWR policy advisor confirmed that carry over storage should be particularly encouraged, at an average volume of 10% of total reservoir capacity (ND1). In a closed river basin where all of the water is utilised characterised by a high level of infrastructure development, such as the Lower Krishna River Basin in Andhra Pradesh, developing carry-over storage should be particularly encouraged; whereas in open river basins with available water for utilisation, all WSM options should be considered, including the construction of new major and medium sized reservoirs (ND1). The promotion of carry-over storage, particularly in closed river basins, is an alternative method of increasing storage potential without the expensive construction of new reservoirs. The primary justification for carry-over storage is to meet increasing water demands, agriculture especially, as well as managing increasing hydrological variability under climate change (ND1, ND4).

5.3.1.4 National River Linking Project

The NWM supports the transfer of water between basins as part of the National River Linking Project (NRLP): ‘strategies like inter-basin water transfers will have to be considered with added gravity because of climate change, and may have to be implemented expeditiously, to improve the situation of increasing water scarcity’ (GoI, 2009b:45).

An interview with the director of the NWDA, a registered society (office) of the MWR that provides technical input and project clearance for the NRLP, confirmed that the primary justification of the NRLP is to ensure food security by supplying sufficient water to meet irrigation expansion, particular to transfer water from surplus regions to water scarce and drought prone areas within India (ND30). The provision of water for urban centres and industrial needs is also considered important (ND30) (Appendix 22 and 23 for maps of the NRLP)

Climate change is considered as an ‘additional reason’ to implement the NRLP, confirmed by a senior MWR policy advisors (ND1, ND4, ND30, ND44). The NRLP is considered as having the potential to ‘even out’ water distribution between river basins, with regards to the possibility of some basins receiving more or less precipitation with climate change projections (ND1, ND2, ND30, ND44). However, owing to the uncertainty of models, climate change is not considered a ‘principal reason’ to implement the NRLP (ND1, ND2, ND3, ND30, ND44).

5.3.2 Water demand management

The NWM recommends numerous water demand strategies (WDM) strategies in Goal 2, 3 and 4 (Appendix 24 for complete list). Based on interviews with MWR officials and highlighted as priority by the NWM policy (GoI, 2011a:34), increasing irrigation efficiency and groundwater management are discussed in this section.

5.3.2.1 Increasing surface water irrigation efficiency

The NWM Goal 4 sets the ambitious target of increasing water use efficiency across all sectors by 20% by 2017, at the end of the 12th FYP (GoI, 2011a). This is a new national policy target, not declared within previous policy documents. Population growth, economic development and agricultural expansion all resulting in declining total renewable water resources availability, were cited by numerous MWR officials and other key respondents as significant reasons to increase water use efficiency across all sectors (ND1, ND3, ND5, ND6, ND8, ND11, ND14, ND15, ND19, ND20, ND22, ND28, ND31, ND38, ND43, ND44, ND47). Interviews with MWR officials confirmed that the primary focus of the NWM Goal 4 is to increase surface canal irrigation water use efficiency by 20% by 2017 (ND1, ND2, ND3, ND4, ND8), in line with MWR objectives.

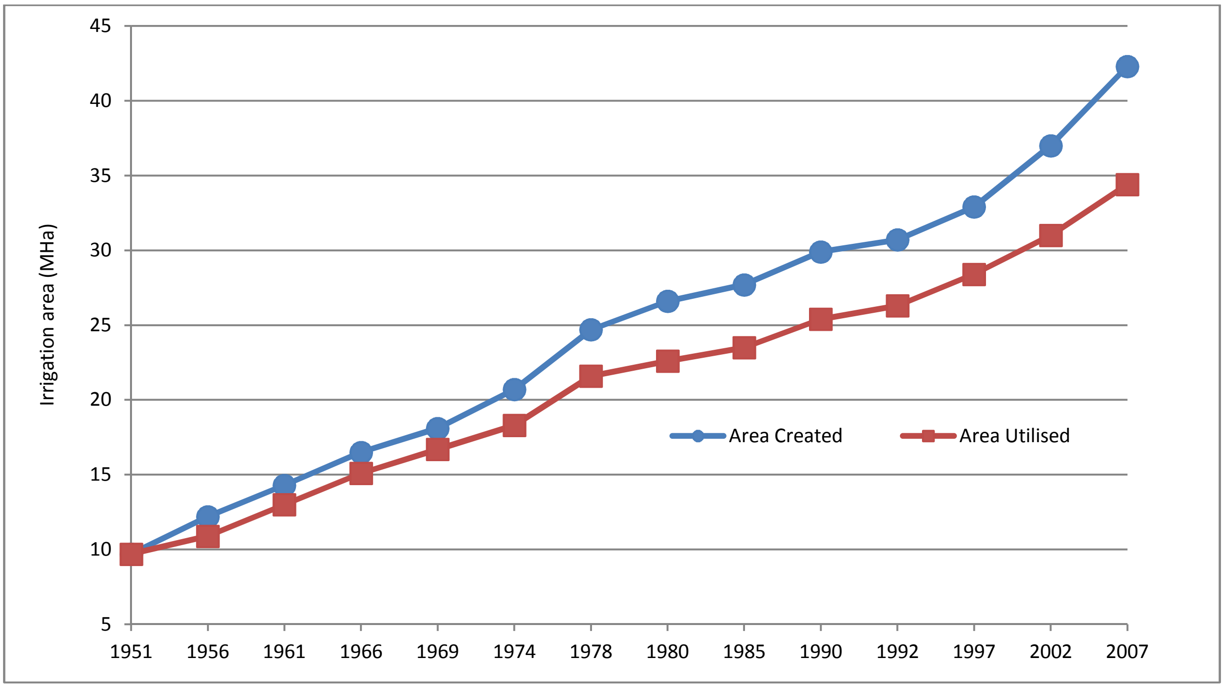
Irrigation water accounts for an estimated 90% of surface and groundwater withdrawal in India (FAO, 2012; Shah et al, 2007). It is estimated by national government statistics that canal irrigation efficiency (as a function of storage, conveyance, on-farm and drainage efficiency) ranges from 14-62% at the state level, at an average of 30%[139] (GoI, 2011a). Calculations of irrigation efficiency are largely estimates, constrained by lack of widespread and accurate hydrological data at canal system level (ND5, ND14, ND7, ND15, ND20). Irrigation efficiency figures also have to be considered in the wider political context of reflecting state irrigation department performance, with such figures suspected of being 'inflated' to portray artificially high levels of efficiency (ND5, ND14, ND14, ND31). However, even if such efficiency figures cannot be taken at face value, they still highlight relatively low levels of overall system efficiency.

The principal author of the NWM stated that 'as irrigated agriculture accounts for the vast majority of water use across India, it is important to increase the efficiency of surface water canal irrigation systems that account for an estimated 45% of all irrigation in the country, especially in light of the need to increase national food production in future years' (ND1). As illustrated by this quote and other interviews, the primary consideration for improving irrigation efficiency is to meet increasing food production throughout the nation, targeting the doubling of national food production levels by 2050, in line with the 'water for food' sanctioned discourse within the MWR (ND1, ND4, ND8, ND44). Climate change as a risk in terms of changing monsoon precipitation patterns, long term changes in precipitation, temperature rise affecting evapotranspiration rates, are all considered as 'additional justification' (ND1) in support of increasing canal irrigation water use efficiency (ND1, ND2, ND8, ND14, ND15, ND20). Furthermore, rain-fed agriculture is considered to be particularly vulnerable to climate change impacts, under the responsibility of the Ministry of Agriculture (ND14, ND19, ND20).

[139] Conveyance efficiency is calculated to be 69% and on-farm efficiency 52%, according to government statistics (GoI, 2012c). Overall system efficiency is reduced by low levels of storage and drainage efficiency, without a percentage attributed to either of these variables (ibid).

The NWM and MWR officials consider that closing the irrigation gap by half, from 8Mha to 4Mha by 2017, a top priority (ND1, ND2, ND4, ND8, ND44). The irrigation gap is the difference between the total irrigation area created (covered by canal infrastructure) and the area within the system that is utilised for agriculture, receiving sufficient irrigation water to cultivate at least one crop per year (FAO, 2012). The irrigation gap is the area within an irrigation system not receiving sufficient water to grown one crop per year. It is a function of the effectiveness of water distribution within a system, including the efficiency of conveyance, storage, on-farm use, drainage, as well as over-building of infrastructure[140] (FAO, 2012; Molle, 2008). Figure 5.4 illustrates the growing irrigation gap since independence, standing at 8Mha by 2007.

Figure 5.4: Irrigation gap in India since 1951 (GoI, 2012c)



A number of strategies are considered important to achieve the 20% increase irrigation efficiency and to halve the irrigation gap, detailed in the NWM and noted in interviews. These include volumetric irrigation water pricing, water audits and benchmarking, participatory irrigation management (PIM), water user associations (WUA), improving operation and maintenance of existing irrigation infrastructure, and water saving technologies including drip and sprinkler irrigation (ND1, ND2, ND3, ND4). Volumetric water allocation and pricing of irrigation water are considered one of the most critical issues for improving efficiency (ND1, ND5, ND8, ND14, ND19, ND20). A notable inclusion in the NWM is the call for each state government to establish regulatory water authorities to promote water use efficiency. Based around the model of Maharashtra Regulatory Authority[141] established in 2005, the NWM advocates the setting of water use standards and

[140] Over-building of canal infrastructure is a phenomenon noted by Molle (2008), who found that even if government or other relevant authorities realise or suspect that there is insufficient surface water to serve planned canal infrastructure development, it is built regardless of this, often to serve wider political and financial purposes (ibid).
[141] Key functions of the Maharashtra Water Resources Regulatory Authority are: 1) to determine, regulate and enforce the distribution of water entitlements for various category of uses at basin and projects levels; 2) to regulate seasonal and annual water entitlements; 3) to establish and regulate water tariff system for various uses of water with the view to ensure full operation and maintenance needs of irrigation and water utilities (GoI, 2012b).

benchmarking, implementation and enforcement of demand management practices at the state level. The NWM reconfirms a number of irrigation efficiency strategies previously advocated in the NWP 2002, including participatory approaches to irrigation management, water user associations, and the rational pricing of irrigation water (GoI, 2002).

Although respondents close to government acknowledged that the 20% efficiency goal is a progressive target in principal, it is considered as somewhat ambitious, with numerous respondents questioning if and how such a target can be achieved by 2017 (ND5, ND11, ND14, ND19, ND20, ND39, ND43, ND47). There are a number of contributing factors which lead to relatively low irrigation efficiency. Water for canal irrigation is heavily subsidised to farmers by state irrigation departments, leading to inefficient use (ND5, ND8, ND11, ND14, ND15, ND19, ND20, ND44, ND47). The low cost recovery by state irrigation departments, at an average level of 15% (MWR, 2011), barely covers the operation and maintenance costs (ND5, ND11, ND14, ND15), which in turns perpetuates the lack of efficiency-orientated re-investment with many canal structures falling into a state of disrepair. Heavily subsidised water also leads farmers at the head-end of large scale canal irrigation systems to cultivate water intensive crops with increasing rates of inefficiency, often depriving sufficient water to the tail-end of the system (ND5, ND8, ND11, ND14, ND15, ND20). Irrigation water is not allocated on a volumetric basis, based on crop water requirements and benchmarking. There is a widespread lack of accurate and reliable hydrological data required for benchmarking and monitoring at state level (ND5, ND11). Volumetric allocation is severely restricted owing to the lack of and poor maintenance of existing hydrological gauging stations, due to the high installation and maintenance transaction costs for state government, perpetuated by low financial cost recovery of the system (ND11). Water is not priced according to specific allocation based on crop requirements and benchmarking (ND5). Technical issues leading to inefficiency were highlighted through interviews, such as poor or non-maintenance of distribution networks; lack of lining in canals and field channels; over-irrigation owing to non-availability of control structures (weirs) in distribution systems; poor management practices; and lack of farmer awareness (ND11, ND14, ND15, ND19, ND20). The political aspect of irrigation water provision to large numbers of farmer constituents at state level, with farmers generally expecting practically-free water, makes moves in the direction of water pricing by volumetric allocation politically sensitive and difficult, especially when considering the five year political cycle of state elections (ND5). Managing such challenges are primarily the responsibility of state government irrigation departments, examined in detail in Chapter 7.

State government response to national policy recommendations varies significantly, as can be witnessed in the adoption of PIM by state governments in recent years. In 1998, the MWR circulated an Act to state government to encourage them to amend existing or establish new irrigation act, to adopt PIM and WUA approaches. However, despite repeated emphasis by national government, to date (late 2012), only 15 out of 28 states have enacted such, with the ‘successful’ functioning of WUA reported in only four states (Maharashtra, Andhra Pradesh, Orissa and Gujarat) (GoI, 2012c). Some states appear to be more progressive than others with regards to implementing demand management practices, based on unique socio-economic and political state level government context, and the responsibility of the state irrigation departments (ND5, ND11, ND30).

There have been recent movements at the national government level to prioritise irrigation efficiency and other demand management issues more generally, primarily driven by the Planning Commission (PC). After the NWM was finalised in April 2011, a charismatic and reformist senior PC official with extensive knowledge and experience in the water sector was appointed by the Prime Minster to reform the water sector. Under the leadership of this individual, the PC established the Water Resources Working Group (WGWR), consisting of national and state government officials as well as non-government experts to develop the strategic direction of water development for the 12th FYP, 2012-2017.

Taking forward many of the NWM irrigation efficiency strategies in an effort to operationalise them, early signs indicate significant momentum has been generated by the Head of the PC's WGWR, and by the working group itself (ND5, ND8). The WGWR has made a number of recommendations to the MWR in this regard, including improving hydrological data collection and monitoring, water saving technologies, improving on-farm efficiency and the equitable distribution of irrigation water throughout the irrigation system. Of particular note is the promotion of WUA and PIM (ND8, ND11, ND14), recommending that the MWR should provide a matching grant every year to each state government equal to its irrigation service fee (ISF) collection, to incentivise state irrigation department to improve ISF collection through better service provision, and also to make more resources available to improve operation and maintenance of existing canal systems. Other notable recommendations include a 30% incentive from national government to state irrigation departments on all ISF collected by a state through WUAs, with an additional 20% incentive for ISF collected against volumetric water supply to WUA under irrigation service contracts between WUAs and irrigation departments. The WGWR consider such incentives important in augmenting the budget of state irrigation departments, upon which it recommends to spend on improving operation and maintenance of existing irrigation systems (ND8, ND11; GoI, 2012c). Furthermore, the WGWR strongly recommends that a CAD component should be a component of all M&M irrigation projects in the present and future, as a strict requirement before the release of AIBP funds; and not be considered a separate component and often neglected, as is the case at present (ND5, ND8).

At least partially owing to the pressure created by the PC's WGWR and also the influence of actors close to the MWR (ND5, ND8, ND11), in 2011 the MWR announced the creation of the Bureau of Water Efficiency (BWE), with the specific mandate to promote water efficiency across all sectors. The BWE is to be housed within the MWR, and is currently (mid 2012) under formation. The recommendations of the PC's WGWR are informing on-going discussions within the MWR on water efficiency norms for different water use sectors (ND8, ND11). The MWR is considering incentives to farmers and industrialists if they follow good water-efficient methods, although specific details are not available at present (late 2012) (ND5, ND8, ND15, ND19, ND20). Potential funding incentives from national government for the implementation of irrigation efficiency measures such as

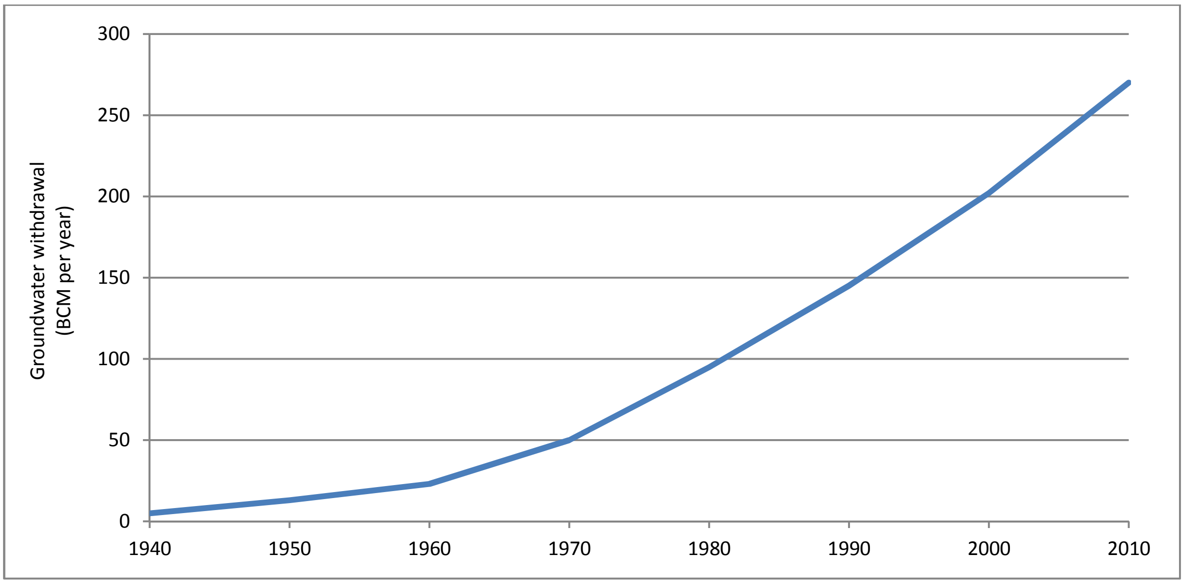
WUA and PIM to state irrigation departments may have some impact. But it is ultimately the decision of state government to take this issue forward, with future uptake likely to vary significantly across states in India.

5.3.2.2 Groundwater management

The NWM Goal 3 calls for the enactment of a groundwater bill at state government level, to promote regulation and enforcement of groundwater withdrawal and sustainable management. Furthermore, groundwater augmentation is encouraged through artificial recharge via rainwater harvesting and dug wells (GoI, 2011a).

Groundwater withdrawal throughout India is informal in nature, with no centralised regulation on rates of withdrawal (ND5, ND11, ND43). Rates of withdrawal have dramatically increased over the last thirty five years in India, as the number of wells has proliferated (Figure 5.5). Heavily subsidised electricity and cheap diesel has powered the increasing rates of pumping throughout India (ND11). Groundwater provides an estimated 60% of irrigation water throughout India (GoI, 2012c), primarily for irrigation purposes but also for drinking water and industrial requirements. Groundwater withdrawal has reached alarming levels in recent decades, particularly in the hard-rock crystalline region of the Deccan plateau in central-south India, within Andhra Pradesh state (Shah, 2009).

Figure 5.5: Rate of groundwater withdrawal in India since 1940 (FAO, 2012; Shah, 2009)



MWR officials acknowledge the unsustainable nature of groundwater withdrawal in recent decades, and the importance of the resource for the supply of irrigation and drinking water, both at present and in the future (ND1, ND2, ND3, ND4, ND34, ND44). Senior MWR officials strongly advocated the enforcement of a groundwater act to regulate groundwater withdrawal, and the promotion of artificial groundwater recharge (ND1, ND2, ND3, ND4, ND8, ND34). These two strategies were also reiterated by water experts close to government (ND5, ND6, ND11, ND22, ND37). The increasing reliance on groundwater for drinking water, industrial use and agriculture (proving 60% of irrigation water in 2010), were all cited as important reasons to promote groundwater regulation to curb the high level of water withdrawal within the last few decades (ND11, ND34, ND32, ND37). Climate change is considered to have potential implications for groundwater recharge rates through changing intra-annual precipitation patterns, particularly changes in monsoon precipitation, and was cited as further reason to promote groundwater regulation, recharge and sustainable management (ND1, ND11, ND23, ND34; GoI, 2011a).

Groundwater regulation faces significant challenges. A groundwater bill to regulate and control groundwater withdrawal was first circulated in 1970 by the MWR, and has been subsequently re-circulated to states in 1992, 1996 and 2005. However, as of late 2012, only eleven state governments have enacted the 2005 groundwater bill, and even after enactment, there has been ineffective regulation with little control of increasing groundwater withdrawal rates (ND5, ND8, ND11, ND36). As one of the leading groundwater experts in India is quoted 'it is tossing around (the draft groundwater bill) for the last 35 years, yet has found few takers because few political leaders are willing to absorb the political transaction costs of seriously implementing it' (ND11). Such transaction costs include the high financial costs to state government governments to install and maintain groundwater meters at thousands of diffuse groundwater pumps throughout rural and urban India (ND11), perpetuated by the prospects of low financial returns of potential metering. Furthermore, there is a significant political dimension. Electoral candidates in some state elections (including Andhra Pradesh) have offered heavily subsidised (practically free) electricity hours for groundwater pumping to the large farmer constituent vote-block, in an effort to win votes, thus perpetuating high levels of groundwater withdrawal as a common pool resource (ND11, ND37).

The MWR has overall responsibility for groundwater planning and policy development, with the Central Groundwater Board providing scientific input, exploration, monitoring, assessment and regulation of groundwater. Although the MWR has circulated various groundwater regulations bills to state government over the last four decades and provided national level monitoring and assessment through the CGWB, the MWR has left the management of this resource primarily to state government and the local NGO/civil society sector primarily through watershed development programmes. The MWR has historically and in the present day under-prioritised groundwater management owing to a number of factors. These include the informal nature of the groundwater economy defined by numerous and diffuse unregulated well, the relative lack of institutional leverage to encourage state government to seriously implement groundwater regulation bills, and entrusting the NGO and civil society sector as the most appropriate actors to implement groundwater recharge through watershed development programmes[142] (ND5, ND11, ND37).

Although the NWM Goal 3.2 calls for the enactment of a groundwater bill at state level, it is the PC's WGWR that has taken this policy recommendation forward. In preparation for the 12th FYP (2012-2017), the WGWR prepared a new groundwater bill, the Groundwater Model Bill 2011. This new bill states that the existing legal framework derived from common law principles and judicial interpretation in recognising private property rights for water is inappropriate for the emerging status, conflicts and dynamics of groundwater (ND33; GoI,

[142] Watershed management programmes are under the responsibility of the Ministry of Agriculture.

2012a). It states that in recent decisions, superior courts in India have affirmed the common property nature of groundwater and have recognised the need to govern this resource under the concept of 'public trust'. The objective of the bill is to ensure the sustainability of groundwater resources, promoting equity between all users. In acknowledgement of the ubiquity of groundwater and its importance to all sections of society, the bill acknowledges the necessary to recognise groundwater as a common pool resource and to adopt an aquifer based approach to management (ibid). Although it is still early days for this bill, the change in focus to managing groundwater as a common pool resource under the legal jurisdiction of public trust can be considered as a step forward (ND11, ND33). Such is a new approach in managing groundwater, albeit as a legal act proposed by national government. This new bill will have to be examined by state governments, legally enacted and implemented accordingly.

5.3.3 Flood management

Flood management is under the responsibility of the MWR, with specific input from the National Institute for Disaster Management. The NWM Goal 3.8 recommends the need to 'develop digital models for flood forecasting in vulnerable areas and to develop schemes to manage floods'. Specific activities include the mapping of areas likely to experience floods, establishing hydraulic and hydrological models, develop a comprehensive approach to flood management and reservoir sedimentation, and to encourage and enforce flood plain zoning in flood prone rivers (GoI, 2011a). The NIDM provides technical guidance to state government in this regard.

Climate change can be seen to be entering national government discourse as a risk, particularly in the form of an increase in the frequency and intensity of extreme weather events, manifest as floods and droughts (ND1, ND2, ND4, ND8, ND28). The NWM policy explicitly states the anticipated increase in flooding: 'increased flood events due to overall increase in the rainy day intensity owing to climate change' (GoI, 2011a:4). Interviews with officials confirmed the need to strengthen on-going flood management activities, particularly anticipatory strategies and planning in the likelihood of an increase in flood events associated with climate change (ND1, ND2, ND4, ND12, ND13, ND28).

5.3.4 Hydrological data, database management and climate change research

The NWM Goal 1 recommends the establishment of a public hydrological database, and research to understand further the impacts of climate change on water resources.

The NWM stresses the uncertain nature of climate change impacts, calling for a programme of data collection and planning: 'the likely climate change, and the concerns caused by the change shall further increase the stress and can make the future more uncertain. A large programme of data collection and of planning and implementation would have to be taken up' (GoI, 2009b:13). Interviews with MWR officials stressed the importance of improved hydrological data and further research for understanding the impacts of climate change in India which are still largely uncertain at present (ND1, ND2, ND21, ND23, ND24). In 2010 the MEF established the Indian Network on Climate Change Assessment (INCCA). The INCCA consists of 250 scientists from 125 Indian research institutions, in collaboration with relevant international organisations[143]. Based on the mandate of 'measuring, modelling and monitoring', the INCCA will publish peer review findings, informing the eight mission of the NAPCC and the IPCC Fifth Assessment Report due in 2014 (GoI, 2010). Jairam Ramesh, the former minister of the MEF, considered the INCCA as a 'sort of Indian IPCC', but not to rival the IPCC (ND5). Furthermore, in 2010, the MEF established of the Indian National Institute of Himalayan Glaciology to examine issues of glacier melt in the Himalaya. In this way, the national government is taking ownership of climate change research within India, moving away from international (non-Indian) assistance in assessing the impacts of climate change within India (ND5).

The promotion of a public water database is a notable inclusion in NWM Goal 1, under the responsibility of the MWR, specifically the CWC. Recommending the establishment of a public hydrological database was made in the National Water Policy (GoI, 2002): 'a standardised national information system should be established with a network of data banks and data bases, integrating and strengthening the existing central and state level agencies and improving the quality of data and the processing capabilities' (GoI, 2002:2). It was noted by interview respondents inside and outside of national government that widespread hydrological data sharing has not materialised in a significant centralised and coherent manner (ND5, ND6, ND9, ND11, ND29). Issues of hydrological data availability and accuracy are problematic in India. Such issues include data secrecy owing to inter-state water sharing between riparian states within India's borders; and external regarding water sharing between India's South Asian riparian neighbours, including Bangladesh, Nepal, China, Bhutan and Pakistan. Lack of sharing of data between and within ministries (especially between the CWC and the Ministry of Agriculture) owing to competition for national funding was cited by numerous respondents, with data being withheld by ministries to promote a single ministerial focus on joint water projects (ND5, ND6, ND10, ND11, ND16, ND26; Saleth, 2004). Regarding data accuracy, published government hydrological data is strongly suspected of being altered to fit the agenda of the ministry or department, especially relating to specific project work or environmental impact assessment (ND5, ND6, ND9, ND26, ND31). Furthermore, based on independent calculations of the total utilisable water resources within India, the figure of 1122BCM declared in the NWP (2002) is claimed to be over-estimated by 40%, raising doubts as to the accuracy of CWC calculations at the national level (Garg and Hassan, 2007).

The NWM states that 'all information except the data of sensitive and classified nature would be in the public domain' (GoI, 2009b:8). The NWM does not specify under what criteria it defines sensitive data. As one respondent noted, the national government could simply classify greater amounts of hydrological data as 'sensitive', especially owing to inter-country and state-water sharing issues, to reduce the amount and coverage of data within the public domain (ND6). The Right to Information Act (RIA) 2005 has provided a mechanism to which hydrological data can be officially requested. However, applications for data are often

[143] Within the INCCA, The Indian Institute of Tropical Meteorology (IITM) are the lead national organisation mandated to develop climate change projection models for India, with the Indian Institute of Technology (IIT) taking the lead on modelling climate change projections impacting on water resources and hydrology. International input is provided by a variety of organisations, including the Met Office Hadley Centre in the UK.

delayed by lengthy bureaucratic application procedures (ND5, ND7). Furthermore, hydrological data which is classified as 'sensitive' by the CWC is not open for wider public distribution, regardless of the RIA.

In late 2010, on the back of the NWM policy, the CWC, in collaboration with the Indian Space Research Organisation, released a web-based portal, the Water Resources Information System (WRIS). The objective of the WRIS is to make standardised water data and GIS maps available to the public through a web-based interface. However, only basic non-politically contentious data has been made available, including river basin and administrative boundaries, and some selected project information. Notably, no politically sensitive data is provided on reservoir and dam characteristics (volumetric capacity), river discharge, multipurpose projects, hydropower, M&M irrigation projects and command areas and canal networks. The assessment of climate change impacts requires accurate and comprehensive data availability and sharing between government and non-government actors. Although the launch of the WRIS portal does signify a step in the right direction, barriers to data accuracy and sharing remain. See chapter 7 for a discussion on barriers to data sharing and management in Andhra Pradesh.

5.3.5 The NWM's water strategies as adaptation to climate change

The vast majority of the NWM's WSM and WDM recommendations are climate change autonomous in nature. As defined by the IPCC, autonomous adaptations are 'those strategies that do not constitute a conscious response to climate stimuli, but result from changes to meet altered demands, objectives and expectations which, whilst not deliberately designed to cope with climate change, may lessen the consequences of that change' (IPCC, 2008:63). The vast majority of the WDM and WSM practices singled out as priority strategies by the NWM and from interviews with MWR officials are climate change autonomous, they were on-going strategies by the MWR before the development of the NWM.

Climate change specific adaptations are the result of deliberate policy decisions and specifically take climate change and variability into account (IPCC, 2008). Government organisational responses such as establishing the INCCA and INIHG in 2010 can both be considered as climate change specific. Both represent an effort to further understand the impacts of anthropogenic climate change on regional meteorology and hydrology (GoI, 2012a, 2010a); as well as understanding potential impacts of glacial melt with rising temperatures in the Himalaya (Barnett, 2005). Autonomous and specific WRM adaptation as well as the robustness of WRM strategies in response to climate change impacts is discussed in detail within AP state in Chapter 6 (Section 6.3.6).

5.3.6 Institutional reform

5.3.6.1 An Integrated Water Resource Management approach

The overall objective of the NWM promotes an Integrated Water Resources Management (IWRM) approach: 'conservation of water, minimising wastage and ensuring its more equitable distribution both across and within states through integrated water resource development and management' (GoI, 2011a:iii). The NWM Goal 5 recommends an IWRM approach to river basin planning (GoI, 2011a). Although some central tenants of IWRM were mentioned in the NWP 2002, such as the establishment of river basin organisations and participatory stakeholder approaches (GoI, 2002), this is the first time in national Indian water policy that IWRM has been explicitly advocated. The importance of an overall IWRM approach is reiterated by MWR officials (ND1, ND2, ND3, ND8, ND30, ND44). In recognition of the present day and future challenges in managing rising water demands from users, particularly for agriculture and drinking water, it was acknowledged that a more integrated and effective management approach is required from government, which can be achieved by appropriate government organisational and policy reform (ND1, ND5, ND7, ND8, ND44). Climate change has added weight to the need to develop more integrated government approaches, as acknowledged by a senior MWR policy advisor (ND1). As explicitly stated by the NWM: 'a paradigm shift towards basin planning approach is necessary, from the project-centric approach to meet the future water demand of all the sectors and adapt and mitigate the effects of climate change (GoI, 2009b:437).

The interpretation and implementation of IWRM is found to be problematic at varying operational levels (Biswas, 2008). The concept is amorphous, the result of its application to improve policy, programmes and projects at macro to meso scales has been somewhat problematic (ibid). Although MWR officials acknowledged that IWRM[144] is a 'loose concept' open to fairly broad interpretation and country level contextualisation, certain central tenets promoting organisational integration and institutional reform are considered relevant to India (ND1, ND4, ND44). The NWM policy and interviews with MWR officials (ND1, ND2, ND4, ND8) highlighted particular strategies deemed appropriate in moving towards an IWRM approach, at a national and state government level. These strategies examined in this section (5.3.3) include establishing river basin organisations, convergence amongst national and state level government ministries and departments working on water issues, interdisciplinary training of staff, review of the NWP 2002, and establishing a National Water Commission.

5.3.6.2 River basin organisations

The establishment of river basin organisations (RBO) is supported by the NWM, and is considered an important strategy by MWR officials in the move towards an integrated approach to water management at the river basin level (ND1, ND3, ND8). The NWM calls for the 'integrated planning, development and management of water resources with active participation of the stakeholders at the river basin level' (GoI, 2009b:iii). This

[144] Section 2.4.3.2 footnote 36 for a definition of IWRM from the GWP.

reiterates the NWP call for ‘appropriate river basin organisations should be established for the planned development and management of a river basin as a whole or sub-basins, wherever necessary’ (GoI, 2002).

Interviews revealed that establishing and operationalising effective multi-stakeholder RBOs faces numerous challenges. There exist a number of RBOs across India, established under the River Boards Act of 1956. The present function include operation of major structures (dams and reservoirs), overseeing the allocation of water according to the tribunal awards of inter-state agreement, and/or development of water resources infrastructure. Existing RBOs are exclusively chaired and populated by national and state government representatives, usually engineers, are highly bureaucratic and top down in approach, with very limited non-government stakeholder representation (ND5, ND7, ND29; ADB, 2007). Integrated river basin management functions are very much secondary and are largely restricted to overseeing or implementing the agreed interstate water allocation and accommodating the state’s water allocations according to their monthly requests under tribunal orders (ND5; ADB, 2007).

A major challenge to establish effective RBOs is that numerous river basins in India are shared by riparian states, with inter-state tribunals legally superseding existing River Basin Boards and proposed RBOs. Furthermore, as water is a state subject under the legal constitution in India, riparian states have the legal right to manager water within their administrative and political boundaries at their discretion (ND5, ND7, ND29, ND31). This has led to very limited support for basin level planning and management by state government, with basin management largely considered in the context of tribunals and the legal processes to maximise the state’s share of the water (ND5, ND29, ND33, ND36).

The NWM proposed RBO arrangement does not offer a new or modification of existing legal framework to a change in the current tribunal deliberated situation of inter-state water sharing (ND5, ND7; GoI, 2011a). The MWR is avoiding addressing this issue by not proposing a legal change through the NWM. It is falling in line with previous policy document, as was the case with the NWP in recommending that ‘the scope and powers of the river basin organisations shall be decided by the basin states themselves’ (GoI, 2002:3), in line with the 1952 Constitutional arrangement (GoI, 1952). In effect, the MWR is side-stepping this legally contentious issue, largely leaving it to state government to address through the ad hoc water tribunal arrangement, with executive decision powers residing with the supreme court in New Delhi. However, it is recommended that initial basin level planning should focus on sub-basins within riparian state administrative boundaries, with the establishment of a new IWRM unit within state irrigation departments (GoI, 2011a). This is to be decided at state government level (ND44).

5.3.6.3 Institutional convergence

Institutional convergence is considered to be the process by which different ministries and state departments of government involved in water management issues effectively coordinate on common water projects and issues. It is characterised by transparent communication, open sharing of data and information, and effective joint operations with regards to common water projects and issues (Saleth, 2004).

The NWM Goal 5 recommends that national and state government 'ensure the convergence among various water resources programmes' (GoI, 2009a:24). This is in line with the NWP, that called for 'the existing institutions at various levels under the water resources sector will have to be appropriately reoriented, reorganised and even created' (GoI, 2002:3). Interviews with MWR officials recognised the need for a more integrated coordination between national ministries and state departments working on water management issues (ND1, ND3, ND4, ND44).

Numerous national government ministries are involved in different aspects of water management (Table 4.1). As noted by Saleth (2004), there is a lack of effective coordination between ministries and departments at the national and state level on common water projects. Water management at the national (and state) level remains very sector driven, with ministries and departments following their own specific and narrow organisational objectives and mandates (ND5, ND7,ND8, ND11, ND22, ND29, ND30, ND43). Interviews confirmed such in the present day context: 'national ministries involved in water management do not communicate adequately with each other, there is little if any coordination of action, characterised by lack of information sharing and ineffective implementation of common water projects' (ND5). The lack of a coordinated approach was reiterated by numerous respondents (ND7, ND8, ND11, ND22, ND30). Furthermore, the issue of funding completion was highlighted as another issue hampering coordination: 'government ministries do not coordinate effectively on water projects. There is little sharing of ideas, data and information for projects. Competition for central funding, particularly between the Ministry of Agriculture and MWR, fuels an air of general secrecy and protectionism' (ND31)[145].

The NWM proposes an organisational arrangement to facilitate more effective coordination, through establishing numerous cross ministerial committees and a secretariat housed within the MWR, bringing together representatives of various ministries with other actors in the water sector (NWM, 2009). However, respondents close to government were critical of the proposed organisational arrangement, stating that it will be 'ruined by a multiplicity of agencies and committees, with different set of guidelines, funding sources and outputs' (ND9). A common criticism was the lack of an integrated institutional framework within the NWM, detailing the steps to be taken to promote effective convergence, and especially one that is politically feasible (ND5, ND7, ND11, ND31). The lack of political will at the top-level of national government, for instance within the PMO, to push effective convergence between ministries was highlighted as a major issue of concern (ND5, ND7, ND31).

5.3.6.4 Promoting Inter-disciplinary training of government staff

The NWM calls for a more inter-disciplinary profile of staff within both the CWC and at state irrigation departments, both to deal with the rising demands of water users and to manage climate change (GoI, 2011a). The CWC human resource profile consists largely of engineers, staffing the various wings of the CWC (GoI,

[145] The rivalry and competition between the MWR and Ministry of Agriculture was mentioned by numerous respondents (ND2, ND5, ND8, ND15, ND19, ND20, ND30, ND31, ND33).

2012c), in line with the MWR's objectives focusing on technical issues in the pursuit of reservoir construction and expansion of irrigation area (ND1, ND5, ND8).

Interviews revealed the current need for a more interdisciplinary staff profile and focus of the CWC, especially in light of the NWM recommendations to introduce IWRM planning at the river basin level (ND1, ND5, ND8, ND11). Although training is provided by the National Water Academy in Pune, it is the opinion of experts close to government that the scope of training needs to be diversified from purely technical engineering approaches, to include issues such as anthropology and social science (ND5, ND8). As part of the CWC's current (mid 2012) public consultation on re-structuring in adapting to an integrated river basin approach to planning, the primary consideration is of technical and structural organisational issues, with inter-disciplinary training of staff under-represented (ND5, ND7).

5.3.6.5 The National Water Commission

The Planning Commission's Working Group on Water Resources (PC WGWR) has recommended that a new independent body be established, the National Water Commission (NWC). Although the specific objectives are still to be finalised, the aim of this organisation is to 'name and shame' state governments and also national level ministries, by highlighting poor institutional and operational performance (ND8). It is proposed to consist of leading water experts throughout the country, primarily non-government personnel, but also some state and national government representatives. It is envisaged that the NWC would also help government prioritise and incentivise the reform process, and assist in guiding where to make financial investments (ND8).

5.3.6.6 Review of national and state water policy

The NWM Goal 5 calls for a review of the National Water Policy (2002), with a revised policy due in late 2012 (GoI, 2011a). Initiated in October 2010, this review process has solicited feedback from non-government water experts within academia, NGO and civil society, and related water organisations throughout India. Many of the recommendations of the NWM covering WSM, WDM and reform measures are being considered for inclusion in revised 2012 NWP[146] (ND5, ND7, ND11). The NWM recommends that state governments review their state water policies, especially in light of climate change impacts (ibid). However, not all states have even developed a state water policy. Progressive governance states such as Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Kerala, Gujarat, Orissa, Uttar Pradesh, Rajasthan, Bengal, Uttarakhand, Jharkhand, Madhya Pradesh and Himachal Pradesh have a state water policy; but a significant number of states do not, especially states in north-east India.

[146] As of mid December 2012, the NWP 2012 has not been finalised by the MWR.

5.4 Discussion

This section presents and discusses the main conclusions in answering the research questions at national level. It draws on theory to understand and contextualise evidence presented in section 5.3, in addition to further evidence presented in this section. Conclusions and insights are presented under the five main themes of this section (5.4.1 to 5.4.5).

5.4.1 Ministry of Water Resources appropriating climate change through the NWM to continue supply-side approaches

The MWR can be seen to be appropriating climate change through the NWM policy to primarily continue its historic agenda of large-scale infrastructure-based supply-side interventions, in line with the national hydraulic mission. Two factors are offered in explanation. Firstly, the resistance of the MWR to fundamentally change from its historic focus on supply-side infrastructure approaches. And secondly, the plasticity of climate change within the MWR's water discourse, with it being cited as 'additional justification' for different water supply approaches.

Climate change plasticity within the discourse

Allan (2002) stresses the importance of the sanctioned discourse within water policy discourses, defined as the 'prevailing dominant opinion and views which have been legitimised by the discursive and political elite' (Jagerskog, 2002:18)[147]. It is argued that the sanctioned discourse sets limits within which policies have to be pursued, indicating what avenues that may be politically feasible (Allan, 2002). Interviews with MWR officials highlight the dominant 'water for food' sanctioned discourse within the MWR. The NWP names drinking water as the top priority of national government, followed by agriculture, hydro-power, ecology, industry and navigation (GoI, 2002:3). The dominance of the 'water for food' sanctioned discourse is in line with the objectives of the MWR in expanding the area under irrigation and increasing reservoir storage capacity, which also provides drinking water in multi-purpose schemes[148].

Interviews revealed that climate change is understood by MWR officials as hydro-meteorologically impacting in a number of different ways. These include changes in summer monsoon precipitation (ND1, ND3, ND4, ND11, ND30, ND34, ND44); long term changes in precipitation (ND1, ND2, ND3, ND4, ND11, ND44) and temperature (ND1, ND3, ND4, ND34, ND44); an increase in intensity and frequency of extreme events in the form of floods and droughts (ND1, ND2, ND4, ND11, ND12, ND21, ND30, ND31, ND34, ND44); sea level rise (ND1, ND2, ND4, ND21, ND34); and an increase in melting of Himalayan glaciers (ND1, ND2, ND44). Changes in intra-annual and long term precipitation levels are acknowledged as affecting water availability (ND1, ND2, ND3, ND4, ND11, ND21, ND30, ND34, ND44) and agricultural productivity (ND1, ND2, ND4, ND20, ND21,

[147] Jagerskog (2002) draws on an earlier definition of sanctioned discourse by Feitelson (1999:438) as 'a normative delimitation separating the types of discourse perceived to be politically acceptable from those that are deemed politically unacceptable at a specific point in time'.
[148] Groundwater is the primary source of drinking water in India, accounting for an estimated 80% of all drinking water in India (GoI, 2009a).

ND44) in India. Climate change impacts are also acknowledged in the NWM policy, including a decline in glaciers and snowfields in the Himalaya, changes in long term precipitation patterns and temperatures, increased intra-annual precipitation variability (particularly the summer monsoon), varying temporal and spatial groundwater recharge rates, saline intrusions, sea level rise, and increase incidence of coastal cyclones (GoI, 2011a).

For all of the WSM strategies (irrigation expansion, increasing reservoir storage capacity, carry-over and NRPL) advocated by the NWM as top priority, climate change is understood by MWR officials as manifesting in a variety of physical impacts (changes in summer monsoon rainfall and long-term changes in precipitation affecting water availability), and is being cited as 'further justification' within the current discourse for a particular water supply approach. However, in no instance is climate change being cited as the primary reason for a particularly water supply strategy. Still the dominant policy drivers prevail within the sanctioned discourse, the provision of increasing water for agriculture is considered as a top priority of the MWR (ND1, ND2, ND3, ND4, ND11, ND34; GoI, 2011a); along with drinking water, and meeting growing urban and industrial needs in light of a rising population and economic development (ND1, ND2, ND3, ND4, ND8, ND10, ND11, ND14, ND20, ND22, ND, 30, ND34, ND44). As stated in the NWM: 'at any given time, climate change related concerns would form but one of the many groups of concerns which would be driving the institutional changes and water management practices' (NWM, 2009). A number of respondents cited the uncertain nature of climate change impacts as a reason why it is not more of a significant policy driver in its own right (ND1, ND4, ND5, ND11, ND15, ND20, ND22, ND31, ND44). The plasticity[149] of climate change within the MWR current discourse is evident, in terms of climate change as a metaphor to capture the multiple framings (e.g. physical impacts) through which it is narrated and rhetorically deployed, with different impacts (changes in summer monsoon and long term precipitation) being cited as further justification for particular WSM strategies in favour of vested interests and projects (Hulme, 2009). Climate change plasticity is attributed to a number of factors. These include the complexity of the physical phenomenon itself; the interweaving of natural and anthropogenic climate change; the multi-scale nature of the phenomenon (global to local level impacts); the cultural filters through which climate change is viewed in order to search for meaning and significance (e.g. the cultural histories that exist around weather and climate); the contested and ideologically shaded arguments about scientific claims; and the many different value-systems which get mobilised when viewed through the lens of economics and social systems (ibid).

Ministry of Water Resources resistance to change

Since independence, the MWR's primary focus has been the development of large-scale infrastructure supply-side approaches, characterised by canal irrigation expansion and increasing reservoir storage capacity, propelling India along its hydraulic mission (Section 4.3 for historical overview of India's hydraulic mission).

[149] The Oxford dictionary (2001) defines plasticity as 'the quality of being easily shaped or moulded'.

The WSM strategies advocated by the MWR through the NWM closely align with existing national water policies and strategies, particularly for irrigation expansion and reservoir storage capacity. Further policy support is gained through the NWM to continue this approach, in line with the MWR's strategic outlook. By appropriating climate change through the NWM policy to re-confirm and strengthen its focus on large scale supply side infrastructure development, the MWR can be seen to be largely resisting fundamental change in outlook and strategic WRM approach. This resistance to change confirms earlier research on the nature of the hydrocracy's inertia (Molle et al, 2009; Mollinga, 2005). As noted by Mollinga (2005) with regards to the Indian hydrocracy: 'even at the symbolic and discursive level, the faithfulness to the old paradigm (supply enhancement) is very strong, and those who advocate the need for alternative approaches seem to be making very little headway within the domain of governance and policy' (ibid:8).

The supply strategies detailed in the NWM are considered as top priority and the primary focus of the MWR (ND1, ND3, ND4, ND44). As stated by the NWM: 'in general, supply side management could be somewhat costlier, but is more likely to succeed provide the scheme is well engineered. On the other hand, the demand side management may be comparatively cheaper, but since a very large number of measures have to manage the demands, it is more time taking and more difficult to execute. It also is likely to take more time, since public awareness and change of habits is a slow process' (GoI, 2009b:22). Furthermore, before the development of the NWM policy, the MWR report for the 11th FYP (2007-2012) signalled initial thinking on how to manage water resources in light of climate change: 'it is an accepted fact that even in the post climate change scenario, systems that are more controlled will fare better than systems that are less controlled. In water resources parlance, control means engineering infrastructure that enables the water managers to store and transfer water with greater certainty, thus reducing the impact of uncertainty. Therefore, dealing with climate change is going to require more infrastructures' (GoI, 2006:43).

The WSM strategies advocated by the MWR within the current policy discourse[150] are considered as expression of power and knowledge (Shore and Wright, 1997), expressed in politically neutral terms of a technical water supply approach (Asthana, 2011; Mehta, 2001; Foucault, 1991[151]; Dreyfus, 1982). These supply approaches are intentional political strategy for controlling water, space and people through the construction of large scale infrastructure (Wester, 2008; Allan, 2002; Swyngedouw, 1999; Reisner, 1993). Such supply approaches allow the further development of water control by the MWR. Control in the form of regulating hydrological process, organisational control guiding human (especially famers) behaviours and practices in water use, and in the wider context of political and economic control in which water management is embedded and contributes too (Sudardiman, 2008; Wester, 2008; Mollinga, 2003; Bolding and Mollinga, 1994). By endeavouring to increase water control through the large-scale infrastructure based WSM strategies advocated in the NWM, the MWR can be seen to be largely consolidating its power base, in a continuation of the national hydraulic mission. Such is an important part of everyday state formation (Wester, 2008; Swyngedouw, 2007; Wehr, 2004; Reisner, 1993; Worster, 1985; Witfogell, 1957), with such large scale

[150] Discourse consisting of NWM policy text and interviews with MWR officials (Sharpe and Richardson, 2001).
[151] Foucault (1991) considers that such ideology informed policies operate as 'political technologies' masking the political agenda and the relations of power that it helps to reproduce.

infrastructure symbolising national prestige (Molle et al, 2009), informed by industrial or high modernity (Scott, 1998). The MWR's continual support of supply-side interventions should also be considered within the iron triangle of actors identified by Molle et al (2009). The national and state hydrocracy, along with private construction firms and politicians, receive significant political benefit and financial kick-backs from continuing large-scale supply orientated infrastructure projects (ND5, ND31) (ibid; Briscoe, 1999).

Historically, the MWR has used various policies, project and initiatives to continue the hydraulic mission. For instance, the World Bank funded Water Resources Consolidation Projects of the early 1990s provided significant funds for state governments, particularly Tamil Nadu and Orissa, to expand irrigation infrastructure and reservoir storage capacity, with only a fraction of the budget allocated to demand management strategies (Wood, 1998). Before the advent of the NWM 1987, the National Water Plans developed by the MWR in the mid-1980s were also used to stress the importance of irrigation expansion for food security (ND5, ND8, ND30). The National River Linking Project with its focus on large scale infrastructure is an overt attempt by the MWR to continue the hydraulic mission, on a grand scale across the country (ND5, ND7, ND8, ND20, ND30). The focus on large-scale supply side strategies can be detected in the draft of the National Water Policy currently (mid to late 2012) being developed by the MWR: 'all water resources projects should be planned to the extent feasible as multi-purpose projects with provision of storage to derive maximum benefit from available topology and water resources (GoI, 2012d:8). Maximum benefit of all available water resources in MWR policy parlance denotes the full capture and full utilisation of a river basins water resources. The draft policy also explicitly supports inter-basin transfer from 'open to closed river basins to maximise all available water resources to meet growing demands' (GoI, 2012d:5).

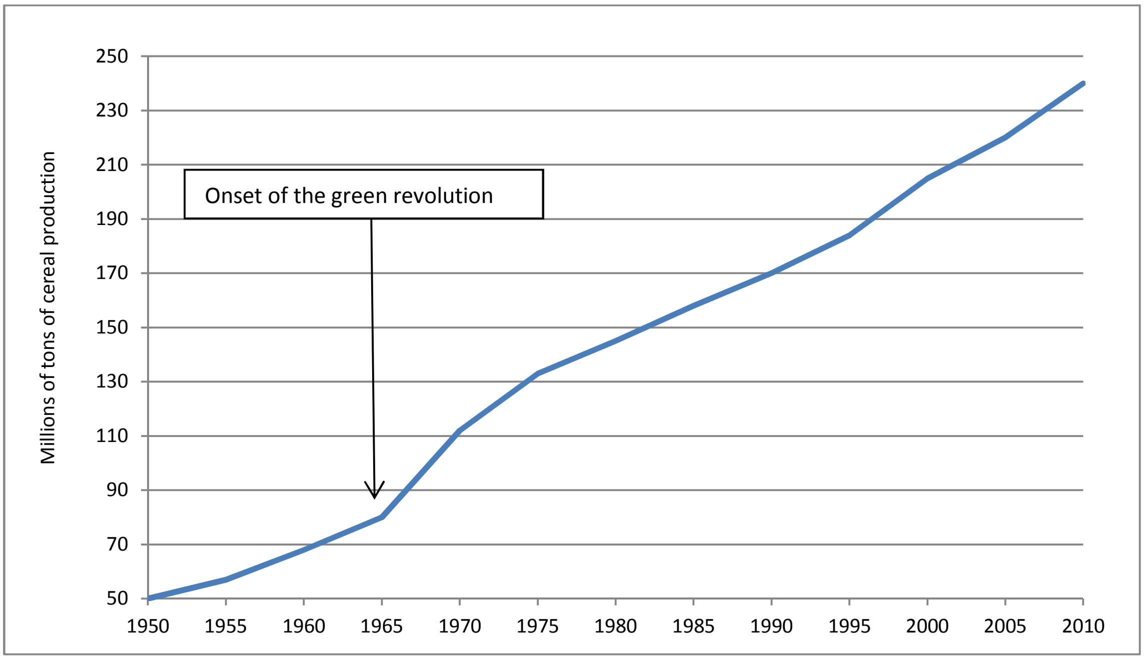
The promotion of supply-side infrastructure projects by the MWR should also be considered with regards to national and state level government dynamics, within the context of water management as a state issue under the legal constitution. M&M irrigation projects under the AIBP[152], including canal irrigation expansion and increasing reservoir storage, provide the MWR with a degree of leverage over water resource development at the state level. Technical clearance for M&M irrigation projects under the AIBP has to be sought by state governments from the CWC before funds are allocated by the PC. The promotion of M&M irrigation projects with significant funds from the AIBP, as well the NRLP defined by ambitious large-scale infrastructure development also with significant funding from national government, can be considered as continuation by the MWR to consolidate supply side approaches. The funds and technical clearance allows the MWR significant power in determining state-level water development, and can be considered as an effort by the MWR to regain 'lost terrain' from state government in recent years (ND36; Mollinga, 2005).

[152] Launched in 1997, the AIBP provides up to 90% of funding to state government for M&M projects from national government. During the 11th FYP (2007-2012), AIBP funding to state governments totalled 49,000 Crore rupees ($11.5 billion US dollars) (MWR, 2011c).

5.4.2 Hydrological critique of the MWR's sanctioned 'water for food' discourse

Cereal (food) crop production in India[153] has increased dramatically from 50 million tonnes in 1950 to 239 million tonnes in 2010 (Figure 5.6). Production of cereal crops accelerated during the onset of the green revolution[154] from the mid to late 1960 onwards, with India becoming food self-sufficient[155] as a nation in 1971. Significant political importance was attached to achieving national food self-sufficiency, and to this day, increasing agricultural production to remain food self-sufficient as a nation is a top political priority of government (ND1, ND2, ND4, ND7, ND13; Allan, 2011, 2002; Shah, et al, 2007; Iyer, 2003). Food production relates to the physical availability (supply) of food, an important component of the four dimensions[156] that determine overall food security[157] (FAO, 2011). Although India is food self-sufficient as a nation it is not food secure, with an estimated one third of children malnourished owing to insufficient calorific intake (Dev and Sharma, 2010).

Figure 5.6: Cereal production in India since 1950 (GoI, 2012f)



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[153] Principal cereal crops in India consists of rice, wheat, maize, barley, sorghum and millet (GoI, 2012f).

[154] Prior to the mid 1960s, India relied on imports and food aid to meet domestic requirements. However, two years of severe drought in 1965 and 1966 led to agricultural policy reform focusing on food self sufficiency. This led to the Green Revolution in which superior yielding, disease resistant wheat varieties in commination of better farming practices dramatically increased yields. In 1948, the average wheat yield per hectare was 0.8 tonnes, rising to 4.7 tonnes in 1975, and up to 6 tonnes per hectare in 2000 in some particularly productive areas such as the state of Punjab (FAO, 2012).

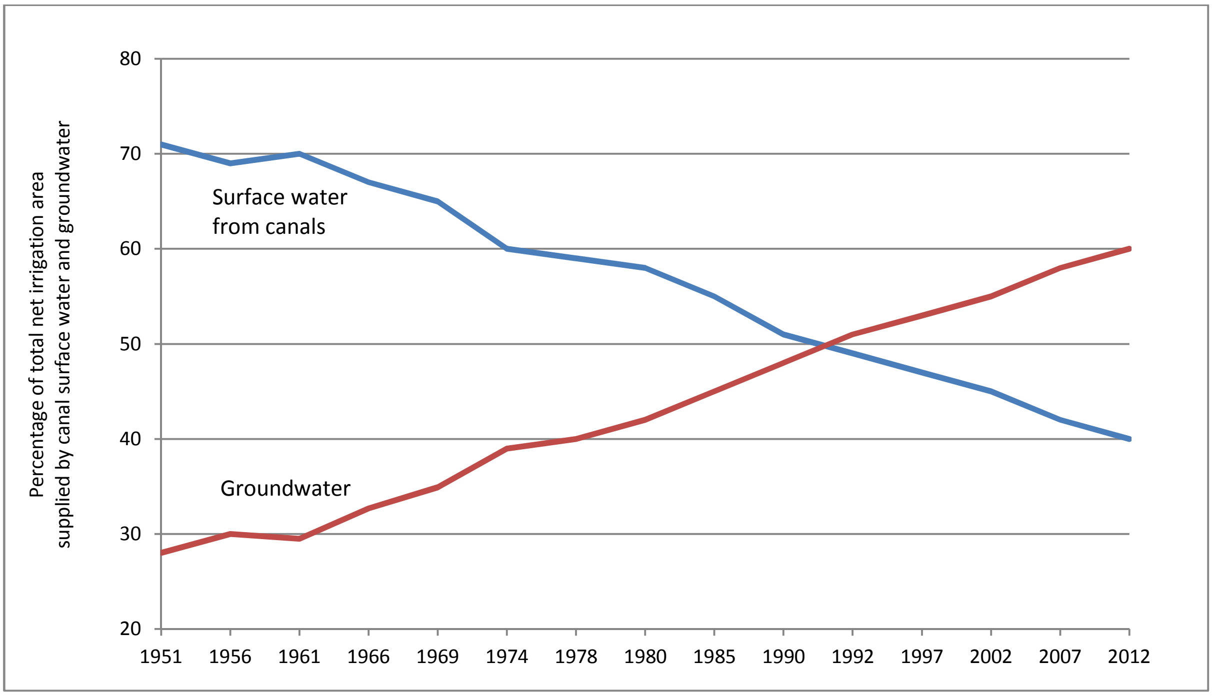
[155] In the context of this thesis, food self-sufficiency is achieved when enough food is produced within a nation or state without relying on external supply from outside of political or administrative boundaries.

[156] Four dimensions of food security are identified by the FAO. The first is the physical availability (supply) of food determined by the level of food production, stock levels and net trade. The second is economic and physical access to food at the house-hold level, determined by incomes, expenditure, and access to markets. The third is food utilisation in which the body makes the most of various nutrients in food, determined by feeding practises, food preparation, diversity of diet and intra household distribution of food. And the fourth is the stability of the previous three factors over time (FAO, 2011).

[157] The FAO define food security as existing when 'all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'. This definition dates back to the World Food Summit in 1986 (FAO, 2011).

Since independence, the MWR has primarily focused on the construction of large-scale reservoirs and canal irrigation systems (Figure 5.1) to increase the supply of water for food production, in line the sanctioned 'water for food' discourse (Section 4.4 for overview of India's hydraulic mission). A historical examination of the relative percentage of both surface water from canal systems and groundwater in supplying water for the total net irrigation in India[158], and hence contributing to cereal crop production, highlights the increasing reliance on groundwater and the diminishing role of surface water from canal systems (Figure 5.7). In 1951, surface water from canals supplied 72% of all water to the net irrigated area in India, with groundwater (primarily from shallow wells less than five metres in depth) providing 28%. From the early 1970s onwards, the withdrawal of groundwater increased dramatically throughout India, characterised by the proliferation of diesel and electrical pumps owned by individual users, and the drilling of bore-wells accessing deep groundwater from aquifers. By 1992, groundwater became the primary source of water for irrigated agriculture in India. This trend has continued over the last 20 years, with groundwater withdrawal increasing further still throughout India. In 2012, groundwater and surface water from canal irrigation systems supplied 60% and 40% respectively to the total net irrigated area in India[159]. This trend is expected to continue in future years, with greater reliance on groundwater as the primary source of irrigation water for food production (ND7, ND11; Shah, 2009).

Figure 5.7: Relative percentage supply of surface water canal irrigation systems and groundwater to the total net irrigation area and hence food production in India (GoI, 2012c)



[158] Net irrigation area refers to the total area that is irrigated at least once per year in India (GoI,2012c), similar to the FAO's term 'area actually irrigated' (FAO, 2012). It includes the areas both within the command area of an irrigation system and rainfed areas not served by canal irrigation.
[159] Conjunctive use of surface and groundwater is a common practice within major and medium canal irrigation systems in India, particularly at the tail end, characterised by the reliance on groundwater during the rabi and zaid (summer) crop seasons when rainfall and water is relatively less available (GoI, 2012c, 2012f). However, no accurate data is available on the volumes or levels of conjunctive water use within major and medium irrigation systems.

The increase in cereal production witnessed over the last three decades (Figure 5.6) cannot be primarily attributed to the construction of large scale irrigation systems providing surface water for agricultural production, even when considering the increase in utilisable irrigated area from 23Mha in 1980 to 35Mha in 2007[160]. A recent report by the GoI's Planning Commission estimated that 83% of the total additional net irrigation area over the last three decades has been supplied by groundwater (GoI, 2012c). Groundwater relative to surface water from canal irrigation has been of more importance in increasing food production and maintaining food self-sufficiency in India over the last thirty years.

It is apparent that the sanctioned 'water for food' discourse primarily pursued through a focus on canal irrigation expansion by the MWR, has not led to a proportional contribution to additional net irrigation area and cereal food production relative to groundwater (Figure 5.7). The MWR's continued focus of large-scale canal irrigation systems is at odds with the hydrological reality, with increasing importance and reliance on groundwater as the primary source of water for irrigated food production. Owing to the importance of groundwater to remain food self-sufficient and to help achieve food security in India, it would be expected that the MWR shift its primary focus away from the construction of large scale irrigation systems[161] to that of groundwater management issues - such as groundwater recharge, wider access for users and increasing efficiency of agricultural use - to increase food production. However, this has not been the case, neither over the last three decades nor at present with the NWM policy. Groundwater clearly has an important role to increase food production as India endeavours to become food secure as a nation.

It is clear that the sanctioned water for food discourse is not solely based on the hydrological situation with regards to cereal food production in India. The sanctioned discourse is politically constructed and propagated, in serving the vested interests of the MWR and other actors whom interests lie in large scale infrastructure development.

5.4.3 Non-government actor's contesting of the strategic WRM direction of the NWM

Non-government actors, particularly NGO and civil society respondents, contest the strategic direction of the NWM on a number of grounds. Water management discourse in India has been found to be characterised by a high degree of polarisation (Asthana, 2011; Thakkar, 2009; Mollinga, 2005; Kaviraj, 2001; Roy, 1999). On one side is the government hydrocracy, dominated by the technocratic engineering approaches in developing supply-side infrastructure to propel India along its hydraulic mission since Independence. And on the other side, an active civil society and NGO sector; highly critical and contesting government approaches that focus on supply-side strategies (Thakkar, 2009, 2012; Mollinga, 2005).

[160] Non-government actors question the accuracy of the MWR's data on canal irrigation area utilised for crop production, claiming that the figure is much lower than presented in official government (MWR and MA) data and reports (ND5, ND7, ND14, ND15, ND20). A report by SANDRP claims that from 1991 to 2004, the canal irrigation area utilised for crop production declined by 3.18Mha (Thakkar, 2009).

[161] Since British colonial rule and in the decades that followed Indian independence, major and medium scale irrigation systems and large and medium reservoirs have already been constructed in the most suitable topographical areas throughout India (e.g. river deltas and v-shaped valley systems).

Interviews with non-government respondents in New Delhi highlighted that opposition to the NWM is characterised by numerous opinions and objections. In terms of the overall strategic approach of the NWM, one of the leading NGO-based water experts considers that 'the NWM represents business as usual, pushing large-scale supply infrastructure projects with little realistic focus on demand management and effective reform' (ND7). Similar opinions from other non-government actors are also critical: 'the NWM policy is too general in nature offering little in terms of new water management approaches (ND27); and 'the NWM plays lip service to demand management without proposing an appropriate framework for action and implementation' (ND31).

With regards to the supply strategies advocated in the NWM, non-government respondents were critical of the MWR's continued focus on the expansion of irrigation area. They consider such as a misguided and ineffective strategy in terms of increasing food production, citing the increasing irrigation gap over the last decades as evidence that continued expansion of irrigation infrastructure has not translated to a proportional increase in the irrigation area utilised for crop production (ND7, ND16, ND20, ND47; Thakkar, 2009, 2012) (Figure 5.4); and that returns on the billions of dollars spent on irrigation infrastructure has not provided a cost effective return in improved irrigation performance and food production (ND7, ND31, ND32; Thakkar, 2009).

Contestation over the construction of large dams and increasing large-scale reservoir storage capacity can be traced back to the Narmada dam dispute[162] from the mid 1980s onwards, led by prominent Indian NGOs and activists. This significantly raised awareness throughout India regarding the negative consequences of large reservoirs, and heralded the third 'environmental awareness' or 'green thinking' paradigm of water management in India, identified by Allan (2003) (Figure 2.13). Debate around large dams in India is very much polarised (Mollinga, 2005). On one side, social movements lead by numerous national and state-level NGOs and civil society groups, vehemently oppose dam and large reservoir construction, owing to issues of land submergence and displacement, ecological destruction, loss of livelihoods and human rights (Thakkar, 2009; Roy, 1999; Singh, 1997; Dhawan, 1990). And on the other side, an aggressive pro-dam lobby considers dams as the only possibility solution for increasing agriculture production through surface water irrigation, and to meet growing domestic and industrial requirements (Briscoe and Malik, 2006; Mollinga, 2005; Iyer, 2003). This latter group consists of infrastructure construction companies, political elites, and some international development banks and organisations (ibid). Non-government respondents, particularly from the NGO and civil society, oppose the ambitious reservoir storage creation targets advocated in the NWM (ND7, ND16, ND20, ND31, ND32, ND39, ND45). They claim that the government's default approach of constructing more large-scale storage is not the most appropriate strategy to manage climate change, particularly with regards to

[162] The Narmada dispute centered on opposition to the construction of the Sardar Sarovar dam on the Narmada river in Gujarat, north-west India. From 1985, a campaign has galvanised many actors together in opposition, including farmers, tribal groups, human rights and environmental activists, academics, writers and celebrities. The issue received significant media attention during the height of the dispute from the mid-1980s to mid-1990s (Roy, 1999).

the uncertainty of precipitation and water availability under climate change projections (ND6, ND7, ND16, ND31, ND45).

Non-government actors opposed the NRLP before the advent of the NWM, and are critical of the MWR's continued support of the project as a strategy to manage climate change impacts (ND6, ND7, ND16, ND20, ND32, ND36, ND45). Opposition is based on issues of the mega-project fuelling mass government corruption, un-ethical land acquisition, loss of ecology and rural livelihoods; along with questioning the technical feasibility of the project, which undermines efforts to increase efficiency use in river basins (ND7, ND16, ND26, ND20, ND31, ND32, ND39, ND45). They consider that the NRLP is not the most appropriate response in managing potential climate change impacts, nor to meet growing water demand from sectors and increasing water scarcity by transfer water from surplus to deficit basins (ND7).

Instead of supply strategies, the general consensus of non-government actors interviewed was the importance of WDM strategies, both to manage climate change impacts and to meet present and future demands in water (ND8, ND14, ND15, ND16, ND20, ND31; Saleth, 2011; Thakkar, 2009, 2012). There is general support for the NWM 20% increase in efficiency target, particularly for surface water irrigation canal systems (ND7, ND20, ND26), but many respondents questioned if and how this can be achieved (ND8, ND14, ND15, ND20, ND31), considering the goal over ambitious (ND16, ND20, ND32). Non-government actors strongly advocated approaches that include watershed development projects, groundwater recharge and regulation, conjunctive use of surface and groundwater, urban and rural rainwater harvesting, small scale storage including check dams and field bunds, on-farm water storage and re-use, and the cultivation of less water intensive crops (ND7, ND14, ND15, ND20, ND22, ND27, ND31, ND36, ND37, ND39, ND41, ND43, ND47; Thakkar, 2012; Saleth, 2011).

The contestation of the strategic direction of the NWM during the policy formation process is consistent with the political nature of water management (Mollinga, 2008; Merry et al, 2007; Mosse, 2003; Mehta, 2001) within the politics of water policy domain in sovereign states (Grindle, 1977). The above mentioned strategies advocated by non-government actors essentially embody decentralisation of power away from the government (Smith, 1985), empowering non-government actors at the individual and community level (Shore and Wright, 1997). These strategies in addition to making hydrological sense by increasing efficiency of use in a given river basin or sub-basin, should also be considered as manifesting exertions of power by non-government actors to gain more control in managing water at the local level (Shore and Wright, 1997). The contestation over the strategic direction of the NWM illustrates the process through which different actors exert their agendas and interests, negotiating modalities of societal governance in consolidating formal and informal institutional water management arrangements (Mollinga, 2008).

5.4.4 Progressive elements of the NWM policy

The NWM can be considered a progressive policy on paper, as it advocates a number of WDM strategies. Interviews highlighted the particular focus on increasing irrigation efficiency by 20% by the year 2017, and the enactment of a groundwater regulation bill at state government level. Owing to the relatively low levels of canal irrigation system efficiency and increasing reliance of groundwater for drinking and irrigation purposes, and in line with the objectives of the MWR, these two strategies are seen as priorities. Although MWR officials recognise the need to effectively implement these strategies to manage projected changes in precipitation and temperature with climate change, such strategies were previously considered important owing to the need to improve irrigation efficiency to increase food production and to regulate the unsustainable level of groundwater withdrawal, in addition to managing increasing water scarcity and declining per capita water availability (Figure 4.3). It would appear that climate change has added further justification for these approaches though the NWM policy.

The NWM reaffirms WDM policy recommendations made in the NWP 2002, notably increasing irrigation efficiency and volumetric water pricing of irrigation water. Such policy recognition represents the fourth paradigm of water management, that of demand management and economic valuation of water, within the reflexive modernity stage identified by Allan (2003) (Figure 2.13). IWRM, including associated institutional reform strategies, is introduced for the first time in Indian water policy by the NWM, in the overall objective and within Goal 5. This is a notable inclusion, in recognising the political and institutional aspects of water management. It signals the fifth and final paradigm of water management, also within the reflexive modernity stage (ibid).

Such WDM and institutional reform recommendations represent 'policy statements of intent' (Saleth, 2004:13), or statements on desired water policy and outcomes (Shah, 2006; Mollinga, 2005; Iyer, 2003). Such statements are considered by government to automatically lead to implementation, as conceptualised by the linear policy model (Grindle and Thomas, 1990; Warwick, 1982). Such policy statements are considered to signify the beginning of the long-term process of institutional change, although it is acknowledged that the policies may not mean much unless they are implemented on the ground (Saleth, 2004:13).

Similar WDM and institutional reform policy recommendations as statements of intent were made in the NWP 2002, in addition to the call of a paradigm shift in WRM: 'there is an urgent need of paradigm shift in the emphasis in the management of water resources sector. From the present emphasis on the creation and expansion of water resources infrastructures for diverse uses, there is now a need to give greater emphasis on the improvement of the performance of the existing water resources facilities' (GoI, 2002:8). However, interviews revealed that the policy recommendations of the NWP 2002 have not materialised or been implemented on the ground in the last decade. Interviews revealed numerous issues and challenges in the present day context regarding the WDM and institutional reform recommendation included in the NWM.

Challenges of national policy implementation

A common criticism levelled against the NWM is that it lacks an 'integrated institutional framework' with sufficient political will to effective operationalise and implement WDM and reform measures (ND5, ND7, ND8, ND11, ND19, ND20, ND26, ND31, ND33, ND34, ND36, N47). A similar criticism was levelled against the NWP 2002, that it had very little operational impact due to lack of proposed institutional mechanisms to plan, coordinate and implement water development projects, particularly relating to WDM and reform measures (ND5, ND7, ND8; Janakarajan, 2006). Such confirms the findings of Grindle and Thomas (1990), who concluded that as conceptualised by the linear model, policy makers neglect or ignore implementation, assuming that 'implementation managers' (eg. the state government and other actors) will implement the policy, with little reason to offer a specific strategy (ibid, p1165). Institutional transformations are inherently political, typically slow and difficult (Merry et al, 2007), driven by interests of government and external actors. Policy makers fail to recognise the political dimensions and contested nature of implementation, as conceptualised by the interactive model (Grindle and Thomas, 1990). Political will at the top level of national government is somewhat lacking at the moment, as claimed by a senior water expert in New Delhi, to first define and then implement an 'integrated institutional framework' to enable institutional reform and WDM (ND5).

Under the legal constitution of India, water management is an independent state subject, with WDM primarily a matter for state government irrigation departments to consider and implement. Although the MWR can recommend demand management strategies, it has little (legal) leverage over state irrigation department's activities to implement and enforce. This is contrary to how the MWR has more control and power over state governments regarding the construction of reservoirs and canal irrigation infrastructure through approving AIBP project technical clearance. The constitutional arrangement favours state government priorities, with the Constitution defining national government influence to policy guidance and facilitating inter-basin water sharing disputes. National policy can be considered as misnomer in some regards, with some respondents arguing for a national water strategy paper in conjunction with the establishing a National Water Commission to 'name and shame' poorly performing state governments (ND5, ND8). Discussion on funding allocations based on the performance of state irrigation departments is currently (late 2012) being debated (ND8).

It can be argued that the MWR's support for WDM and reform in the NWM could be largely superficial in nature, a subtle reorientation in strategic direction in policy statement, allowing the MWR sufficient space to largely continue the pursuit of infrastructure-based supply management. Such is in line with previous research which identified various strategies in which government water bureaucracies have adopted to secure their interest and reinvent themselves in a changing world, under internal and external pressure to change. Of particular relevance are the manners in which water bureaucracies have 'diverted, neutralised and re-configured reform effects', for instance, by capitalising on the rhetoric of privatisation, shifted costs to the users through irrigation management transfer, and taking advantage of the observed difficulty in harmonising competing claims from provinces or sub-basins and coordinating their needs and actions to recentralise decision making (Molle at al, 2009; Mollinga et al, 2007).

5.4.5 Reformist agenda within national government

Under the leadership of a senior Planning Commission official perusing a reformist agenda, the PC WGWR is actively endeavouring to operationalise many of the WDM and reform recommendations of the NWM. The head of the PC WGWR explicitly promoted a reformist approach, concentrating on improving water governance as the main focus of the 12th FYP, effectively working towards a new paradigm shift in water management in India, with a focus on WDM, IWRM principles and recognising that water reform has a significant political dimension that must be addressed (ND8). This represents a direct effort to operationalise the fourth and fifth water management paradigms identified by Allan (2003). The head of the PC's WGWR can be considered as an 'agent of change' (Sutton, 1999:6) or 'outstanding manager' (Israel, 1987:4) within government, giving direction and momentum to new polices and methods, regarding reform as an opportunity and not a threat (Teskey, 2005; Sutton, 1999).

The reformist approach taken by the head of Planning Commission's WGWR can be considered as challenging the MWR's primary focus on large-scale supply strategies. This has the potential to cause tension between the two ministries (ND8, ND33). However, the PC's head of the WGWR is not a MWR official, and cannot be considered to belong or operate within the small group of senior MWR officials who are influential in setting the policy agenda or developing strategies for implementation. The WGWR recent endeavours to operationalise WDM and reform initiatives has initiated discussion between the PC and MWR, particularly as some senior MWR are members of the WGRW (ND8, ND33). Debate between MWR officials and members of the WGWR in setting the strategic direction of the PC's Water Resources section for the 12th FYP is current (late 2012) on-going (ND33). However, the MWR is under no obligation to take forward strategies advocated in the Water Resources section of the 12th FYP. MWR officials consider the NWP as the principal policy document that provides direction and guidance (ND1, ND4, ND44). On-going internal discussions are also feeding into the current development of the NWP 2012, with progressive elements of the NWM, including WDM and reform initiatives, included in the first draft (in June 2012) of this policy (GoI, 2012d). Such can be considered a positive development, although as discussed above, policy statements of intent are only the beginning of institutional change (Saleth, 2004), with implementation of crucial importance.

Practical leverage that the PC can exercise over state governments includes the authority of approving funding allocation for AIBP M&M irrigation projects, following technical clearance from the MWR. A notable development is the PC's WGWR recommendation that all funding allocation for M&M irrigation projects should be granted on the premise of a CAD component within the irrigation project, with the PC having the power to refuse funding if not adhered to by state government (ND8). Initial signs of the influence of the PC's WGWR can be detected by the MWR in establishing the BWE; as well as financial incentives offered by the national government to encourage the set-up of WUA and to promote volumetric irrigation water pricing at state level (GoI, 2011c). Although it is still early days in gauging the effectiveness of the recent initiatives lead by the PC's WGWR and experts close to government stress the importance of a new approach focusing on

WDM and reform, these points could be seen as a positive development in promoting debate within government and challenging the MWR's primary orientation towards large-scale supply-side water strategies.

5.4.6 Conclusions

The NWM represents national policy recommendations for supply, demand and reform measures for state governments to consider and implement. The MWR can be seen to be appropriating the policy space created by climate change through the NWM to primarily continue its large-scale infrastructure supply-side approach, particularly by setting ambitious irrigation expansion and increasing reservoir storage capacity targets. However, paradoxically, the NWM also includes progressive policy recommendations, with the PC's WGWR endeavouring to support and operationalise WDM and reform measures. With water management being a state issue under the legal constitution of India, it is the discretion of state government to interpret and implement the NWM policy recommendations. The following Chapter examines AP state government Irrigation Department's interpretation and uptake of the WRM strategies recommended in the NWM, and whether climate change is linked to a strategy.

6.0 Andhra Pradesh Irrigation Departments water management response

6.1 Introduction

This chapter focuses on Andhra Pradesh (AP) state and examines the third research question: what is the state government's adoption of the NWM Goals through water management strategies, and is climate change linked to the choice of particular water management strategy?

Section 6.2 details the supply and demand strategies and institutional reform measures adopted by the AP Irrigation department (ICAD), in addition to examining whether and how climate change impacts are understood to link to a particular strategy. The section also details the October 2009 flood in AP, examining the operational responses of the ICAD, and the planned modelling assessment of climate change impacts in AP. Section 6.3 discusses insights into how and why the ICAD is adopting NWM Goals and climate change within the discourse to largely support the continued supply management approaches to continue the state hydraulic mission. Water management strategies are hydrologically contextualised at the river basin level in AP, with numerous political considerations discussed in order to understand the ICAD's approach (Section 6.3.1). The reformist agenda within the ICAD is discussed with regards to a small group of senior Command Area Development (CAD) officials, who are endeavouring to continue the water reforms initiated in 1997 (Section 6.3.3). The October 2009 flood event is then examined, acting as a window of opportunity in which direct operational responses and institutional learning can be attributed (Section 6.3.4). Internal contestation between the ICAD's Construction Wing (CW) and CAD departments regarding the water management strategies adopted is discussed, in addition to non-government actors in AP (Section 6.3.5). Finally, the water strategies adopted by the ICAD are examined within the context of climate change adaptation (Section 6.3.6). A screening exercise is presented to offer insights into the robustness of the strategies to climate change impacts in AP, and a decision making framework to understand how different water strategies and responses can adapt to climate change impacts. The chapter concludes by reviewing the main findings, leading to the implementation challenges and wider political context examined in Chapter 7.

6.2 Choice of water management strategy

This section examines the water supply and demand strategies and institutional reform measures adopted by the ICAD from the NWM policy, and to manage climate change impacts. It draws on interviews with senior CW and CAD officials.

6.2.1 Water supply management

Before detailing the water supply strategies, it is important to introduce the Jalayagnam programme to contextualise and understand the responses advocated by the ICAD. The sanctioned water discourse within the ICAD is for the expansion of surface water irrigation systems and reservoir storage to enhance agricultural production to attain state level food security (AP1, AP2, AP3, AP4, AP5, AP6, AP7, AP8, AP 9, AP10, AP12, AP14, AP17, AP18, AP20)[163].

Jalayagnam programme

The Jalayagnam programme is an ambitious irrigation expansion project in AP. It was launched in 2004 by the former Chief Minister, Y.S. Rajasekhara Reddy, as a state general election promise to the large rural farmer block of constituents (AP1, AP3, AP7, AP22, AP23, AP26, AP46). It accords the highest priority to irrigation infrastructure development and increasing reservoir storage. It targets an increase in the area under irrigation by 4.05 million hectares by 2020 in AP, primarily to serve the semi-arid drought prone Rayalaseema and Telegana regions which are heavily reliant on rainfed agriculture, along with serving coastal areas of the Lower Krishna River Basin (LKRB) and the Lower Godavari River Basin (LGRB) (GoAP, 2012, 2010a) (Figure 4.6 and Appendix 10 for regional map of AP). Agricultural water provision via canal irrigation is the primary goal, although water is also planned for rising urban drinking water and industrial demands (GoI, 2012; AP3, AP7, AP9). It is claimed that the programme will also generate 2700MW of hydro-electricity (GoAP, 2012).

A defining feature of the Jalayagnam programme is the full utilisation of the LGRBs surplus water, estimated to be 22.5BCM according to ICAD statistics (GoAP, 2012). It aims to increase storage capacity by 7.5 Billion Cubic Metres (BCM) by 2020, primarily through medium and minor reservoir construction (AP2, AP3, AP7, AP9, AP10). The remaining 15BCM not stored is planned to be utilised for irrigation purposes, diverted and pumped to serve the LGRB and the delta region of the LKRB (Figure 4.6). Lift irrigation is a defining characteristic of the programme. Water is planned to be withdrawn directly from the LGRB, characterised by topographically low and uneven terrain largely within deep canyons, pumped upwards (via electricity generator pumps) 300-500m to newly constructed medium sized reservoirs adjacent to the river. The stored water will then be again pumped, against gravity, through large pipe structures hundreds of kilometres, feeding into large scale canal systems and then distributed to supply individual irrigated plots. To date (late 2012), 86 projects are planned under Jalayagnam: 44 major and 30 medium irrigation projects, four flood bank works and eight

[163] Interview respondents in Andhra Pradesh are coded with the acronym AP. Section 3.3.2.2 and Appendix 2.

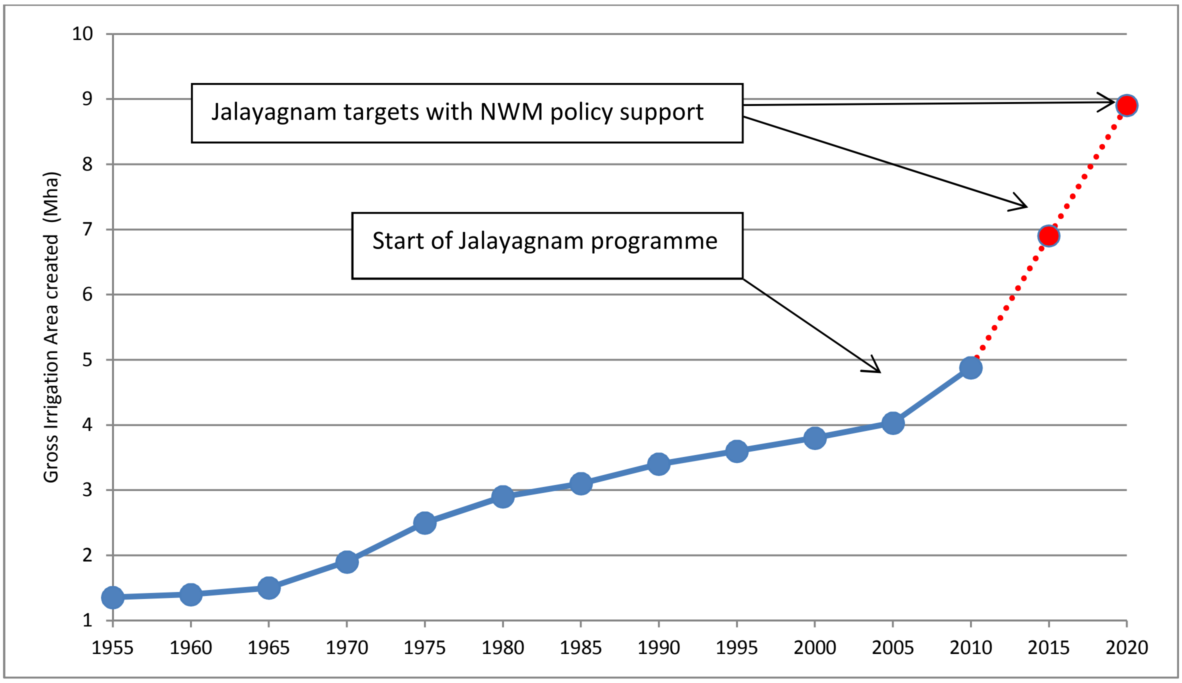
modernisation projects (GoI, 2012). Major projects include the Polavaram and Dummugudem inter-basin transfers, transferring 2.2BCM and 4.4BCM, respectively, from the LGRB to the LKRB.

The total cost of the programme is estimated to be $38 US billion dollars[164], of which 94% is for the 44 major irrigation projects (GoAP, 2012). The current Chief Minister of AP, Kiran Kumar Reddy of the ruling Congress Party, pledged his full political support for Jalayagnam, allocating $5.1 billion US dollars[165] from 2010 to 2013. The ICAD has prioritised 43 projects (33 major projects) for completion in 2013, creating an additional 1.7 million hectares of irrigated area and stabilising supply for existing irrigation systems (ibid).

6.2.1.1 Irrigation expansion

CW officials consider the NWM's Goal Two, of increasing national area under irrigation by nine million hectares by 2012 through the completion of 205 major and medium irrigation projects (GoI, 2011a:65), as directly related to the Jalayagnam programme. Interviews revealed that the CW is using the Jalayagnam irrigation expansion target of 4.05Mha by the year 2020 to meet this NWM policy objective (Figure 6.1) accounting for 40% of the national target of 9MHa (AP1, AP2, AP7, AP8, AP9, AP10, AP20). The Jalayagnam irrigation target was established at the launch of the programme in 2004, and was not specifically related to the NWM policy or climate change impacts. By attaching the Jalayagnam irrigation target to the NWM policy, national policy support is gained for on-going irrigation expansion and infrastructure development within AP.

Figure 6.1: Gross irrigation area created in AP since 1956, with Jalayagnam targets highlighted for 2015 and 2020 (GoAP, 2009)



[164] Equivalent to 2.08 trillion Indian Rupees.
[165] Equivalent to 280 million Indian Rupees.

Within the ICAD, the sanctioned discourse is the expansion of surface water irrigation system and reservoir storage to enhance agricultural production throughout the state through the Jalayagnam programme (AP1, AP2, AP3, AP4, AP5, AP7, AP8, AP 9, AP10, AP11, AP12, AP17, AP20). The provision of irrigation water to support agricultural activities of farmers through large scale infrastructure development in the semi-arid rain-fed Rayalaseema region and coastal regions of AP is considered a top priority, particularly by senior CW officials (AP2, AP7, AP8, AP9, AP10, AP20), as illustrated with a quote from one of the senior policy advisor within the CW: 'the government is keen to see that farmers in rainfed, drought prone regions get irrigation facilities fast' (AP8).

How does climate change interact with this supply-side discourse? Interviews with CW officials revealed that climate change is understood as a risk to food production in the state, in terms of changing monsoon precipitation patterns, floods and temperature rise leading to increased evapotranspiration rates and drought conditions (AP2, AP3, AP5, AP7, AP8, AP9, AP10, AP12, AP14, AP20). With specific regard to irrigation expansion, a CW official considers that increasing food production by irrigation expansion via the Jalayagnam programme is the number one strategy to deal with rising food demand and urbanisation throughout the state, and to manage climate change if temperatures rise and rainfall patterns become more variable (AP5). As epitomised in an interview a senior water policy advisor within the CW, climate change can be seen to be entering the ICAD's discourse as further justification: 'Irrigation expansion through Jalayagnam is crucial to secure state food production and rural farmer livelihoods especially in the Rayalaseema region, and to help secure food production in the face of climate change' (AP7). This quote reflects how climate change is starting to enter the ICAD's discourse, as a new issue used to strengthen the rationale for irrigation expansion under the Jalayagnam to help increase food production and attain food security within AP state (Table 6.1 for similar quotes).

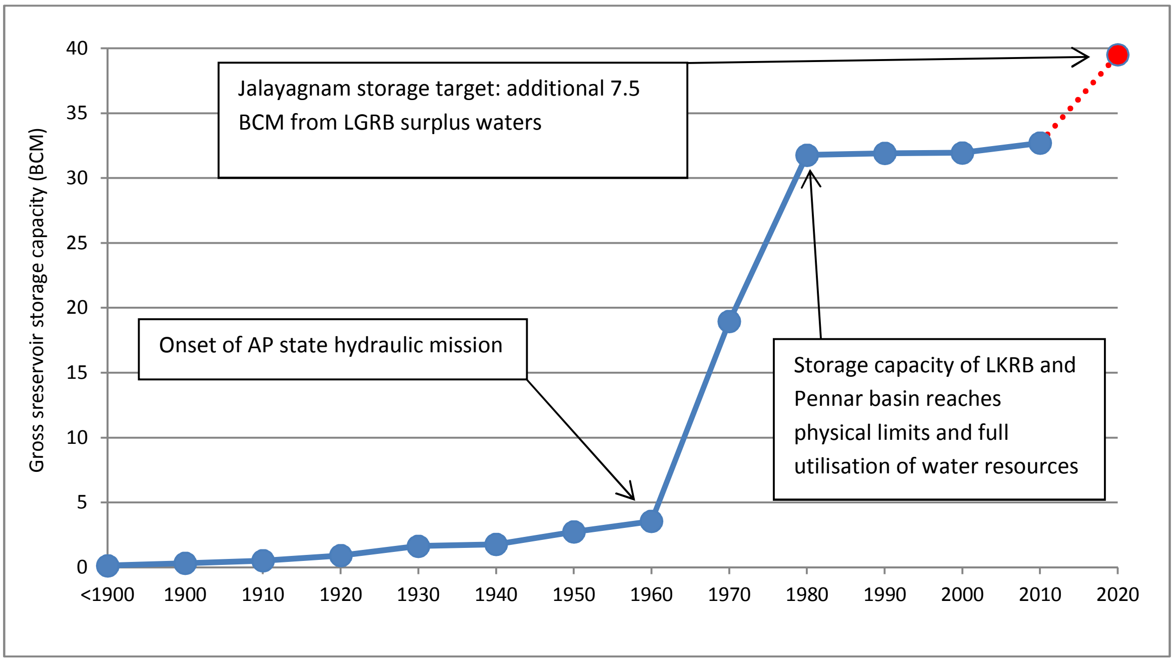
6.2.1.2 Surface water storage

NWM Goal Three identifies the creation of 64 BCM of additional surface water storage by 2017 at the national level (GoI, 2011a). CW officials interpret this national policy target as directly relevant to the increasing reservoir storage capacity under the Jalayagnam programme (AP2, AP2, AP5, AP6, AP7, AP8, AP9, AP10, AP20). The surplus water of the LGRB is estimated to be 24BCM, according to ICAD data (GoAP, 2012). This water is considered 'lost' by CW and CAD officials (AP1, AP7, AP8, AP9, AP10), draining into the Indian ocean each year, and needs to be 'captured and fully utilised for irrigated agriculture' (AP2, AP7, AP8, AP9). The CW plans to develop an additional 7.5BCM of reservoir storage, primarily by capturing and storing the one third of the surplus waters of the LGRB (Figure 6.2). Such storage will primarily take the form of medium sized reservoirs[166]. Under the Jalayagnam programme, 7.5 BCM of surplus water from the LGRB will be lifted

[166] The definition of dam size is contentious in India. The CWC classify large dams in line with the International Commission on Large Dams (ICOLD) definition, with a large dam as one with a maximum height of more than 15 metres from its deepest foundation to the crest. A dam between 10 and 15 metres in height from its deepest foundation is also included in the classification of a large dam provided it complies with one of the following conditions: (a) length of crest of the dam is not less than 500 metres or (b) capacity of the reservoir formed by the dam is not less than one million cubic metres or (c) the maximum flood discharge dealt with by the dam is not less than 2000 cubic metres per second or (d) the dam has specially difficult foundation problems, or (e) the dam is of unusual design (CWC, 2009;

(pumped up from an elevation of 300m) from the Godavari river, stored in medium sized reservoirs, and then transported via canals 300km south west primarily to provide year-round irrigation water to the arid Rayalaseema region of AP. The remaining two-thirds (15BCM) of the LGRB surplus waters is planned to be pumped and diverted to irrigation systems in the Krishna and Godavari river deltas during the summer monsoon kharif[167] agricultural season, and not stored to in reservoirs to provide year-round agricultural water supply (AP2, AP7). 60 projects are identified for lift irrigation schemes in total (AP2, AP7, AP8), transporting water (7.5BCM) from the LGRB to supply irrigation water to the LKRB and Rayalaseema region. Hydrological constraints are a factor that somewhat limits further large-scale large reservoir and infrastructure development in the LKRB. It is a water deficit basin, with all existing water fully utilised and highly regulated, with no additional water is available for utilisation (AP2; Venot et al, 2007, 2008). Furthermore, all suitable topographical and hydrological sites for major reservoir construction have being developed in previous decades, especially during the 1970s and 1980s during the height of the state hydraulic mission (Figure 4.15). Some limited small reservoirs are planned for the LKRB, in addition to existing tank rejuvenation, particularly to capture the summer monsoon rains; but no major or medium sized reservoirs are planned in future years (AP2). The capture and storage of the surplus LGRB waters under the Jalayagnam programme is considered by a senior ICAD official as the 'last major supply intervention' planned for AP (AP2).

Figure 6.2: Cumulative storage capacity of large and medium reservoirs in AP (GoI, 2009a).



ICOLD, 2000). However, the Planning Commission categorises dams as large, medium and small irrigation schemes on the basis of the area irrigated they serve. With large, medium, and small dams irrigated command areas of greater than 10,000 hectares, 2000 to 10000 hectares, and less than 2000 hectares, respectively (GoI, 2003). Whereas ICAD define major irrigation schemes as severing a command area of <25,000-5000ha; medium 5000-500ha; and minor >500ha. For the purpose of this research, the CWC's classification is use in line with ICOLD definition.

[167] The three principal agricultural seasons in India are the rabi, kharif and summer (zaid) crops. The kharif is the summer monsoon season, with crops sown in June with the onset of the rains and harvesting in September. The rabi is the winter cropping season, with crops sown in October and harvested in March. Summer (zaid) crops are sown in late March/early April and harvested in late May before the onset of the summer monsoon.

There is widespread consensus within the ICAD that increasing surface water storage, at all scales, is one of the most appropriate water management strategies to deal with climate change (AP2, AP3, AP5, AP6, AP7, AP8, AP9, AP10, AP15, AP20). 'Increasing storage is essential to adapt to changes in summer monsoon precipitation patterns and longer term changes in levels of precipitation with climate change, at all scales, especially in the LGRB via medium scale storage in order to utilise the 22.5BCM of surplus water' (AP9). The current plans to increase storage potential by fully utilising the LGRB's surplus water were already in existence under the Jalayagnam programme, and were not developed specifically to deal with climate change impacts. Climate change, understood as a risk in the form of increasing monsoon precipitation variability and long term changes in precipitation patterns leading to further scarcity and drought-like conditions, as noted earlier, is starting to enter the governments' discursive as further justification for such storage approaches, particularly in order to utilise the LGRBs surplus waters (AP2, AP7, AP9, AP10) (Table 6.1 for similar quotes).

6.2.1.3 Carry-over storage

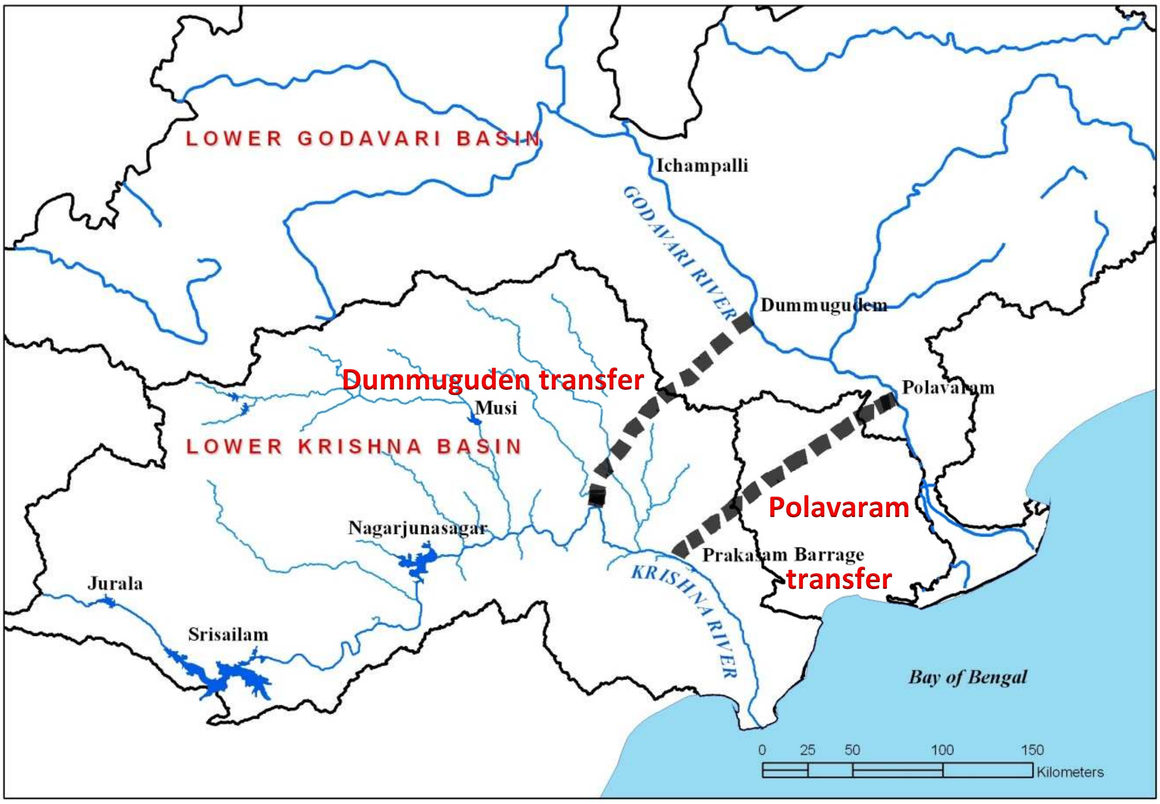
Reservoir carry-over storage is promoted by NWM Goal Three, at an average of 10% by reservoir volume (GoI, 2011a). Carry-over or 'within the year' storage is the amount of water stored in a reservoir throughout the year, the residual volume that is retained even at the onset of the summer monsoon in June. Historically and to this day, large and medium scale reservoirs release the vast majority of their water (>95% of volume) during the dry summer months preceding the summer monsoon to serve primarily irrigation needs but also those of urban drinking water and industrial requirements (AP3, AP7, AP8, AP10). Owing to farmer demands and relatively low precipitation during the summer months, the pressure on reservoir managers to release all of the water is significant (AP3, AP9, AP10). Upon which they usually comply by releasing all water available, both to serve the summer irrigation demands and also to make available maximum reservoir storage capacity when the summer monsoon rains arrive in late June with associated high levels of runoff and river flows. However, as the onset of the summer monsoon rains varies from year to year, reservoirs are often left completely empty for significant periods of time (weeks), which can reduce the amount of water released for irrigation purposes to meet urban and industrial needs. The promotion of carry over-storage is considered 'good practice' to safeguard agricultural supply during this time, for year around continual availability (AP9).

Interviews with CW officials revealed that developing greater carry over-capacity within existing reservoirs in AP is deemed too expensive and technically difficult in terms of construction (AP3, AP7, AP 10). However, new reservoirs under the Jalayagnam programme are being designed to hold 20% carry-over storage (AP 10). This new approach is primarily in response to increasing irrigated agriculture and urban water demands within the LKRB in recent years (AP 10). However, senior water managers cited the inclusion of the need to increase reservoir carry-over storage within the NWM policy as further justification for this approach (AP2, AP5, AP6, AP7, AP8, AP 10, AP20). Developing carry over capacity is considered as an appropriate method to deal with the impacts of climate change, with regards to variations in intra and inter annual precipitation levels, as stated by the Chief Engineer of the Infrastructure Central Design Office: 'increasing carry over will take care of changes in monsoon and long term precipitation levels under climate change' (AP10) (Table 6.1 for similar quotes).

6.2.1.4 Inter-basin transfer

NWM policy advocates the consideration of river inter-basin transfers as part of the National River Linking Project (NRLP), to promote further water utilisation (GoI, 2009b:25). Two inter-basin transfer schemes are included in the Jalayagnam programme, both aiming to transfer water from the water surplus LGRB to the water deficit LKRB. The Polavaram link is currently (late 2012) under construction, and when fully operational in 2016, will deliver an estimated 2.2 BCM of water for irrigation and urban requirements. The Dummudgen link, currently under design, will deliver 4.4BCM by 2020 (Figure 6.3). Both transfers are considered by CW officials as top priority and essential for securing water provision to the deficit LKRB, particularly for high value urban needs (including Hyderabad) and agricultural purposes within the Krishna river delta and coastal region of AP (AP 7, AP8, AP9, AP10). CW officials consider that the NWM provides national level policy support for such inter-basin transfers (AP1, AP2, AP7, AP9, AP10).

Figure 6.3: Polavaram and Dummugudem inter-basin transfers from the LGRB to the LKRB (dashed-lines)



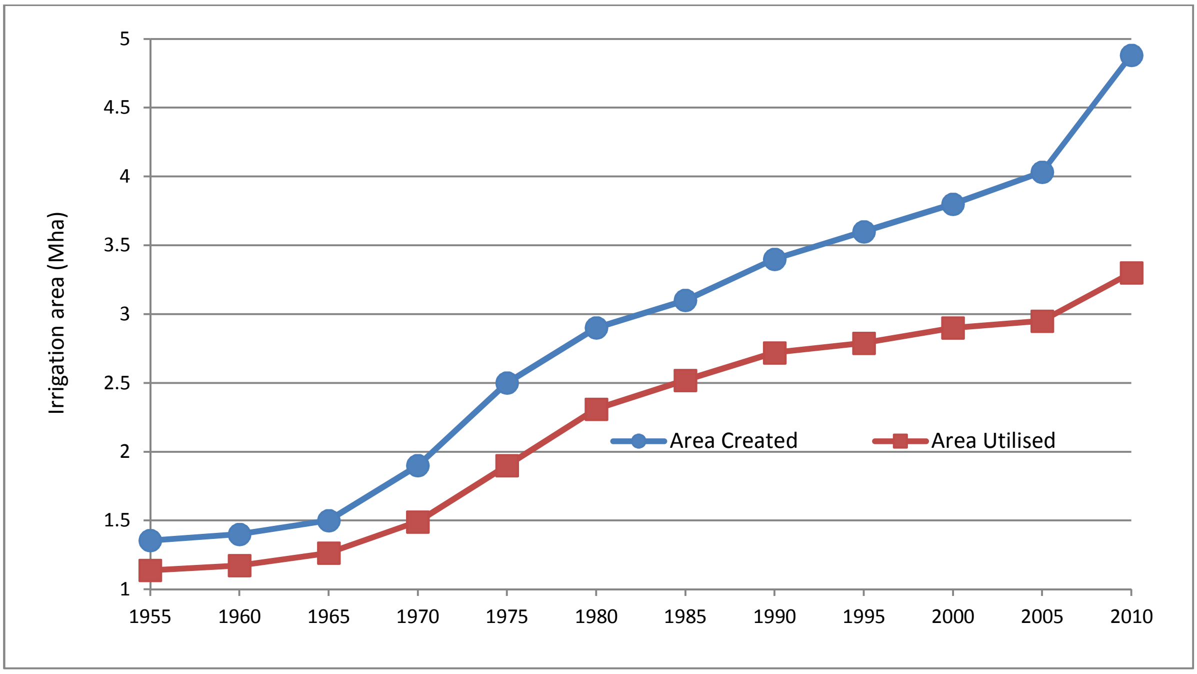
Interviews revealed how climate change as a risk in the form of increasing summer monsoon precipitation variability is considered as further justification for the need to transfer water from the LGRB to the water scarce LKRB (AP 2, AP3, AP7, AP8, AP10, AP12). As illustrated in the quote from a CW official: 'water transfer from the Lower Godavari to the Lower Krishna is needed to meet growing demands of population and farmer to reduce water scarcity, and if monsoons rains become more erratic in the future with changing climate' (AP10). Furthermore, reduction in annual precipitation levels under climate change projections in future decades is linked to increasing water scarcity in LKRB, with water managers stressing the importance of the inter-basin-transfer from the LGRB to the LKRB 'inter-basin transfer is essential to secure water supplies for agriculture and urban needs especially, as well as to manage future changes in rainfall in years to come with climate change' (AP2) (Table 6.1 for similar quotes).

6.2.2 Water demand management

6.2.2.1 Irrigation efficiency

Senior CAD officials consider the NWM's Goal Two and Four as directly relevant to their on-going work. Specifically, the promotion of citizens and state action for water conservation, and increasing canal irrigation efficiency by 20% by 2017[168] (AP1, AP2, AP3, AP17; GoI, 2011a). The CAD adopts NWM Goal Four to support on-going initiatives to increase state-level irrigation efficiency by 20% by the year 2020, from average of 34% at the canal irrigation system level (AP1, AP2, AP3, AP4; GoI, 2011a) (Appendix 25 for average irrigation efficiency of the major irrigation systems in AP). The CAD also considers that the NWM Goal Four of reducing the irrigation gap by 15% by 2017 supports on-going CAD operations (AP2, AP3) (Section 5.3.2.1 for explanation on irrigation gap). The irrigation gap in AP has steadily increased, from 0.21 Mha in 1955 to 1.58 Mha in 2010 (Figure 6.4).

Figure 6.4: Irrigation gap in AP since 1955 (GoAP, 2010a, 2009)



[168] A 20% increase in canal irrigation efficiency would results in an estimated surface water saving of 9.82 BCM within Andhra Pradesh, including the LKRB, LGRB, Pennar and Group of East Flowing river basins (Figure 4.6), based on GoAP's hydrological data (GoAP, 2012). Within the LKRB, a 20% increase in canal irrigation efficiency would save an estimated 2.52 BCM of surface water, based on the water accounting calculations carried out by Venot et al, 2007 for the period 1986 to 2004 (Section 4.3.2 for overview of AP water resources).

In order to increase canal irrigation efficiency and to close the irrigation gap, interviews revealed that the CAD will continue to work on irrigation efficiency initiatives launched in 1997 and re-strengthened in 2005 (Section 6.3.3 for overview of reform initiatives). Particular strategies include a focus on irrigation performance management (benchmarking, water audits, water saving technologies[169], conjunctive use of surface and groundwater), and user organisations including Water User Associations (WUA) and Participatory Irrigation Management (PIM), in addition to considering how to move towards pricing volumetric water allocation within canal irrigation systems (AP1, AP2, AP3, AP7, AP17, AP18) (Table 6.1 for complete list of demand management strategies). CAD officials claim that such measures have increased irrigation efficiency by 10-12% from 2005 to 2010 (AP2). However, this figure has not been independently verified. Senior CAD officials consider that the NWM provides substantial national policy support for on-going irrigation efficiency measures, and consider that CAD's initiatives help to meet the national level target of increasing irrigation efficiency by 20% by 2017.

Climate change is understood by senior CAD managers as a risk to irrigation systems, through changes in summer monsoon patterns and annual precipitation levels affecting water runoff and availability, as well as temperature rise leading to increased evapotranspiration (AP1, AP2, AP3, AP7, AP8, AP4, AP17, AP18). Interviews revealed how climate change is understood to impact irrigation systems in AP: 'increasing summer monsoon variability with climate change will lead to a change in the timing and intensity of water delivery to the surface water canal irrigation system (at an hourly to daily to weekly timescale) during the kharif and rabi cropping season' (AP2). Furthermore, the need for more efficient canal irrigation systems is considered important to meet growing farmer demand and to manage summer monsoon variations and long term decadal changes in precipitation patterns with climate change: 'more efficient use of irrigation water is required to deal with increasing demand from farmers and to feed the state population, and if the summer monsoon becomes more erratic and annual precipitation level changes in the long term, in decades to come' (AP2) (Table 6.1 for similar quotes). In response, the CAD department advocate a continuation of existing irrigation efficiency initiatives, targeting an improvement of 20% in efficiency levels by 2020 relative to 2005 levels (AP 1, AP2, AP3, AP4, AP12, AP16, AP 18, AP19).

6.2.2.2 Hydrological data and database management

CAD officials adopt NWM Goal One, focusing on digitising hydrological data for irrigation projects and establishing a hydrological database; in addition to strengthening operations in hydrological data collection, remote sensing, geographic information systems and satellite imagery (AP2, AP3, AP17). CW officials consider that the NWM supports these activities and programmes, which were on-going before the policy (AP1, AP2, AP3, AP17, AP18). A tentative link between climate change and the need for hydrological data digitisation is made in recognising that climate change requires up-to-date situation analysis for current precipitation and water availability and status for irrigation projects: 'climate change requires up-to-date data for present day, and to monitor future changes in precipitation and temperature for water resources and irrigation within the

[169] Narayanamoorthy (2009) finds that sprinkler and drip irrigation can raise water use efficiency as much as 60% and 40% respectively in India.

Lower Krishna and Lower Godavari river basins' (AP2). This quote illustrates how climate change can be seen to further strengthen the case for accurate and current data for water resources and irrigation projects.

6.2.2.3 Groundwater management

ICAD and Groundwater department officials interpret NWM Goal Three in relation to the enforcement of the AP Land, Water and Trees Act 2002, which specifically calls for the 'regulation of exploitation of groundwater resources' in AP (GoAP, 2002:4) (AP2, AP3, AP7, AP8, AP15, AP17) (Appendix 12 for details on the AP Land, Water and Trees Act and Section 4.3.2 for overview of groundwater status in AP). The Deputy Director of the Groundwater Department considers this as the top priority for groundwater management in the state (AP15). Specifically, this includes halting illegal bore-well drilling, regulating the volume of water extracted by groundwater pumping (either through electricity tariffs and/or volumetric pricing), the promotion of conjunctive surface and groundwater use in water scarce areas, and the construction of groundwater recharge structures (AP15). The Deputy Director of the Groundwater department considered that changing precipitation patterns under climate change projections could have negative consequences for groundwater recharge and availability (AP15). If summer monsoon precipitation intensity increases, soil will quickly become saturated decreasing the levels of infiltration and groundwater recharge; as well driers months and years under long-term projections, leading to an overall reduction in groundwater recharge levels. Central inland regions of AP were highlighted as particularly vulnerable, with already over exploited groundwater status, heavily reliant on groundwater for agricultural and drinking water needs (Figure 4.6). Climate change is considered as a 'further reason', along with growing water scarcity and declining groundwater levels owing to increased withdrawal to meet growing sectoral demands, to continue programmes of groundwater conservation and recharge (AP2, AP3, AP7, AP12, AP15, AP17).

6.2.3 Institutional reform

Senior CAD officials have adopted various institutional reform measures from the NWM Goal Five and consider them to build on existing reform endeavours (AP1, AP2, AP3, AP17, AP18), initiated in 1997 and re-strengthened in 2005 (Section 6.3.3 for discussion on AP reform initiative). The NWM is regarded as strengthening existing reform measures by providing national policy support (AP1, AP2, AP3, AP12, AP17, AP18).

6.2.3.1 Integrated Water Resource Management

The NWM explicitly advocates Integrated Water Resource Management (IWRM), for the first time in Indian national water policy. This is in line with the AP State Water Policy that advocates 'making a systematic transition from the water resource development mode to an integrated water resource management mode, with appropriate reforms in water sector' (GoAP, 2008:4). However, senior water managers have differing opinions on what exactly constitutes IWRM. IWRM is generally poorly understood at an operational level, with managers somewhat unclear how to operationalise it on the ground and at the management level (AP1, AP3). ICAD officials are of the opinion that the on-going institutional reform initiatives and demand management strategies constitute IWRM. Furthermore, the Water Management Committee (WMC) and AP Water Resources Regulatory Authority (APWRRA) are considered as appropriate organisations to promote integrated holistic planning at the state level (AP1, AP2, AP3, AP17) (Section 4.2.4 for details on the activities of the WMC and APWRRA). The CAD Commissioner and Principal Irrigation Secretary, who is also the chairman of the WMC, have no immediate plans to change the present organisational arrangement to align with the IWRM concept and its definition provided by the Global Water Partnership (AP1, AP2) (Section 2.4.3.3 for definition of IWRM).

6.2.3.2 State government cross-departmental convergence

NWM Goal Five advocates cross-departmental convergence on water programmes and is considered to provide national policy support for the on-going initiatives of the WMC with regards to convergence at state government level (AP1, AP2, AP3, AP17). CAD officials highlighted the need to improve communication, data and information sharing between state departments working on common water projects (AP1, AP2, AP3, AP7, AP17, AP18). The WMC, formed in 2007 with representatives of all of the state government departments involved in water issues, is considered sufficient to achieve cross-departmental convergence, with no additional initiatives planned in the future (AP1, AP2).

6.2.3.3 River basin organisations

It is acknowledged by ICAD officials (AP1, AP2, AP3, AP5, AP7, AP8, AP10, AP12, AP17, AP18, AP20) that there is a need for a River Basin Organisation (RBO) for the entire Krishna River Basin (KRB), encompassing the LKRB in AP, to facilitate more effective water allocation between riparian states and water users. The establishment of effective and operational RBO are advocated by the NWM Goal Five (GoI, 2011a). However, as discussed in Chapter 7, tension between riparian states over the KRB shared waters is a major obstacle to effective operationalisation, with disputes being adjudicated by the Krishna Water Disputes Tribunal (KWDT).

6.2.3.4 Climate change awareness and retraining of ICAD staff in inter-disciplinary approaches

In direct response to the NWM policy, the Centre for Climate Change and Environment Advisory (CCCEA) was established in mid-2010, housed within the Department of Human Resource Development in Hyderabad. The creation of the CCCEA represents a significant organisational response of the AP Government specifically in relation climate change. The CCCEA consists of eight full-time staff, that conduct raising climate change awareness and inter-disciplinary training of staff across all state government departments involved in environmental issues, including the ICAD (AP12, AP13).

As well as raising awareness of impacts of climate change in AP, inter-disciplinary training offered by the CCCEA covers cross thematic areas of water management outside of the traditional focus of ICAD staff on irrigation engineering. Topics include forestry, soil science, water conservation, meteorology, energy, health, carbon mitigation, water supply and sanitation, disaster management (floods and droughts), livestock management and agriculture, as well as socio-political considerations. Such inter-disciplinary training encourages career-long ICAD engineers to look beyond their technical discipline and professional focus, to consider and understand the inter-linkages between cross thematic environmental issues relating to irrigation water management (AP12, AP13, AP14, AP17). The CCCEA training also complements already existing training of ICAD staff offered by WALAMTARI in AP since 1982 (AP14) (Section 4.2.4 for training activates of WALAMTARI).

6.2.4 Flood management

This section details the October 2009 flood in AP, leading to an examination of the responses by the ICAD. Flood management operations are divided between the CW and CAD, although officials from both are represented on the Flood Management Committee.

6.2.4.1 Andhra Pradesh October 2009 flood

AP suffered a severe flood in October 2009. The 2009 summer monsoon within AP had been a below average (-23% in precipitation level from 1 July to 29 September), leading to seasonal water scarcity in numerous districts throughout the state (GoAP, 2010b). The state government was in the process of declaring five south-eastern inland districts as drought prone. However, on the 30 September 2009, a meteorological depression formed over the western border of AP, centred on Kurnool district, bordering on the state of Karnataka (Figure 4.10 and Appendix 9).

Over the next four days, until the evening of 3 October 2009, heavy precipitation fell at unprecedented levels. Within Kurnool district, 560mm of precipitation was recorded during these three days, over five times the average for the month of September alone (110mm) and over 80% of the mean annual level (670mm). Such intense and prolonged heavy precipitation and associated surface runoff led to extremely high river flows. At the Srisailam reservoir, inflow peaked at 719,247 m^3 per second. The previous highest peak inflow recorded for the reservoir was 257,683 m^3 per second in October 1998. The Srisailam dam was designed for a thousand year return flood at 572,000 m^3 per second, whilst discharging 314,317 m^3 per second at 885 feet water level The October 2009 inflow was calculated to be a 1:10,000 year flood event (GoAP, 2010b), with the dam structure withstanding the inflow for four hours. However, owing to the heavy rains and back-log of water from the Krishna River and tributaries, there was severe flooding with loss of life and inundation of land immediately upstream of the Srisailam dam[170] (Figure 6.5).

[170] Immediately after the flood, some member of the ruling AP Congress Party attributed part of the blame for the flood on Karnataka, claiming that too much water was released from the Almatti dam flowing down into the Srisailam dam, which, compounded by the high level of precipitation the three pervious days, lead to the severe flooding. However, official from Karnataka Government counter this claim, by stating that too much water was being stored in the Srisailam prior to the period of heavy rainfall, with AP officials not adequately prepared for the high precipitation and reservoir inflows. The CWC and National Institute for Disaster Management endeavoured to take a politically neutral stance, without attributing blame to either state. However, in the months after the flood, political blaming somewhat subsided with both states acknowledging the need to improve communication during similar flood events.

Figure 6.5: Area upstream of the Srisailam dam severely affected by the October 2009 flood (shaded blue) (GoAP, 2010b)

With such high inflows into the Srisaliam dam, the Flood Control Centre located in the ICAD made the decision to release a significant volume majority of this water to prevent dam failure. The next downstream reservoir to absorb the high inflows was the Nagarjuna Sagar reservoir, receiving 391,621 m^3 per second, just below the design capacity of 450,237 m^3 per second. And finally, the flow at the Prakasam barrage peaked at 314,317 m^3 per second, just below the design capacity of 336,970 m^3 per second (Figure 4.10 for locations of Nagarjuna Sagar and Prakasam barrage on the Krishna River). Although there was no major dam failure, the Krishna River broke its bank along major stretches between the reservoirs, causing widespread flooding of vast areas within five districts: Nalgona, Krishna, Guntur, Mahabubnagar and Kurnool (Appendix 9 for district map of AP). Within AP, the flood inundated 2.8 million hectares of cropland, affected over 1.8 million people with a total loss of 155 lives (ibid). It is estimated that the cost of the flood was in the region of $235 million US dollars[171], particularly when considering the damage to transport infrastructure and over 70,000 houses. Within Karnataka, 1.5 million people were affected and 251 lives lost, over 300,000 houses being damaged or destroyed. The October 2009 flood event in AP was an unprecedented event, a 1 in 10,000 year hydro-meteorological event (GoAP, 2010b), surpassing all previously measured hydrological and meteorological records. It is an example of non-stationarity, a hydro-meteorological event occurring outside of the envelope of previously observed physical limits (Milly et al, 2008).

[171] Equivalent to 12 billion Indian Rupees.

6.2.4.2 ICAD response to the flood

Officials within the Central Design Office housed within the CW, responsible for the Jalayagnam programme infrastructure design, initiated a programme of dam safety checks in direct response to the October 2009 flood (AP6, AP7, AP 10). Immediately after the flood, a programme of dam safety checks for probable maximum floods of 1:10,000 was initiated, to test all major and medium dams over the next three years (AP10). Furthermore, dam break analysis is being carried out over the next three years (AP10), in addition to plans to strengthen canal irrigation structures to withstand intense precipitation events and high flows (AP2, AP9, AP10). The CW is also considering re-enforcing canals and embankments at critical points, and to increase the drainage capacity in the irrigation system, especially in the delta and coastal regions (AP7, AP8, AP10). The flood event has also led the Chief Engineer responsible for designing new infrastructure for the Jalayagnam programme to begin to 'consider' how to design new infrastructure to accommodate future climate change projections (AP10). These include how to design infrastructure for varying reservoir in-flows under changes in precipitation level at the long term decadal level. In addition, consideration is being given how to design new infrastructure to withstand similar high volume flows witnessed during a flood event of 1:10,000 years (AP10, AP9).

Within the ICAD, flood management operational responses and institutional learning can be directly attributed to the October 2009 flood event. The Flood Management Committee housed within the CAD convened for five days during the flood bringing together senior CW and CAD officials, to monitor and advise on the most appropriate action. During this time, real time data on river flows and reservoir capacity was relayed and monitored, with collective decisions being made as to water should be released from reservoirs along the Krishna River and tributaries to reduce localised flooding.

Immediately after the flood event, the CAD established a flood control centre to monitoring hydro-meteorological data on a year-round basis, including monitoring of precipitation, river flows, reservoir levels, utilising meteorological data from weather observatory points in the LKRB (AP2, AP3, AP7, AP12). The latest information technology is being deployed to monitor and present this data, including geographic information systems. Furthermore, operational plans and support is being provided to water users associations (farmer groups) with the provision of relevant equipment (sand bags, boats) to deal with future floods.

Climate change impacts in terms of future changes in annual precipitation has led senior CAD (as well as CW) officials to start to consider long-term planning issues, beyond the short to mid-term planning horizon (up to ten years) to encompass water resource considerations in decades to come (AP1, AP2, AP3, AP7). Although owing to the uncertainty of climate change projections at the moment, the Jalayagnam infrastructure is not being planned to accommodate specific projections (AP3, AP7, AP8, AP10). However, the process of considering long-term water resource planning and issues of sustainability can be considered a positive development, if acted on appropriately (AP2, AP3, AP7, AP9).

The NWM policy supports developing a compressive approach to flood management, including flood mapping, hydrological models and increased monitoring (NWM, 2011). ICAD officials acknowledged that although the NWM policy inclusion of flood management was important in providing national policy support, and adopts flood management approaches form Goal Three of the policy (AP2, AP3, AP7, AP8, AP12). However, the operational responses of the ICAD were in direct response to the October 2009 flood (AP1, AP2, AP3, AP7, AP8, AP12, AP17).

6.2.5 Assessment of climate change impacts on water resources in AP

ICAD officials adopted the NWM Goal One of assessing the impacts of climate change on water resources in AP (AP2, AP3, AP7, AP17), and consider that 'understanding potential impacts of climate change on Andhra Pradesh's water resources requires further research and technical modelling input and advice from relevant individuals and organisations' (AP2). Research to understand climate change impacts on water resources in AP started in mid 2009, after the launch of the NWM policy. Technical knowledge and expertise on climate change impacts within the ICAD is non-existent. Instead, ICAD officials rely on external input from national research organisations (Indian Institute of Technology in Delhi, Indian Institute of Tropical Meteorology in Pune, and the Institute of Hydrology); as well as internationally from academia and international organisations (AP2, AP3, AP7, AP8, AP9, AP12, AP13, AP18).

6.2.6 Summary

The ICAD's adoption of the NWM Goals and the role of climate change in justifying a particular water management strategy and institutional reform measures, as well as the operational response to the October 2009 flood event, is summarised in Table 6.1. CW officials in particular can be seen to be primarily adopting supply strategies from the NWM that align with the Jalayagnam programme, with other strategies considered of secondary importance. CAD officials are primarily adopting institutional reform measures, irrigation efficiency strategies and groundwater management from the NWM to support on-going demand management and reform initiatives (Appendix 26 for complete list of NWM Goals and strategies adopted CW and CAD officials). Climate change in a variety of hydro-meteorological impacts can be seen to be cited by CW and CAD officials as further justification for supply and demand strategies within the current discourse. Institutional reform measures are adopted from the NWM policy, but no climate change impacts are cited as a reason for these measures. Flood management activities are divided between the CW and CAD, with the October 2009 flood event in AP leading to direct operational responses. The significance of these findings will be discussed in detail in Section 6.3.

Table 6.1: ICAD water management adoption of the NWM Goals, and the role of climate change in justification

	NWM Goal adoption	Specific details of water management strategy or operational response	Role of climate change impacts in justification of response
Supply Management (NWM Goal Two)	Irrigation expansion	4.05 million hectares by 2020 Full utilisation of LGRBs surplus water (22 BCM)	'Irrigation expansion through Jalayagnam is crucial to secure state food production and rural farmer livelihoods especially in the Rayalaseema region, and to help secure food production in the face of climate change'. (AP7) 'Increasing food production through expanding canal irrigation number one strategy to deal with rising food demand and urbanisation throughout the state, and to manage climate change if temperatures rise and rainfall patterns become more variable'. (AP5) 'Expansion of irrigation facilities in the Rayalaseema region important to encourage rural growth and agricultural production, and to combat risk of climate change for crop growth and food production in the state'. (AP9)
	Reservoir storage increase	7.5BCM additional storage to capture surplus LGRB waters Considering climate change projections in design of future infrastructure (reservoirs).	'Increasing storage is essential to adapt to changes in summer monsoon precipitation patterns and longer term changes in levels of precipitation with climate change, at all scales, especially in the lower Godavari via medium scale storage in order to utilise the 22BCM of surplus water'. (AP9) 'More reservoirs is crucial to meet growing water demand and to supply Jalayagnam programme for irrigation, and to deal with reductions in rainfall with climate change'. (AP8) 'Increasing storage must be pursued to secure water to increase food production across the state, and if precipitation levels decrease with climate change to capture more water'. (AP7) 'Essential to expand storage potential across the state, particularly to utilise all of the Lower Godavari river basins surplus water to meet growing water demand in future years and decades, and to secure water for food in the face of climate change'. (AP20)
	Carry-over storage	20% carry-over capacity in new reservoirs (medium)	'Carry-over storage is important to meet growing demands from farmers and to provide water all the year around, and to manage impacts of climate change if summer monsoon and rainfall levels change in the future' (AP7) 'Increasing carry over will take care of changes in monsoon and long term precipitation levels under climate change' (AP10)
	Inter-basin transfer	Polavaram transfer (2.2BCM) Dummudgen transfer (4.4BCM)	'Water transfer from the lower Godavari to the lower Krishna is needed to meet growing demands of population and farmer to reduce water scarcity, and if monsoons rains become more erratic in the future with changing climate'. (AP10) 'If water availability decreases with climate change in lower Krishna basin, important to transfer more of surplus Godavari's water to supply growing agricultural needs in Krishna delta region and to Rayalaseema region, and to secure state food production in face of climate change'. (AP7) 'inter-basin transfer is essential to secure water supplies for agriculture and urban needs especially, as well as to

			management future changes in rainfall in years to come with climate change' (AP2).
Demand Management (NWM Goal Four)	20% increase in irrigation efficiency	Performance management/ impact assessment: Benchmarking Water Audits Water Saving Technologies Conjunctive use of SW and GW GIS, remote sensing, satellite imagery User organisations: Water User Associations Participatory Irrigation Management	'State must improve irrigation efficiency to deal with growing water shortages and scarcity especially in lower Krishna basin, and if rainfall levels decrease because of climate change'. (AP1) 'more efficient use of irrigation water is required to deal with increasing demand from farmers and to feed the state population, and if the summer monsoon becomes more erratic and annual precipitation level changes in the long term, in decades to come'. (AP2) 'Increasing summer monsoon variability with climate change will lead to a change in the timing and intensity of water delivery to the surface water irrigation system (at an hourly to daily to weekly timescale) during the kharif and rabi cropping season' (AP2). 'Important to increase efficiency if precipitation levels decrease with climate change leading to more water shortages' (AP3) 'Better use of water in irrigation systems in the rabi season especially to counter the effects of changes in precipitation and drier winter months' (AP17)
Groundwater (NWM Goal Three)	Groundwater sustainable management	Enactment of AP Land, Water and Trees Act 2002 Regulation of groundwater extraction Increase groundwater recharge	'Groundwater is crucial for the states agriculture and drinking requirements and must be managed in a more sustainable manner to continue to provide in years to come, and it could become a more important source of water in future years if rainfall decreases with changing climate'. (AP15)
Hydrological data and database management NWM Goal one)	Programme of hydrological data collection and database in the public domain	Strengthen operations in hydrological data collection, remote sensing, GIS and satellite imagery Digitising hydrological data and information from paper format, establish hydrological database	'Better data collection and information management is required to provide better understanding of the hydrology and allocation of water within AP, which is also useful to better monitor climate change impacts with flood and droughts '(AP3) 'Climate change requires up-to-date data for present day, and to monitor future changes in precipitation and temperature for water resources and irrigation within the lower Krishna and lower Godavari river basins'. (AP2)
Assessment of climate change impacts on water resources (NWM Goal One)	Understand the impacts of climate change on water resources in AP	Hydrological modelling on climate change impacts on water resources (precipitation, surface runoff, river flows, groundwater). Input from external organisations in India (IITM, IITD, IH) and internationally	'Understanding potential impacts of climate change on Andhra Pradesh's water resources requires further research and technical modelling input and advice from relevant organisations' (AP2).
Flood management (NWM Goal Three)	Developing comprehensive approach to flood management	Flood Management Committee Flood control centre Increase monitoring of river levels and use of real time meteorological data throughout the year Dam break analysis Dam testing for probable maximum flood event (1:10,000)	October 2009 flood event (in direct response) 'It is important to strengthen flood management practices in the likelihood of more floods with climate change' (AP3, AP12) 'In the likelihood of future flooding with climate change, flood management responses should be continued, developed further and strengthened to state build resilience' (AP9)

Institutional reform (NWM Goal Five)	Integrated Water Resources Management	Operationalise and integrate organisational work on water projects	None
	Organisational convergence	Between state departments working on common water projects	None
	Human resources	Re-training ICAD staff in inter-disciplinary issues	None
	River basin organisation	Establish pan Krishna River Basin Organisation	None

6.3 Discussion

This section draws on the evidence presented in section 6.2 to discuss findings in relation to relevant theory in answering the third research question. It is structured around five main themes (6.3.1-6.3.6).

6.3.1 ICAD's adoption of NWM policy goals and appropriation of climate change impacts to continue the state hydraulic mission

The ICAD department, particularly CW officials, are intent on continuing AP's state hydraulic mission (Section 4.4.2 for overview of AP state hydraulic mission). This is gauged on the fact that CW officials are aligning Jalayagnam targets with the NWM policy, and are appropriating climate change impacts within the discourse as 'further justification' to continue the expansion of irrigation area and increasing reservoir storage capacity. As discussed below, the broad nature of the NWM policy and the plasticity of climate change within the discourse lend themselves to being appropriated by the ICAD to continue the state hydraulic mission.

The NWM is a broad natured policy, recommending a large number of supply and demand strategies, as well as institutional reform measures. This allows the ICAD a wide degree of flexibility in adoption. Various strategies have been singled out by the CW as top priority, whereas other strategies are considered of secondary importance (see Annex 26 complete list of strategies adopted by the ICAD). CW officials can be seen to be primary adopting NWM strategies that focus on large-scale supply-side infrastructure development. The majority of these strategies were on-going initiatives before the advent of the NWM policy, in line with the objectives of the CW in constructing major and medium irrigation infrastructure. CW officials are attaching the Jalayagnam programme's irrigation expansion and increase in reservoir storage targets to the NWM's national policies targets. CW officials consider the time-bound Jalayagnam targets are important in achieving national level targets. Furthermore, they also consider that NWM provides national policy support for the irrigation expansion and reservoir storage capacity strategies of the Jalayagnam programme (AP1, AP2, AP3, AP7, AP9, AP10).

Climate change is understood by ICAD officials as impacting AP state in a number of hydro-meteorological dimensions. These include changes in the onset and intensity of summer monsoon precipitation (AP1, AP2, AP3, AP4, AP7, AP8, AP9, AP17); an increase in frequency and intensity of extreme weather events particularly droughts, floods and cyclones (AP1, AP2, AP3, AP4, AP5, AP6, AP7, AP8, AP9, AP11, AP14, AP15, AP17, AP18, AP20); an overall decrease in long-term annual precipitation levels (AP2, AP3, AP4, AP7, AP9, AP14, AP17, AP18, AP20); long-term annual temperature rise (AP1, AP2, AP3, AP7, AP18, AP20); increased variation in intra-annual precipitation levels (AP2, AP3, AP4, AP7, AP17); increase in incidence and intensity of heatwaves (AP2, AP3, AP12); and sea level rise in coastal AP (AP2, AP3, AP7). The most commonly cited understanding of climate change impacts are an increase in the incidence of extreme weather events, with some ICAD officials linking the October 2009 flood to climate change as a past event of climate variability (AP1, AP2, AP3, AP5, AP7, AP9, AP19) (Section 2.3.1 for discussion on climate change and climate variability). Numerous ICAD officials consider that climate change model projections and future impacts in AP are highly uncertain[172] in nature, which they consider makes specific water management planning difficult (AP1, AP2, AP3, AP4, AP5, AP7, AP9, AP10, AP12, AP13, AP17, AP18, AP20). An ICAD publication detailing the flood event stated that 'precipitation uncertainty and heavy stormy precipitation is more likely with climate change' (GoAP, 2010b:64). ICAD official's understanding of climate change has risen in recent years. This is particularly owing to a small group of senior water managers within CAD who took it upon themselves to further understand the impacts of climate change in AP (AP2, AP3), by reading the latest academic literature (IPCC 2007; Gosain, 2006) and by soliciting feedback from international academia and national research centres (AP1, AP2, AP3), then discussing the significant of climate change impacts with other ICAD officials (AP2, AP3, AP7, AP8, AP12, AP13, AP17). Furthermore, interactions with international actors[173] and national government (Ministry of Environment and Forests), particularly after the launch of the Prime Minister's Action Plan on Climate Change, has increased senior ICAD officials understanding of climate change impacts (AP2, AP3, AP7, AP9, AP10, AP17). ICAD officials understanding of climate change is broadly in line with model projections for AP, which project an increase in the variability, onset and intensity of the summer monsoon and an increase in incidence of floods and droughts, although projected changes in annual precipitation and runoff vary significantly across state within associated river basins (Gosain et al, 2011; Kumar et al, 2011; GoI, 2010a; Gosain et al, 2006) (Table 2.2 for overview of climate change impacts in AP).

The ICAD, particularly CW officials, can be seen to be appropriating climate change impacts as 'further justification' for already existing supply-side strategies of the Jalayagnam programme. The plasticity of climate change within the current CW discourse is evident, in terms of climate change as a metaphor to capture the multiple framings (e.g. physical impacts) through which it is narrated and, more importantly, rhetorically deployed in favour of vested interests and projects (Hulme, 2009). Climate change plasticity is attributed to a number of factors. These include the complexity of the physical phenomenon itself; the interweaving of natural and anthropogenic climate change; the multi-scale nature of the phenomenon (global to local level

[172] Uncertainty is defined by the IPCC (2008) as an expression of the degree to which a value (e.g. the future state of the climate system) is unknown (ibid, p236). Uncertainty can be represented by quantitative measures (eg. a range of values calculated by various GCMs), or qualitative statements reflecting the judgement of an individual or group. In the case of ICAD officials, qualitative statements regarding the uncertainty of future climate change projections relating to precipitation variation (annual and intra annual), temperature rise and the incidence and intensity of extreme weather events within AP in future years were communicated during interviews (AP1, AP2, AP3, AP4, AP6, AP7, AP8, AP9, AP10, AP12, AP17, AP20).

[173] The World Bank, The International Water Management Institute and the United Nations Development Programme have all had direct interactions with senior ICAD officials regarding climate change mitigation and adaptation programmes in AP state.

impacts); the cultural filters through which climate change is viewed in order to search for meaning and significance (e.g. the cultural histories that exist around weather and climate); the contested and ideologically shaded arguments about scientific claims; and the many different value-systems which get mobilised when viewed through the lens of economics and social systems (ibid).

In no instance is a medium to long-term water management strategy (termed strategic and tactical by the decision framework introduced in Section 6.3.6.2) being advocated in direct response to manage only climate change impacts. Numerous respondents cited the uncertainty of climate change projections and hydro-meteorological impacts as a significant reason why it is difficult to plan more specifically (AP1, AP2, AP3, AP5, AP6, AP7, AP8, AP9, AP10, AP15, AP17, AP18, AP20). The uncertainty of climate change projections and associated hydrological change is acknowledged by the IPCC as a significant reason why scenario-based planning leading to climate change specific responses and management strategies in the water sector is rare; in addition to climate change being one of many drivers affecting water management choice (ibid, 2008:63; Wilby and Dessai, 2010) (Section 2.4). Instead of climate change specific mid to long-term planning, the plasticity of climate change is being mobilised within the current discourse as further justification for supply side approaches of the Jalayagnam programme, in line with the sanctioned 'water for food' discourse'. However, short-term responses by the ICAD (termed operational responses by the decision making framework) can be directly attributed to the October 2009 flood event. These are discussed further in Section 6.3.6.2.

Understanding ICAD's choice of water management strategy at the river basin level

By primarily adopting large-scale supply strategies from the NWM and appropriating climate change impacts as further justification within the AP state government discourse, the ICAD, particularly CW officials, can be seen to largely resisting fundamental change in continuing to pursue the state hydraulic mission (Molle et al, 2009; Suhardiman, 2008; Wester, 2008; Mollinga, 2005; Allan, 2003). The choice of a water management strategy by the ICAD is understood to be inclusive of not only the hydrological and physical constraints at the river basin level, but also the distribution of power amongst the actors, and their interests and strategies (Molle, 2003). Such a hydro-social approach is inclusive of political, economic and social factors set within the hydrological conditions at the river basin level (Swyngedouw, 2009). Understanding ICAD policy makers and senior managers decision process is complex (Molle, 2003; Allan, 2003; Schlager and Blomquist, 2000; Turton and Ohlsson, 1999). Drawing on river basin trajectory theory (Molle, 2003) to understand the choice of water strategy in AP, particularly the LKRB, numerous factors are identified as important in understanding why the ICAD, particularly the CW, is intent on continuing supply-side approaches through the Jalayagnam programme.

The sanctioned discourse legitimises which strategies can be pursued in a given (political) context in AP (Wester, 2008; Allan, 2002; Jagerskog, 2002; Ingram, 1971). The sanctioned water discourse within the ICAD is the expansion of surface water irrigation systems and reservoir storage to enhance agricultural production to attain state level food security (AP1, AP2, AP3, AP4, AP5, AP6, AP7, AP8, AP9, AP10, AP11, AP12, AP17, AP19, AP20, AP44, AP45). Numerous factors, many political in nature, examined below offer an insight into how the supply strategies pursued by the ICAD are largely orientated to sustain and strengthen this sanctioned 'water for food' discourse.

The agrarian pressure to expand irrigation area and to provide sufficient water is significant in AP (AP1, AP3, AP6, AP7, AP8, AP12; Wester, 2008; Allan, 2003). An estimated 76% of AP's population live in rural areas, with 60% of the state's workforce engaged in agricultural activities (GoAP, 2010c) (Section 4.2.2 for overview of AP water resources and agriculture). The potential to capture the large farmer vote block[174], on the promise of bringing irrigation water to the semi-arid drought prone Rayalaseema and Telegana regions, making 'deserts bloom' (Molle et al, 2009:330), is a major political driving force of the Jalayagnam programme (AP2, AP3, AP7, AP22, AP23, AP26, AP31, AP43; Vaidyanathan, 1993). The launch of the Jalayagnam programme in 2004 by the then incumbent Chief Minister of AP, Y.S. Rajasekhara Reddy was made six months before the state general election, interpreted as a direct political manoeuvre which led him to successful election (AP3, AP7, AP8, AP12, AP22, AP23, AP26, AP31, AP35, AP36; AP46). The political dimension to irrigation provision has also been used by previous AP Government Ministers for Major and Medium Irrigation Projects to secure re-election for themselves and also party members (AP3, AP21, AP22, AP23, AP26). Furthermore, the Jalayagnam programme is framed by CW officials as important to achieve equitable spatial development across AP state (AP1, AP7, AP8, AP9, AP20), which has been found to drive supply-side strategies, even when potential and actual economic return is low (Molle, 2003). The planned infrastructure development with the provision of irrigation water to the relatively less-developed rural Rayalaseema and Telegana regions is considered an important political and social development strategy in achieving state-wise development (AP7, AP8, AP26, AP31, AP33). The wider political importance of attaining state level food security through the Jalayagnam programme cannot be over-emphasised in the case of AP (AP1, AP3, AP7, AP26, AP31; Molle, 2003; Allan, 2002; Turton and Ohlsson, 1999).

Inter-state water sharing disputes within the Krishna River Basin (KRB) are on-going, and are an important political consideration in understanding the ICAD's support for the Jalayagnam programme. In an effort to strengthen its legal claim within the Krishna Water Disputes Tribunal (KWDT), both prior to the 2010 allocative declaration and afterwards characterised by continuing legal disputes, the construction of reservoirs and canal infrastructure generates a physical (infrastructure) requirement for more water, strengthening AP's claim for a higher allocative share of the KRB's shared waters (AP3, AP5, AP22, AP23, AP26, AP33, AP35, AP36, AP45, AP46). All large-scale infrastructure development including major and medium irrigation projects as well as reservoir storage should be considered within the wider political context of the KWDT (AP3, AP5; AP7; AP17; AP22, AP23, AP26, AP33, AP34, AP38, AP46, ND5, ND7, ND11, ND22, ND26, ND27, ND31, ND38) (Section 4.2.3.1 for further details on the KWDT).

Political economy considerations related to state economic growth within AP (Keller, 1998) include meeting growing water demands from all sectors, not only rising agricultural demands but also those of urban centres

[174] A vote block is a group of voters that are strongly motivated by a specific common concern or group of concerns to the point that such specific concerns tend to dominate their voting patterns, causing them to vote together in elections.

and industry (AP3, AP7, AP8, AP26) (Appendix 16 for future water demand projections for AP). With increasing scarcity and competition between users in the last decade, allocation has become more important, particularly to higher value industrial and drinking water uses within large urban centres; and also within the agricultural sector, particularly to irrigate high economically valued cash crops which are also water intensive (AP3, AP7, AP24, AP28, AP29, AP35). Although economics has an impact on water management choice as illustrated by models of rationality (eg. transaction costs) (Saleth and Dinar, 2004), political considerations have been found to often over-ride rational decision making processes (Allan, 2003; Molle, 2003; Schlager and Blomquist, 2000; Keller, 1998; Ramamurthy, 1995).

The CW's support for the Jalayagnam project should also be understood within the political and financial context of the iron triangle of actors (Molle et al, 2009) that constitute powerful coalitions (Moore, 1990) involved in large-scale infrastructure development projects. This triumvirate of actors includes local (district level) and state politicians (O'Mara, 1990), private infrastructure construction firms (Scudder, 1994) and the ICAD (Molle et al, 2009; Wester, 2008). State and local level politicians aim to benefit from the vote-winning potential of farmer constituents in state and district elections, particularly the Minister for Major and Medium Irrigation Projects over-seeing large-scale infrastructure development, through the promise of making 'deserts bloom' (Molle et al, 2009:330) by bringing irrigation water to previously un-served areas, especially in the semi-arid Rayalaseema region of AP. The CW, as the procurement and management department for large-scale infrastructure development projects, handles large financial contracts in the region of millions of US dollars, with the potential for corruption[175] and financial kick-backs in awarding construction companies large financial contracts with little accountability in spending and meeting time-bound project deadlines (AP21, AP23, AP26, AP28, AP46; Molle et al, 2009; Mollinga, 2005; Briscoe, 1999; Vaidyanathan 1993; Repetto, 1986; Wade, 1985, 1982). Furthermore, the iron triangle of actors operates within a web of interests – including research organisations, business contractors, consultants, banks, private water companies and rural farmer elites – who implicitly support and benefit from the hydrocracy's approach. A recently released report by the Comptroller and Auditor General of India[176] states that the rush to initiate the Jalayagnam infrastructure projects 'was largely driven by the urgency to award contracts rather than focusing on immediate benefits to target beneficiaries' (GoI, 2012e:64). And that contracts were awarded to 'in favour contractors', without any assurance on completion of work within the envisaged time and budget (ibid:76). Chapter 7 discusses further the issue of corruption and project mismanagement for the Jalayagnam programme.

Financial incentives from national to state government through the Accelerated Irrigation Benefit Programme (AIBP) help to consolidate the ICADs, particularly the CW's, approach for large scale infrastructure. In the 2010-2011 financial year, the ICAD received $230 million US dollars[177] through the AIBP for major and medium

[175] The term corruption is used to refer to a range of misconducts involving the use of public office for private gain, including bribery, extortion, theft, and embezzlement (Kaufmann, 1998).

[176] The Comptroller and Auditor General of India is a national government organisation, established by the Constitution of India to audit the expenditure national and state government ministries and departments.

[177] Equivalent to 2.6 billion Indian Rupees.

irrigation projects of the Jalayagnam programme[178]. Furthermore, the ICAD is currently (late 2012) seeking to declare the Polavaram inter-basin transfer as 'national project', in which case national government will provide 90% of the total funding. The estimated cost of the Polavaram project is $2 billion US dollars (GoI, 2012e; GoAP, 2010a). Although this allows the MWR a degree of financial and political power over state water resource development, it serves the CW's agenda in continuing large-scale infrastructure development, particularly when considering the relative poor economic performance of AP state economy in recent years, with little surplus finances to fund such projects estimated to run into billions of dollars in cost (AP3, AP22, AP23, AP26, AP42).

Hydrological and physical considerations are important in understanding the choice of WRM strategy in AP. The area under irrigation, the number of large dams and total reservoir storage capacity all dramatically rose from the 1960s to 1980s at the height of AP's state hydraulic mission, with infrastructure development concentrated in the LKRB and Pennar basins (Section for 4.3.2 for overview of AP state hydraulic mission along with Figures 4.15, 4.16 and 4.17). This period witnessed the development stage of the LKRB and Pennar basins, characterised by rapid water withdrawal, particularly by the irrigation sector. During this phase, supply management was the principal strategy (Figure 2.11). Both the LKRB and Pennar basins have been closed basins (Molden et al, 2005) for the last decade, with all the water fully utilised (Gaur et al, 2008; Venot et al, 2007, 2008); in addition to all of the most suitable topographic areas for large reservoirs in the basins already utilised. Such hydrological and physical factor in the LKRB affects the particularly choice of supply-side strategy by the CW. The hydrological reality characterised by increasing water scarcity in the LKRB and Pennar basins points to the importance of water demand measures within the utilisation and reallocation phases of river basin development (Figure 2.11; Molden et al, 2005). However, the CW is intent on re-opening the LKRB and Pennar basin by transferring the surplus water from the LGRB to supply continued irrigation expansion. Re-opening basins through water transfer has been found to be a strategy by government in response to increasing water scarcity and full water utilisation (Molle, 2003). Inter-basin transfer leads to hydrological inter-connectedness between river basins as hydrological units. In the case of increasing reliance on inter-basin transfers to meet present and future water demands, in time, the LKRB will become potentially more vulnerable to fluctuations in the LGRB water resources status, itself a function of upstream water use by upstream riparian states (Appendix 20 for map of Godavari River Basins riparian states).

The closure of the LKRB is considered to ultimately be a political process (Wester and Warner, 2003). The overbuilding of the LKRB, whereby the infrastructure development and commitment of water resources outstrips available resources (Molle, 2009), is driven by a powerful convergence of interests of the iron triangle of actors at state level in AP, operating under the approach that 'enough is never enough' (Molle, 2008:218), where large-scale infrastructure development 'has become an end in itself, rather than a means to an end' (Molle et al, 2009:328). The iron rectangle of actors itself operates within a wider web if interests – including research organisations, consultants, business contractors, private water companies, banks and rural elites –

[178] From 2007 to 2011, $1.07 billion US dollars have been granted to the ICAD from national government through the AIBP for 33 major and medium irrigation projects (GoI, 2012c).

who implicitly support and benefit from the hydrocracy's approach. Numerous political factors driving supply strategies, both in the 1960s to 1980s during the peak of the hydraulic mission (Section 4.4.2) and with regards to the continued support for the Jalayagnam programme, are identified in the case of the LKRB and AP. Political factors leading to the overbuilding of basins is considered to over-rule what can be considered as rational (hydrological) planning (Schlager and Blomquist, 2000). The ICAD, particularly CW officials, plans to re-open the LKRB through inter-basin transfer, particularly when considering that the basin is water scarce characterised by full water utilisation, points to the importance of focusing on water demand management strategies within the utilisation and re-allocation phase of river basin development phases (Molden et al, 2005). However, the ICAD is intent on large-scale infrastructure-based supply strategies in serving wider political interests, continuing to pursue the state hydraulic mission to consolidating its power and control over water resource management in the state.

In summary, consistent with the conceptualisation of water management as a political process and resource base (Mollinga, 2005, 2008; Mosse, 2003; Mehta, 2001) within the politics of policy in the context of sovereign states (Grindle, 1977), the above mentioned political dimensions of the supply-side approaches of the Jalayagnam programme are understood with regards to the benefits and increased power and control[179] over water resources they allow the ICAD (Suhardiman, 2008; Wester, 2008; Molle, 2003; Wester and Warner, 2003, Turton and Ohlsson, 1999). The primary focus on large-scale infrastructure supply side strategies is interpreted as an expression of power (Shore and Wright, 1997; Foucault, 1991), an intended political strategy to increase the control of water and people through the Jalayagnam programme (Wester, 2008; Allan, 2003; Swyngedouw, 1999; Reisner, 1993). Expressed in politically neutral terms (Asthana, 2011; Mehta, 2001; Foucault, 1991[180]; Dreyfus, 1982), the supply-side strategies underlie a political agenda of the CW to consolidate the state hydraulic mission. Furthermore the Jalayagnam programme is a continuation of state formation in AP (Molle et al, 2009; Wester, 2008; Swyngedouw, 2007; Wehr, 2004; Reisner, 1993; Worster, 1985; Wittfogel, 1957), with such large scale infrastructure symbolising state prestige and development (Molle et al, 2009; O'Mara, 1990), informed by industrial or high modernity (Scott, 1998).

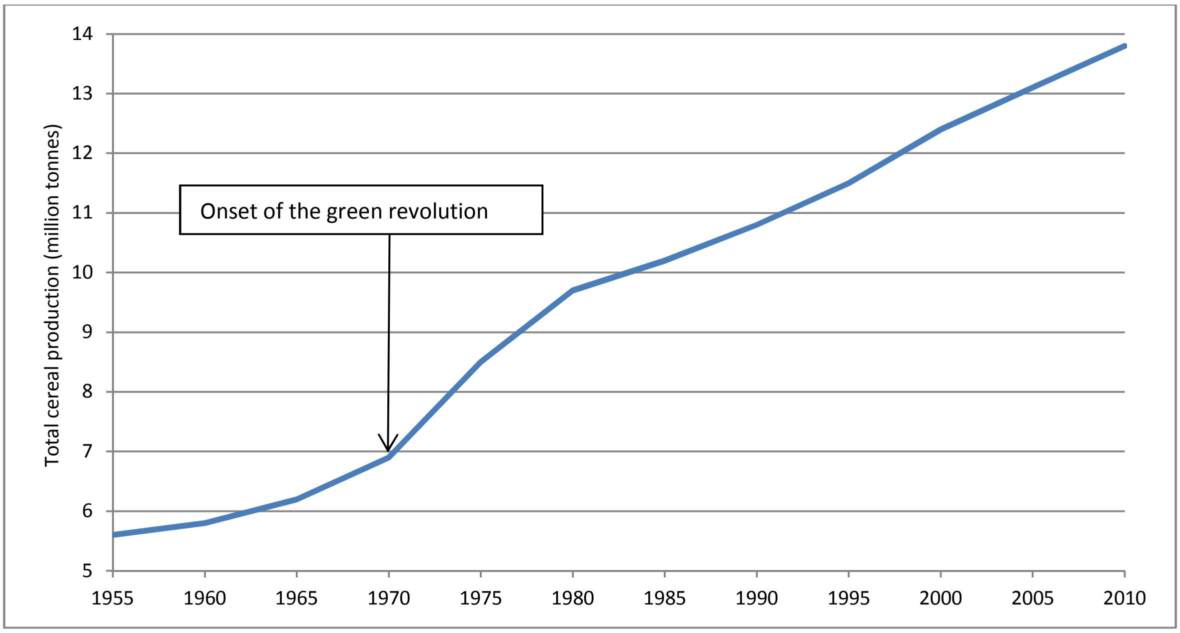
[179] Control in the form of regulating hydrological process, organisational control guiding human (especially famers) behaviours and practices in water use, and in the wider context of political and economic control in which water management is embedded and contributes too (Wester, 2008; Mollinga, 2003; Bolding and Mollinga, 1995).

[180] Foucault (1991) considers that such ideology informed policies operate as 'political technologies' masking the political agenda and the relations of power that it helps to reproduce.

6.3.2 Hydrological critique of ICAD's water for state food security sanctioned discourse

Cereal crop production in AP has increased significantly from 5.6 million tonnes in 1954 to 13.8 million tonnes in 2010 (Figure 6.6). Production increased significantly from the onset of the green revolution from the mid to late 1960s onwards. Rice is the staple crop of AP, accounting for over 92% of cereal production in 2010[181]. AP state is the second largest cultivator of rice in India, behind West Bengal (GoI, 2012f) (Appendix 8 for state map of India). However, AP is not food self-sufficient[182] at the state level and remains food insecure[183], with frequent food shortages and localised famines over the last two decades, particularly in the semi-arid Rayalaseema region[184] (GoAP, 2012; GoAP 2010c; Kumar, 2003). Attainting and sustaining state level food self-sufficiency and security is a top political priority of AP state government (AP1, AP2, AP3, AP5, AP7, AP10, AP12, AP24, AP30).

Figure 6.6: Total cereal production in AP since 1955 (GoAP, 2010c)

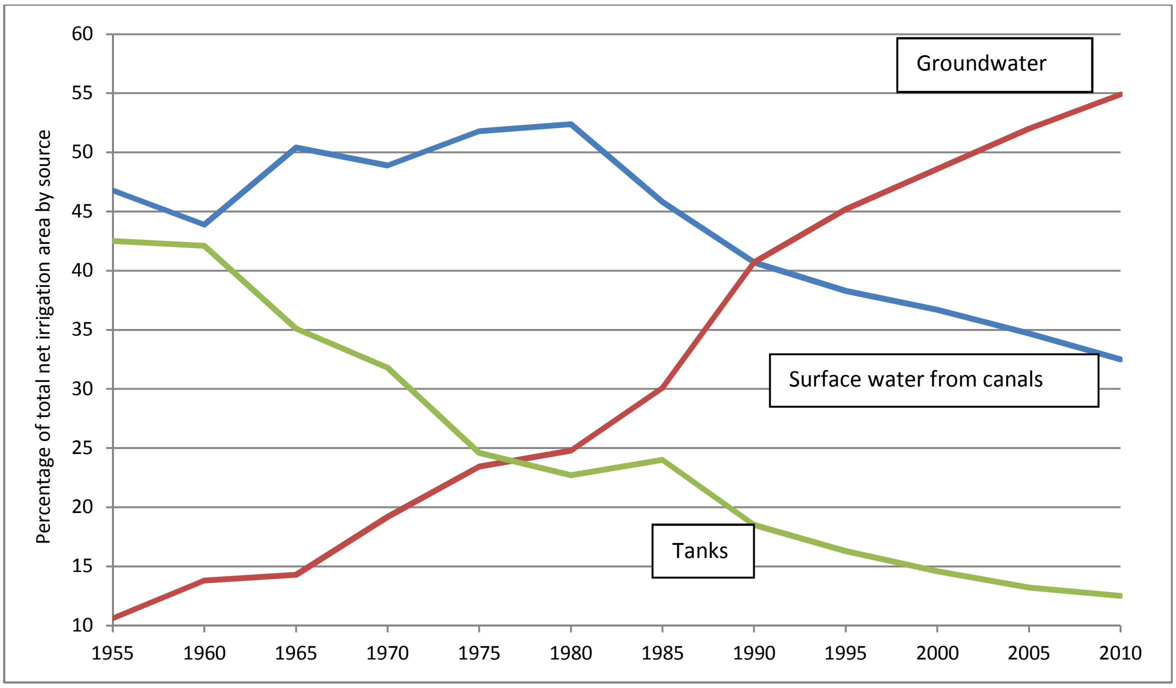


Since formation, the ICAD has primarily focused on the construction of large-scale reservoirs and canal irrigation systems (Figure 6.1) to increase the supply of water for food production (Section 4.4.2 for overview of AP's hydraulic mission). A historical examination of the relative percentage contribution of surface water from canal systems, groundwater and tanks in supplying water for the total net irrigation in AP, and hence contributing to cereal production, highlights the increasing reliance on groundwater and the diminishing role of surface water from canal systems and tanks (Figure 6.7). In 1955, surface water from canals supplied 46%

[181] Of the 13.8 million tonnes of cereal production in AP in 2010, 12.7 million tonnes were rice (GoI, 2012f).
[182] Although AP does produce enough cereal crops internally within its state boundaries, it does not cultivate sufficient pulses and oil-seeds and other essential food products for a nutritionally balanced died to be food self-sufficient at the state level, instead relying on food imports from other Indian states (GoAP, 2010; Kumar, 2003).
[183] State level food security is not a function of cereal crop production alone, but is dependent on the four dimensions of food security identified by the FAO (2011) (Section 5.4.2). Particularly in the case of AP, other non-agricultural externalities such as rural transportation infrastructure, grain storage capacity, crop price and access to markets affects state level food insecurity (Kumar, 2003).
[184] Kumar classifies AP state as 'moderately food insure' (2003:15).

of all water for net irrigation, climbing to 53% by 1980. The role of tanks as a major source of water has steadily declined, from 42.5% in 1955 to 7.5% in 2010. The importance of groundwater providing irrigation water has dramatically increased, particularly from the mid to late 1970s as the number of diffuse groundwater pumps and bore-wells has proliferated across AP[185]. By 1990, groundwater became the primary source of water for irrigation in AP. Over the last two decades, this trend has continued with groundwater providing 55% of water for irrigation and hence cereal production in the state. Even with the launch of the Jalyagnam Programme in 2004, the relative contribution of surface water from canals has declined to 33% by 2010.

Figure 6.7: Relative percentage supply of water from canal irrigation systems, groundwater and tanks to the total net irrigation area in AP (GoAP, 2010c)



The ICAD's sanctioned discourse has not led to a proportion contribution to net irrigated area and cereal food production relative to groundwater, particularly over the last 20 years. The ICAD's continued focus on large scale irrigation infrastructure, characterised by the Jalayagnam programme in recent times, is at odds with the hydrological reality, with the increased reliance on groundwater as the primary source of water for irrigated agriculture and cereal production in AP. It would be expected that the ICAD shift its primary focus to that of groundwater management issues - such as sustainable withdrawal, recharge and efficiency of agricultural use - to increase state food production, particularly considering the critical status of groundwater in the interior of AP and the fact that only 3.5BCM is potentially available throughout the state (Figure 4.7 and Section 4.3.2 for overview of groundwater status in AP). However, this has not been the case with the launch of the Jalayagnam programme in 2004. Groundwater clearly has a crucial role in cereal and non-cereal food

[185] It is estimated by a senior official at the AP Groundwater Department that there are over 26 million individual groundwater withdrawal points across the state in 2010 (AP15).

production to reach state-level food self-sufficiency in AP and to attain food security in future years. It is clear that the sanctioned discourse is not solely based on the hydrological situation with regards to cereal production in AP. As discussed in Section 6.3.1 with regards to the political dimensions of the choice of WRM strategy at the river basin level, the sanctioned discourse in AP is politically constructed and propagated, in serving the political and financial vested interests of the iron rectangle of actors including ICAD, politicians and infrastructure construction companies.

6.3.3 Reformist agenda within the ICAD

A handful of senior CAD officials are intent on continuing endeavours to promote a reformist agenda within the ICAD. Interviews revealed that they are adopting NWM policy goals and citing the impacts of climate change within the discourse to promote such an agenda.

Senior CAD officials are adopting numerous demand management and institutional reform measures from the NWM, in line with CAD's objectives. The vast majority of these strategies are on-going measures, started in 1997 during the reform initiate and re-strengthened in 2005 (see below for overview of AP reform initiative). Considered as particularly important, the AP state target of increasing irrigation efficiency by 20% by 2020 is considered to contribute to the NWM Goal Four of increasing national irrigation efficiency by 20% by the year 2017 (AP1, AP2, AP3, AP7, AP8, AP17, AP18). The regulation of groundwater extraction is also considered as a priority (AP2, AP3, AP15, AP17) (Appendix 26 for complete list of strategies adopted by the CAD). CAD officials consider that the NWM provides national policy support to continue their strategies that promote irrigation efficiency. Furthermore, they consider that the NWM policy adds support in justifying institutional reform measures (AP1, AP2, AP3, AP4, AP17).

Senior CAD officials can be seen to be citing climate change impacts within the discourse, particularly to justify irrigation efficiency measures. CAD officials can be seen to be appropriating the plasticity of climate change to suit their agenda, with a variety of physical impacts being cited to 'further justify' irrigation efficiency measures (Table 6.1). The dominant justification for promoting irrigation efficiency within the CAD is to manage rising water scarcity and competition between users, particularly within the LKRB (AP1, AP2, AP3, AP4, AP17, AP19). Senior CAD officials have adopted climate change specific approaches from the NWM. These include understanding climate change impacts in AP through research and technical input from national government organisations, as well as external assistance from international academia and organisations. Furthermore, the training of ICAD staff in climate change awareness is a new approach adopted from the NWM, conducted by the CCCEA cell located in the Human Resource development department of AP government. This strengthening of existing efforts to re-train ICAD staff in more interdisciplinary methods, an approach originating from the 2005 reform initiative.

Within the context of the water management paradigms identified by Allan (2003), the strategies advocated by CAD officials represent reflexive modernity stage (Section 2.5.2 and Figure 2.13). The demand management strategies, particularly irrigation efficiency and economic valuation of water, represent the fourth paradigm; whilst the institutional reform measures signify endeavours to address institutional and political aspects of water management in AP, the fifth paradigm[186] (ibid). With regards to river basin development characterised increasing water scarcity in the LKRB and Pennar basins, the pursuit of demand management strategies by CAD officials represents the utilisation and re-allocation phases identified by Molden et al (2005). Within closing or closed basins, it is found that all three options (development, utilisation and reallocation) are perused simultaneous (ibid; Molle, 2009). This is the case with the LKRB and Pennar basins, with the CW pursuing supply side strategies, particularly inter-basin transfer to re-open the basin, whilst at the same time, CW officials pursuing demand management options. Clearly not all ICAD officials consider the full utilisation of water within the LKRB and Pennar basins as a hydrological limiting factor which should lead to only demand management strategies being pursued, only a handful of CW officials recognise this (AP2, AP3, AP17, AP18).

Moving the water institutional reform initiative forward in Andhra Pradesh

In 1997, AP launched an ambitious irrigation reform initiative, enacting state-wide legislation[187] with strong political support at the top level of state government[188]. This entailed a reorientation of the ICAD towards service-orientation, including the creation of legally prescribed elected bodies a different levels of the system (WUA distributary committees and project committees), as the structure of farmer management and governance (Merry et al, 2007; Bolding and Mollinga, 2004). However, based on fieldwork in AP, it was concluded that the reform initiative was captured at the field level by economically and politically powerful rural elite consisting of rich farmers and party members, undermining the representation and accountability component of the WUA and distributary committees (ibid). It is claimed that the ICAD department regained much of the lost control through amendments to the original Act that was the basis of the reform (Nikku, 2006). Vested political interests within the hydrocracy and at the local field level severely limited the overall effectiveness (Bolding and Mollinga, 2004). Political momentum driving the reform waned as government reform initiatives multiplied and spread across sectors, in addition to consecutive drought years in AP from 2001-2004[189] leading to a reduction in the irrigation area, and the electoral defeat in 2004 of the Chief Minister who initiated the reform measures. In the same year under the leadership of the new Chief Minister, the Jalayagnam programme[190] was launched on the promise of bringing water to drought prone under-developed areas of the Telegana and Rayalaseema regions. However, in 2005 the reformist initiative was re-strengthened. Informed by the National Water Policy (2002) and in response to increasing water scarcity and

[186] The third 'environmental awareness' paradigm began from the early to mid-1980s in India, with questioning over the negative consequences of large dams led by prominent NGOs initially focused on the Narmada dam dispute in north-western India (Roy, 1999) (Section 5.4.3).

[187] The AP Farmers Management of Irrigation Systems Act, 1997. Appendix 12 for details on this and other Acts in AP.

[188] The irrigation reform initiative was part of the overall institutional modernisation programmes launched by the then Chief Minister of AP, Chandrababu Naidu, also supported by the World Bank and UK Department for International Development.

[189] AP suffered a major drought from 2001-2004, with an average 10% reduction in annual precipitation levels during these three years. The drought led to sever crop failure, particularly in the rabi and summer (zaid) seasons, forcing thousands of farmers to migrate to urban centres in search of alternative livelihood activities (Venot et al, 2007).

[190] The Jalayagnam programme was launched a few months after AP Government released its Vision 2020 policy for state-wise development (GoAP, 2004). This policy was developed by the AP Government in collaboration of McKinsey Limited Consultancy and the World Bank, and explicitly advocated large-scale infrastructure construction approaches including irrigation systems and reservoirs to increase agricultural production throughout the state.

demand projections out-stripping supply by the year 2025 for the LKRB (Appendix 16 for future water demand scenarios in AP), internal discussion within the ICAD, particularly within a small group of senior CAD officials at the Secretary, Commissioner and Consultant level, strongly advocated the need to seriously consider institutional reform and water demand management, particularly irrigation efficiency. Irrigation efficiency measures centred on PIM and WUA, to improve cost recovery as well as operation and maintenance. In the years immediately after 2005, 'politically low cost' insignificant issues were pursued[191], such as development of information technology, increased monitoring and re-structuring the CAD department to include multi-disciplinary teams (AP1, AP2, AP3, AP17, AP18). In addition, the formation of the AP State Water Policy allowed demand management and reform measures to be confirmed as a statement of AP government policy intent (Saleth, 2004). Albeit slower in nature than originally anticipated and not in line with its original objectives when launched in 1997, the process of reform has somewhat endured in AP. The reform initiative created groups of farmers and irrigators pursuing change, and galvanise a small group of senior bureaucrats within the CAD department in 2005, intent on endeavouring to continue pursuing a reformist agenda, internally, from within the ICAD.

This same small group of five senior CAD officials are endeavouring to continue the reformist agenda, internally within the ICAD, by adopting institutional reform measures and demand manage strategies from the NMP policy and to manage climate change impacts. They can be considered an 'agents of change' (Sutton, 1999:6) or 'outstanding mangers' (Israel, 1987:4) within the ICAD, giving direction and momentum to new polices and methods, regarding reform and an opportunity and not a threat (Teskey, 2005; Sutton, 1999). However, with the majority of the 'politically low cost' demand management strategies and institutional reform measures already operationalised since 2005, implementing the strategies advocated by CW officials from the NWM represent a significant (political) challenge, particularly issues of state department convergence, river basin organisations, groundwater regulation and political economic dimension of irrigation efficiency. The challenges of implementing these strategies and reform measures will be examined in detail in Chapter 7.

6.3.4 The October 2009 flood in AP as a 'window of opportunity' and resulting operational responses

The October 2009 flood in AP led to direct operational responses by the ICAD. The programme of dam safety checks, dam break analysis and establishing a year-round flood control centre represents a direct response of the ICAD to the October 2009 flood event in AP. These strategies were not in place prior to the flood, and represent a direct operational response both during and immediately after the flood. This is an example of how an extreme weather event such as a flood can act as a 'window of opportunity' (Kingdom, 1984), in so much as generating sufficient (political) momentum within government to develop appropriate operational, management and policy responses. The operational responses of the ICAD can be considered a positive

[191] These strategies were also referred to as 'low hanging fruit' (AP2, AP3).

development, an example of institutional learning from the flood, helping to build resilience against future flood events as well as strengthening anticipatory flood planning within the ICAD[192]. The responses of the ICAD are primarily short-term in nature, termed 'operational responses' by the decision framework introduced in Section 6.3.6.2. They are focused more on disaster management[193] than to mid to long term (tactical and strategic) water management strategies (Section 6.3.6.2 for further discussion on timeframe of response to the flood event and climate change).

Molle (2003) also found that a shock or extreme weather event creates a window of opportunity which can influence the choice of water management strategy at the river basin level, although he did not specify the timeframe of the strategy or response. However, in the case of the October 2009 flood event (the most commonly understood impact of climate change by ICAD officials), only short term operational response can be directly attributed to the flood. No mid to long term (tactical and strategic) water management strategies are planned specifically for future climate change in AP, primarily owing to the uncertainty of projections and (AP1, AP2, AP3, AP7, AP8, AP9, AP10, AP12, AP17, AP19, AP20) and the limitation of scenario-based planning (IPCC, 2008). Instead, the plasticity of climate change is being used to support as further justification for the mid and long term Jalayagnam supply-side approaches, in line with the sanctioned 'water for food' discourse in pursuit of the state hydraulic mission.

6.3.5 Contestation of water strategies adopted from the NWM and to manage climate change

Within the politically contested domain of the politics of policy of sovereign states (Grindle, 1977), contestation is found to occur both between government institutions, and also between non-government actors opposed to the government's management approach (Mollinga, 2008; Merry et al, 2007; Grindle and Thomas, 1990; Warwick, 1982).

Internal contestation within ICAD

Internally within ICAD, senior CW officials are particularly intent on continuing the AP state hydraulic mission with a focus on large scale infrastructure supply side approaches of the Jalayagnam project, in response to the NWM policy and in managing climate change impacts. Whilst on the other hand, a small group of senior CAD officials are advocating a move to demand management strategies and institutional reform, adopting NWM Goals and climate change impacts to support on-going reform initiatives initiated in 1997 and re-strengthened in 2005. This internal contestation, with the potential for tension between the CW and CAD, is consistent with

[192] After political blaming had subsided between Karnataka and Andhra Pradesh (Section 6.2.4.1), the two states agreed in principal to share real-time hydro-meteorological data (river discharge, reservoir levels, satellite imagery, meteorological data) prior and during a similar extreme weather event to help mitigate the flooding impacts (AP1, AP2, AP12, AP34).

[193] Disaster management is defined by the United National Development Programme as 'the body of policy, administrative decisions and operational activities required to prepare for, mitigate, respond to, and repair the effects of natural or man-made disasters' (UNDP, 2002:5).

earlier findings by Grindle and Thomas (1990) with regards to both the linear and interactive model of policy processes, which states that struggles and contestation can take place internally within government (ibid; Warwick, 1982). Furthermore, it also illustrates the political nature of water management within the ICAD, how both CW and CAD officials are mobilising the NWM and appropriating climate change impacts to serve their different strategic agendas (Wester, 2008; Mollinga, 2005; Mosse, 2003; Grindle, 1977).
However, the over-riding primary objective of the ICAD at a collective organisational level remains the pursuit of the Jalayagnam programme in expanding irrigation the area to attain state level food security, the sanctioned discourse within the ICAD (AP1, AP2, AP3, AP4, AP7, AP8, AP9, AP10, AP12, AP18, AP19, AP20). The majority of ICAD staff (6700 out of 7000) are engaged in activities related to infrastructure development and construction (AP1, AP7, AP8, AP9, AP10, AP17; ICAD, 2010a). The small group of senior CAD officials are in a minority with the ICAD. CAD's operations are staffed by 300 personnel, and are peripheral in nature relative to ICAD's organisational focus on infrastructure development (AP2, AP3, AP7, AP9). Furthermore, many of the 'politically low cost' demand management and institutional reform strategies are already in various stages of implementation since 2005. As discussed in chapter 7, the demand management and institutional reform measures advocated by CAD officials face significant implementation challenges.

Andhra Pradesh's non-government actors contestation

Interviews with non-government actors in AP revealed a different interpretation of the NWM policy than the ICAD's primary focus on supply-side approaches. Non-government actors were particularly critical of the ICAD's continued support for the Jalayagnam programme, claiming that is not the most appropriate strategy to management growing water scarcity, in addition to climate change impacts in AP. The Jalayagnam programme, including the controversial Polavaram inter-basin transfer[194] (Gujja et al, 2006), is considered a misguided approach to water management within the state, contested on numerous points including loss of habitat and land, human displacement, incomplete environmental impact assessment, fuelling corruption within state government and construction companies, project construction mismanagement; in addition to questioning whether there is sufficient surplus water within the LGRB to supply the transfers (AP21, AP22, AP23, AP26, AP27, AP28, AP30, AP31, AP32, AP34, AP37, AP38, AP39, AP40, AP41, AP42, AP43, AP46; Gujja et al, 2006). Furthermore, they claim that the 4.05Mha of additional irrigation area planned under the Jalayagnam programme will only increase the irrigation gap within AP (Figure 6.4), and not lead to a substantial rise in the area receiving sufficient water to irrigate one crop per year (AP21, AP23, AP28, AP30, AP35, AP39, AP40, AP41, AP42). Non-government actors claim that the ICAD's default position with regards to the Jalayagnam programme is not the most appropriate strategy to manage climate change, particularly with regards to the uncertainty of climate change projections for future precipitation and temperature (AP21, AP22, AP23, AP25,

[194] The Polavaram project has been controversial over the last decade. Objections have been raised on the ground of land submergence , the loss of biodiversity, the displacement of thousands of people within the area of the reservoir and loss of livelihood activities. Legal objections from Orissa and Chhattisgarh states based on the submergence of land within their administrate boundaries have been filed to the Godavari Water Disputes Tribunal, with legal negotiations still on-going to this day (late 2012). Furthermore, allegations of corruption have been made with regards to unaccountable project funds and infrastructure construction proceeding at a much slower than expected pace (GoI, 2012e; Gujja et al, 2006).

AP26, AP27, AP31, AP39, AP42, AP 43, AP46). Non-government contestation represents the polarised nature of water management discourse in AP state, with non-government actors highly critical of the ICAD's approach. This is consistent with the high level of polarisation in water discourse found across India (Asthana, 2011; Mollinga, 2005; Mehta, 2001; Kaviraj, 2001; Roy, 1999). Furthermore, in a rare study of the policy process in AP regarding health reform policy in the mid-1990s, Mooji (2003) found that there was little debate or protest against the 'policy on paper', with non-government opposition weak and on the whole unable to develop alternative scenarios (Suri, 2005). However, non-government actors reaction in opposing the ICAD's adoption of the NWM Goals and overall strategic water management direction illustrates that contestation of 'policy on paper' is evident. It is apparent that non-government actors within the water sector in AP are relatively more engaged, active and coordinated in opposition (AP21, AP22, AP31, AP38, AP39, AP40, AP41, AP42, AP43, AP46).

Instead of large-scale supply strategies, non-government actors, particularly NGO and civil society members, advocate water demand management strategies and efficiency of water use across all water sectors. These include watershed development programmes, increasing water use efficiency in irrigation and other sectors, groundwater recharge, on-farm small scale storage, check dams, rainwater harvesting in urban and rural areas, less water intensive cropping patterns and conjunctive use of surface and groundwater (AP21, AP22, AP23, AP26, AP28, AP30, AP31, AP34, AP38, AP39, AP40, AP41, AP42, AP43, AP46; Thakkar, 2012). The above mentioned strategies advocated by non-government actors essentially embody decentralisation of power away from the ICAD (Smith, 1985), empowering non-government actors at the individual and community level (Shore and Wright, 1997). These strategies advocated, in addition to making hydrological sense with the potential to improve water use efficient in AP, can also be considered as manifesting exertions of power by non-government actors to gain more control in managing water at the local level (ibid). Contestation over water management strategies illustrates the process through which different actors (both ICAD and non-government actors) exert their agendas and interests, negotiating modalities of society governance in consolidating formal and informal institutional water management arrangements (Mollinga, 2008).

6.3.6 Climate change adaptation

This section begins by examining the supply and demand strategies advocated by the ICAD in terms of their relevance for adaptation to projected climate change impacts in AP. It then examines the water strategies in the context of a decision making framework based on timescales of projected climate change impacts.

The challenge to water managers

Water managers are posed with the task of how to include non-stationarity considerations for water management (Milly et al, 2008), characterised by uncertainty in both the present and future hydro-meteorological conditions (Aerts et al, 2011; Van Pelt and Swart, 2011; Wilby and Dessai, 2010; Milly et al, 2008; IPCC, 2008). Furthermore, Molle (2009) notes that managing demands for water (e.g. from population growth and economic development leading to increased agricultural, urban and industrial water use) in addition to climate change hydro-meteorological non-stationarity, water managers are poised with highly complex challenge (Molle, 2009; Lach et al, 2005) (See Chapter 1 for further discussion on the challenge to water managers). The adaptation screening and decision making framework exercises presented offer useful insights into the general nature of water management strategies as adaptations to climate change, and also illustrates the complexity and difficulty in planning to manage climate change non-stationarity and uncertainty.

6.3.6.1 Adaptation screening

Climate change projections are introduced in detail in Chapter 2, detailing the numerous hydro-meteorological impacts in AP (Section 2.3.2.2 and Table 2.2). In summary for AP, projections indicate a rise in temperature of 1.7°C for 2030 and 3.2°C by 2080; a rise in evapotranspiration and river sediment yield by 15% and 40% respectively; an overall reduction in annual precipitation by 10% across AP particularly in the LKRB; an increase in intra-annual precipitation variability, characterised by wetter summer monsoons (with an increase in the frequency and intensity of rainy days) and drier winter months; an overall reduction in surface water runoff by 10% but with large spatial variability across AP (10% reduction by 2080 and 9% increase by 2050 in surface water runoff for the LKRB and LGRB respectively (Gosain et al, 2011); and an increase in the frequency of floods and droughts (with large spatial variation across AP) (GoI, 2012a; Kumar et al, 2011; Gosain et al, 2011). However, it should be noted that these impact projections are based on the output of a single GCM (PRECIS regional model) and SWAT hydrological model analysis (ibid) (Section 2.3.2), and are subject to inherent model uncertainty (GoI, 2012a; Kumar et al, 2011; Gosain et al, 2011; GoI, 2010a; IPCC, 2008, 2007).

The ICAD advocate a number of water management strategies from the NWM and to manage climate change impacts in AP. This section uses a scenario planning approach for future climate change (IPCC, 2008; Beuhler, 2003; Simonovic and Li, 2003), with the strategies advocated by the ICAD screened (assessed) with regards to an adaptation criteria framework (Wilby and Dessai, 2010; Hallegate, 2009; IPCC, 2008; UKCIP, 2003) (Appendix 27 for adaptation screening matrix). The adaptation screening exercise utilises a scenario approach for future variability in surface water runoff with regards to the adaptation criteria for each supply and demand strategy, in assessing the overall robustness (Section 2.4.2.2 for further information on adaptation criteria in assessing the overall robustness of a strategy). Climate change projections for future surface water runoff are considered the principle variable of most importance for water management, although it is acknowledged that other hydro-meteorological variables are also important considerations in adaptation (particularly annual and intra-annual precipitation variability and evapotranspiration). However, the projections in surface runoff are derived from a single GCM and SWAT hydrological model analysis, and are uncertain (Gosain et al, 2011; IPCC, 2007), for example, previous hydrological models predicted a decrease in runoff of 10% for both the LKRB and LGRB (Gosain et al, 2006).

Although the adaptation screening exercise is subjective (based on the author's knowledge) and reductionist by using only surface runoff as the principle indicator of climate change impacts, it provides a general insight into the robustness of strategies as adaptation to future climate change impacts.

Autonomous adaptation

The water strategies advocated by the ICAD are predominately climate change autonomous in nature. They are not designed or in direct response to climate change (IPCC, 2008). Both the supply and demand strategies were already in the process of planning and implementation by the ICAD. Such strategies are in direct response to meeting the water demands in the immediate to mid-term future, up to the year 2020 for the Jalayagnam programme and irrigation efficiency targets for 2017. They are in line with the dominant discourse within the ICAD, that of irrigation expansion to attain food security throughout the state.

Future climate change specific plans include 'considerations' (AP10) for designing new reservoirs and infrastructure under the Jalayagnam programme to encompass long-term climate change projections; the pursuit of further understanding of how climate change impacts on water resources in the state; and climate change orientated awareness and inter-disciplinary training of mid to lower level staff within the ICAD. Flood management plans such as increased hydro-meteorological monitoring, the establishment of the flood management committee and dam safety checks for probable maximum flood event of 1:10,000 year events, can also be considered as climate change orientated, owing to the projections of increase flooding in AP.

No regrets strategies

A no regrets decision is one that is deemed to be 'worthwhile now (in that it would yield immediate economic and environmental benefits which exceed its cost), and continues to be worthwhile irrespective of the nature of future climate' (UKCIP, 2003:66). In addition, a no regrets decision is deemed to be able to cope with projected impacts of climate change (Hallegate, 2009). Increasing irrigation efficiency by 20%, sustainable groundwater management and improving the programme of hydrological data collection and management, can all be considered as no regrets strategies. Improving irrigation efficiency is particularly relevant with decreasing surface water runoff and availability in the future under climate change projections, to make better use of the available water to improve crop productivity. Managing groundwater in a more sustainable manner, for instance, by reducing levels of abstraction and promoting groundwater recharge, is an appropriate strategy to deal with reduction in future water runoff and resulting decline in the levels groundwater recharge. A programme of increased hydrological monitoring, data collection and improved database management will lead to a better understanding of water availability, with current and comprehensive data having the potential to inform decision making processes including allocation, particularly if water scarcity increases with reductions in surface water availability.

Low regrets

Low regret solutions only go part of the way towards resolving the decision uncertainty concerning effective climate change adaptation. Adaptation options known to be costly or with relatively unknown performance under climate change projections can be classified as low regrets. Consequently, some important choices will remain regarding the uncertain impacts of possible climate change, and should be appraised as and when projections are updated (Wilby and Dessai, 2010; UKCIP, 2003).

The infrastructure developments planned under the Jalayagnam project (irrigation expansion, increasing reservoir storage capacity, carry-over storage and inter-basin transfer) are considered as low regret strategies to climate change. In the case of projected decrease in water runoff, increasing storage capacity is an appropriate method to capture more runoff with water stored for drier months. However, if water runoff decreases substantially in future decades, then there could be insufficient inflows to fill the additional storage capacity, in which case they would remain under-utilised with regards to full capacity. In this case, additional storage can be considered as having a relatively unknown performance with regards to future changes in runoff, and hence can be considered a low as opposed to no regrets adaptation. A similar assessment is made with regards to increasing carry-over capacity. Additional water can be captured and stored with increasing carry-over capacity, which is important if surface runoff decreases; in addition to water being stored between years serving dry months and the immediate years ahead. However, if a decrease in runoff reduces the levels of flow substantially, then the additional capacity (10-20%) of a reservoir may not be entirely utilised in the first place. In this regards, carry-over storage can be considered as a low regrets strategy.

Increasing irrigation canal infrastructure coverage must be considered within the context of whether there is sufficient water to supply the system. If surface water runoff decrease, there is the potential for less inflow to the irrigation canal system from either a river or reservoir, in which case, additional irrigation infrastructure would remain under-utilised and add to the irrigation gap within AP. Furthermore, with temperature rise under climate change projections, evapotranspiration rates could increase (up to 15% by the 2080s), leading to an overall loss of water within the canal system and irrigation field plots. With regards to inter-basin transfer, the LGRB is projected to received an additional 9% surface runoff by the 2050s, with the LKRB projected a 10% reduction in runoff by the end of the century. In this case, the inter-basin transfer from the LRGB to the LKRB would help the LKRB in adapting to climate change impacts in declining surface water runoff and availability. However, the projections in surface runoff are derived from a single GCM and SWAT hydrological model analysis, and are uncertain (Gosain et al, 2011; IPCC, 2007), for example, previous hydrological models predicted a decrease in runoff of 10% for both the LKRB and LGRB (Gosain et al, 2006).

Overall, owing to the fact that these infrastructure-based supply strategies only go part of the way in resolving the uncertainty regarding their effectiveness as climate change adaptation, they are classified as low regrets adaptations, as opposed to no regrets. Although the Chief Engineer of the Jalayagnam programme is ‘considering’ (AP10) how exactly to incorporate long-term climate change projections in new infrastructure design, owing to the uncertainty of model projections, no direct action is being taken at present until more reliable and accurate projections are developed. And secondly, all of these strategies are financially very expensive, which is also a criteria on which low regrets adaptions are based (Hallegate, 2009; UKCIP, 2003).

Reversibility

The supply-side infrastructure strategies of the Jalayagnam programme are largely irreversible. Once constructed, there exists an infrastructural 'lock-in' (Hallegate, 2009). It would be very expensive and time consuming to modify the design and construction at a later stage to incorporate climate change projections (AP10). Whereas the irrigation efficiency measures, notably performance management, technical initiatives and user organisation groups, are flexible enough to allow modification and alteration in time under a changing climate (Hallegate, 2009). Chapter 7 discusses the timeframe miss-match between the infrastructure under the Jalayagnam programme being designed for a 50 years, and climate change projections for 2080 and beyond.

Safety margin strategies

Safety margin strategies are those that reduce vulnerability at null or low costs (Hallegate, 2009). They represent the safety margin designed and developed in, for example, calibrated drainage infrastructure or a reservoir capacity. The known capacity is calculated on historic data, and then a safety margin is incorporated into the design, to deal with 10%, 20% or more increase in capacity or performance (this is particularly relevant in the case of increased variability in summer monsoon precipitation levels with flood implications). The exact safety margin cannot be calculated owing to the uncertainty of climate change projections under a scenario-based planning approach (IPCC, 2007). Instead, a rough safety margin is designed and developed, so long as the cost of doing so is not too high (Hallegate, 2009). Such an approach is not currently being developed for the infrastructure development under the Jalayagnam programme at the moment (mid 2011) (AP10). The Chief Engineer is waiting for further guidance from relevant organisations[195]. However, owing to the uncertainty of climate change projections, the safety margin strategy offers a 'rough and ready' approach to dealing with potential changes in hydro-meteorological conditions for large-scale infrastructure. The demand management strategies, significantly cheaper than the supply strategies of the Jalayagnam programme, can be considered to reduce vulnerability if surface water runoff decreases in future decades.

Robust adaptation

Robust adaption to climate change is defined as measures that are 'no or low regrets, reversible, reduce decision making horizons, incorporate safety margin strategies, that are flexible and mindful of actions being taken by others to adapt to climate change' (Hallegate 2009). Furthermore, robustness indicates how well a system performs over a range of input scenarios pertaining to what is uncertain (Wilby and Dessai, 2010; Hashimoto et al, 1982). Robust adaptation is considered to constitute adaptive management approaches,

[195] Guidance is sought from the MWR, particularly the CWC, as well as international organisations such as the World Bank, IWMI and the Asian Development Bank, as well as specialist international and national technical consultancies (AP10).

involving the increased use of water management strategies that are relatively robust to uncertainty, in addition to strengthening anticipatory over reactionary strategies (Stakhiv, 1998).

The mixture of supply and demand management strategies advocated by the ICAD is in line with the general recommendations of the IPCC Technical Paper on Water Resources and Climate Change (IPCC, 2008), which advocates a blend of both supply and demand options as adaptation to climate change, depending on local conditions (IPCC, 2008:63). The majority of the strategies advocated by CAD officials including irrigation efficiency (performance management and user group), groundwater management, hydrological data management and monitoring can be considered as robust adaptations to climate change (Wilby and Dessai, 2010; Hallegate, 2009; UKCIP, 2003). These strategies generally perform well under a range of possible scenarios in the face of uncertainty (Hashimoto et al, 1982). However, the infrastructure-based supply side strategies of the Jalayagnam programme represent a relatively less robust adaptation to reduced surface water runoff, as well as climate change impacts more generally (Appendix 3 for adaptation matrix). The infrastructure supply strategies as adaptation are irreversible, inflexible and static in nature (Hallegatte, 2009; Lempert and Groves, 2000), characterised by infrastructure 'lock in', heavy financial costs and relatively unknown performance under climate change uncertainty (Wilby and Dessai, 2010; Hallegate, 2009; Hashimoto et al, 1982).

Bottom-up adaptation approaches

An alternative method to scenario planning (IPCC, 2008) is what is termed as bottom-up approaches. This approach focuses on reducing vulnerability to past and present climate vulnerability, usually after an extreme event such as a flood or drought (Wilby and Dessai, 2010; Dessai and van der Sluis, 2007) (Section 2.4.2.2 for further information). The direct operational responses of the ICAD to the October 2009 flood event constitute bottom-up approaches. The institutional learning both during and immediately after the flood has somewhat reduced vulnerability to similar flood events in the future, in terms of the direct responses and procedures put in place by the ICAD. This confirms earlier findings by Tanner et al (2007), who found that flooding led to bottom-up approaches in the form of upgrading flood monitoring systems and improving dam safety analysis.

6.3.6.2 Water management decision framework

The timescale of climate change impacts should be considered when developing appropriate water management strategies and responses. In order to understand how different water management strategies have the potential to adapt to climate change impacts over varying timescales, a cross tabulation framework is adapted from Schulze (2011) (Table 6.2).

The timescale of climate change impacts varies significantly. Three timescales have been adapted from Schulze's (2011) decision framework. In the short term up to one week in duration, the weather impacts include extreme events such as the floods, droughts and cyclones. At the medium-term from six to twelve months in duration, the climate impacts include intra-annual precipitation variation, particularly changes in summer monsoon precipitation, seasonal drought (increasing seasonal water scarcity) and heatwaves. For the long term, 1-10 and 10-50 years and beyond, climate variations in annual and seasonal average precipitation and temperature, shifts in variability, as well sea level rise are categorised. Variations in surface water runoff (and hence water availability), evapotranspiration and river sediment yield are considered to mirror long, medium and short term climate change impacts, as a direct function of changes in precipitation and temperature.

Water management decisions can be classified into three broad categories: strategic, tactical and operational. The classification is based on the planning time-frame of the decision. Strategic decisions consider long-term aspects of water management, from years to decades. These include reservoir construction that will store water in years and decades, for instance, to meet growing demands from population growth and canal irrigation expansion; demand management interventions that can take years to implement in increasing efficiency of water use over the long-term, particularly if they involve changing human (e.g. farmer) behaviour; improving hydrological data collection, monitoring and database management to help make better informed long-term decisions; and further research and understanding of climate change impacts (scenario approach) in considering potential changes in precipitation and temperature impacting long-term water availability. Tactical decisions consider mid-term aspects of water management, within the year, on a seasonal and monthly timescale. These include management responses that deal with intra-annual variability, including summer monsoon precipitation and seasonal droughts, as well as managing seasonal water availability. The types of tactical decisions aim to mange water on a monthly time-frame. They include carry-over reservoir storage that can provide additional water during the summer (zaid) irrigation season or to urban centres in times of shortage; irrigation efficiency measures such as drip irrigation that can improve agricultural water use within an agricultural season, freeing up more water for further irrigation; groundwater recharge that can provide additional water for agriculture or drinking purposes, particularly in the summer season before the onset of the summer monsoon rains; improving hydrological data collection and management to better inform allocative decision during times of scarcity. Operational decisions operate on short-term timescales, within the week on a daily and even hourly basis. Such decisions are largely in response to extreme weather events such as floods or cyclones. They constitute responses that are more akin to disaster management than tactical or strategic mid to long-term water management decisions. Responses include flood management early warning systems; real-time hydro-metrological monitoring and flood assessment; dam safety analysis during peak capacity; and field relief operations such as the distribution of sand bags and boats to people affected by the flood or related extreme weather event.

Table 6.2: Water management decision framework for climate change impacts (adapted from Schulze, 2011)

Climate		**Weather**
Long term (1-10, 10-50 years and beyond) (eg. decadal changes in precipitation and temperature with climate change projections)	**Medium term (6-12 months)** Seasonal forecasts (eg. summer monsoon variation)	**Short term (0-7 days)** Real time – week (eg. flooding)
Strategic **Supply management** Jalayagnam programme • Water storage increase • Increase canal irrigation area • Inter-basin transfer • Dam break analysis (PMF) • Reinforce embankments/canals/weirs at critical points • Planning to incorporate CC projections into new infrastructure **Demand management** • 20% efficiency for the year 2017 Performance management/ impact assessment; and Water user group **Groundwater** • Regulation of extraction (enactment of AP Land, Water and Trees Act 2002) **Hydrological data and data management** • Hydrological data collection and monitoring, database management **Assess impacts of climate change n water resources** • Understand climate change impacts on water resources in the long term.	**Tactical** **Demand management** Improve irrigation efficiency Performance management/ impact assessment: • Benchmarking • Water Audits • Water Saving Technologies • Conjunctive use of SW and GW • GIS, remote sensing, satellite imagery • Water User Associations **Supply management** • Carry over reservoir storage **Groundwater** • Recharge and reduction in withdrawal **Hydrological data and data management** • Hydrological data collection and monitoring, database management	**Operational** **Flood management/warning** • Flood mmgt committee coordination during flood • Flood control centre • Flood warming and early warning systems; remote sensing, satellite imagery, GIS. • Real time hydro-meteorological monitoring during flood and all year round • Dam safety during peak operational capacity • Irrigation scheduling • Field operations (relief equipment to farmer orgs) **Hydrological data and data management** • Hydrological data collection and monitoring, database management

When considering the timescale of projected impacts of climate change in AP, the supply and demand strategies advocated by the ICAD, as well as the responses to the October 2009 flood, can be considered as potentially adaptive in relation to climate change impacts on different timescales (Table 6.2).

Strategic water management decisions align as potential adaptation to long-term climate change impacts, from 1-50 years and beyond. The supply management strategies under the Jalayagnam can be considered in this context, particularly increasing reservoir storage capacity and inter-basin transfer. Dam break analysis and reservoir safety can also be considered as long term strategic decisions. Furthermore, the 'consideration' (AP10) of how to incorporate long term changes in precipitation and temperature into the design of new infrastructure under the Jalayagnam programme can also be seen as a strategic consideration. The long term demand management target of increasing irrigation efficiency by 20% by 2017 through water user associations and the variety of performance and impacts assessment initiatives by the CAD can also be considered as strategic planning for the long term, particularly if water runoff decreases in future decades. The enactment of the AP Tree, Land and Water Act (GoAP 2002), specifically the enforcement of groundwater regulation curbing the high levels of aquifer extraction, can also be considered a strategic decision that could potentially adapt to long term changes in annual precipitation under climate change projections. A programme of improving hydrological data collection and monitoring, as well as establishing a hydrological database, will inform strategic decisions rewarding long term water management in river basins.

Tactical water management decisions align as potential adaptation to medium term climate change impacts, particularly changes in summer monsoon precipitation intensity and duration, crucial for the agricultural sector in AP. The promotion of carry-over storage in major and medium reservoirs could potentially adapt to mid-term (week to month) agricultural irrigation demands during the summer (zaid) cropping season, as well as to help meeting urban demands during the dry summer monsoons, especially if the timing of the onset and intensity of the summer monsoon becomes more erratic. The demand management options aimed at increasing irrigation efficiency could potentially adapt to intra-annual and seasonal precipitation variation. Performance management and assessment, particularly the benchmarking, water audits, water saving technologies, promotion of conjunctive surface and groundwater use, and the use of information technology (GIS and remote sensing). The inclusion and mobilisation of famers within the Water User Associations can also be considered a tactical decision to help deal with seasonal precipitation variation.   The promotion of groundwater recharge structures could replenish shallow aquifers for times of particular need if the onset and intensity of the summer monsoon becomes more variable. Hydrological data collection and database management at the seasonal timeframe is also an important tactical decisions, to aid informed decisions (e.g. allocation between sectors) based on accurate and reliable data

Operational decisions are directly relevant to the projected increase in intensity and frequency of extreme weather events such as floods, droughts and cyclones. ICAD’s operational response to the October 2009 flood is an example of operational decisions, including establishing and convening the flood management committee consisting of senior CW and CAD staff, who during a five day period took decisions on releasing water from reservoirs based water flow data relayed in real time. Early warning systems and data management utilising the use of field hydrological monitoring, remote sensing and satellite imagery is an appropriate operational response during the flood event. Furthermore, infrastructure sensors on dams or major irrigation canals during times peak capacity helped warn of the potential infrastructure failure. The collection and management of such real-time hydrological data facilitates informed decisions in short (daily and hourly) time periods. At the field level, irrigation scheduling and the distribution of relief equipment (sand bags, boats and lifejackets) can be considered appropriate operational response to help adapt to short term weather conditions resulting in a flood.

In conclusion, depending on the time-scale of climate change impacts being considered, different water management decisions can be identified and act as potential adaptations. Mid to long-term water management tactical and strategic decisions potentially adapt to climate change impacts on an intra-annual and annual timeframe. Whereas short-term operational decisions, more akin to disaster management responses, can potentially adapt to short-term climate change impacts in the form of extreme weather events.

6.3.6.3 ICAD organisational adaptation

Organisational adaption to climate change is an emerging field (Linnenluecke and Griffiths, 2012; WWDR, 2012; Dovers and Hezri, 2010; Somers, 2009; IPCC, 2008; Berkhout et al, 2006). There are very few insights into organisational adaptation to future climate change impacts from scenario planning, with the few existing studies based on retrospective assessments of extreme weather events such as floods and droughts (Somers, 2009). Organisations have been found to have difficulty adapting specifically to climate change owing to the weakness and ambiguity of impact signals and the uncertainty of benefits from climate change specific adaptation measures (Berkhout et al, 2006). However, theory suggest that strengthening organisational adaptation to climate change has many similarities with (non-climate change orientated) organisational learning and reform (Dovers and Hezri, 2010; Berkhout et al, 2006). Reform measures such as an overall IWRM approach including decentralisation, staff inter-disciplinarily, availability of resources (financial and human development capacity), flexible internal structures; in addition to processes to identify problems, establish priorities and mobilise and deploy resources accordingly are advocated (IPCC, 2008; Sutcliffe and Vogus, 2007; Merry et al, 2007; Bruneau et al, 2003).

The institutional reform measures adopted by CAD officials (IWRM, organisational convergence, river basin organisations, inter-disciplinary training of ICAD staff) constitute on-going non-climate change orientated reform initiatives, and also by their very nature, strengthen the adaptive capacity of the ICAD with regards to future climate change (Somers, 2009; Berkhout, et al, 2006). The uncertainty of future projections under scenario based planning is found to be a factor which limits more specific organisational planning (AP1, AP2AP 3, AP7, AP8, AP10, AP17, AP20; Somers, 2009). Only two (future) climate change organisational responses of the ICAD can be detected. Firstly, the retraining programme which aims to raise ICAD staff's awareness of climate change impacts, conducted by the CCCEA. And secondly, understanding future climate change impacts in AP with input from relevant organisations. However, tangible organisational learning can be detected in direct response to the October 2009 flood event as a retrospective assessment of past extreme weather events, in term of the organisational and operational responses by the ICAD during and immediately after the flood. This represents a bottom-up organisational adaption to climate change as a flood event (Wilby and Dessai, 2010). Such organisational learning includes the establishing and conveying the flood management committee, communication and sharing of information and data between the CW and CAD and convergence of operations; as well as operational responses such as increased flood monitoring, early warning systems and the programme of dam safety checks.

6.3.7 Conclusions

This chapter concludes in finding that the ICAD is adopting NWM Goals and using the plasticity of climate change impacts within its discourse to primarily support on-going large-scale infrastructure supply-side strategies of the Jalayagnam programme, in line with the sanctioned 'water for food' discourse to consolidate the state hydraulic mission. A number of factors are offered in explanation: the broad nature of the NWM policy, the plasticity of **c**limate change within the discourse, and the ICAD's fundamental resistance to change.

The NWM is a broad policy document and offers a large number of supply and demand management strategies, as well as institutional reform measures. This allows a degree of flexibility in interpretation and adoption, as well as offering national policy support, with senior CW officials primarily adopting supply-side approaches to support on-going infrastructure development strategies of the Jalayagnam programme.

CW officials are appropriating climate change within the discourse to further justify supply-side approaches. In no instance is a mid to long-term water management strategy advocated to manage primarily climate change impacts in AP, owing to the uncertainty of future projections, the limitations of scenario-based planning and the political importance of other factors (drivers) regarding the choice of water management at the river basin level. Instead, the plasticity of climate change (Hulme, 2009) is being mobilised to support the state-level sanctioned 'water for food' discourse to consolidate the state hydraulic mission. However, short term operational responses can be directly attributed to the October 2009 flood in AP, with tangible institutional learning resulting from this extreme weather event (Kingdom, 1984).

The underlying reason in explaining why primarily supply side strategies are being adopted from the NMW policy and the plasticity of climate change impacts is being used within its discourse as further justification for supply strategies is the ICAD's fundamental resistance to change its strategic outlook and water management approach. This confirms earlier findings documenting hydrocracies inertia and resistance to change, both in India (Mollinga, 2005) and internationally (Molle et al, 2009) within Mexico (Wester, 2008; Rap, 2004), Indonesia (Suhardiman, 2008), Thailand (Molle and Floch, 2008) and the Philippines (Panella, 2004). The ICAD's primary focus on supply strategies of the Jalayagnam programme represents an intended approach to consolidate its power base and control over water development and management in AP (Shore and Wright, 1997; Foucault, 1991). Numerous factors are identified in understanding the choice of supply strategy at the river basin level in AP, many of which are political in nature and serve vested interests of the state hydrocracy and aligned actors. The sanctioned 'water for food' discourse within the ICAD dominates the political waterscape, legitimising infrastructure supply-side approaches in consolidating the state hydraulic mission.

However, change can be detected at the margins of the ICAD. A handful of senior CAD officials are contesting the overall approach of the ICAD by adopting NWM Goals and appropriating climate change within the discourse to support on-going demand management and institutional reform measures, many of which build on the AP water reform launched in 1997 and re-strengthened in 2005. Many of the 'politically low cost' demand management and reform initiatives have been initiated and implemented since 2005, leaving the politically more challenging measures to be negotiated in implementation. Chapter 7 examines the implementation challenges of the demand and supply strategies, as well as institutional reform measures.

7.0 Challenges to implementation of supply and demand strategies and institutional reform measures in Andhra Pradesh

7.1 Introduction

This chapter examines the fourth research question at state government level: what are the challenges to implementing the demand and supply strategies and institutional reform measures adopted by the AP Irrigation department? Many of the challenges identified existed before the advent of the NWM policy and the threat of climate change impacts in AP. However, adoption of the NWM Goals by ICAD officials highlights numerous contemporary policy implementation challenges in AP. Section 7.2 addresses these challenges, considering how they affect demand and supply strategies, institutional reform measures, and mainstreaming climate change. The observations come from interviews with ICAD officials and also non-governmental water experts in AP. Section 7.3 discusses implementation challenges in relation to the theory of the interactive and linear policy process models. Political dimensions of policy implementation are discussed, in addition to other challenges relating to organisational inertia, technical constraints and financial limitations. Finally, the hydrocracy's approach is contextualised within the wider political environment to understand why it is largely permitted to continue its approach to water management.

7.2 Exploring the implementation challenges

7.2.1 Demand management

7.2.1.1 Irrigation efficiency

The CAD is targeting an increase of 20% in irrigation efficiency by 2017 (AP1, AP2, AP3). Since 2005, a number of politically low cost approaches are being implemented, including benchmarking, water audits, operation and maintenance of irrigation infrastructure, in addition to WUA. In order to increase efficiency further, a number of measures are advocated and considered important, including volumetric water allocation and pricing, shifting from water intensive cropping patterns, the farmer uptake of water saving technologies, and improving the efficiency of large irrigation systems[196]. However, implementing such demand management options including irrigation efficiency measures will be difficult, as stated by the CAD Commissioner when considering the balance between demand and supply management: 'so long as supply side is an option (e.g. the Jalayagnam programme*),* demand management is very difficult. When constraints around supply occur, only then take demand management seriously' (AP2). Constraints around supply management are not envisaged any time soon, owing to the Jalayagnam programme planning to provide water to the year 2020.

[196] Tangible irrigation efficiency measures were taken by farmers during the 2001-2004 drought in AP, characterised by widespread water scarcity. During these three years, farmers willingly shifted agricultural production to less water intense crops (away from rice and sugarcane), and took less productive land out of commission (Venot et al, 2008).

Volumetric water allocation and pricing

Numerous respondents at the national and state level, including ICAD officials, considered volumetric pricing for water allocation within irrigation systems as a method to increase irrigation efficiency at the overall system level (ND1, ND5, ND11, ND14, ND19, ND20, AP2, AP3, AP17, AP18, AP22, AP23, AP24, AP47). However, there are significant political, technical and financial challenges in implementing volumetric water allocation within irrigation systems in AP (AP1, AP2, AP3, AP21, AP22).

The financial price of canal water to farmers served by irrigation systems in AP is calculated on the basis of the crop water requirements (as a standard figure per crop throughout the state), multiplied by the area of crop grown at a seasonal timeframe in the kharif (summer monsoon), rabi (spring) and summer (zaid) agricultural seasons. For instance, during the kharif season, 500 Indian rupees are charged for water supplied to cultivate an area of one hectare of rice (AP2, AP23, AP24). Payment is made to the WUA in the majority of cases (AP3). Irrigation water is often supplied in excess to what is required at the field plot level, especially at the top and middle sections of large-scale irrigation systems during the kharif season when water is relatively abundant (AP3, AP23, AP24). This is due to operational mis-management of discharge volumes at the gates and weirs at canal system level, with water being supplied in excess, especially in the kharif season. Although discharges are monitored at major weirs at the top end of large canal systems, the precise volume being delivered at the field level is unknown due to the absence of accurate volumetric gauges measuring discharge (AP3, AP24). This, combined with absence of a price per volume of water allocated, often leads to over-allocation and inefficiency in use, particularly during the kharif season (AP3, AP23, AP24, AP30).

Political challenges in moving towards volumetric pricing should be understood within the wider populist electoral politics of the state. The large farmer constituent group have become accustomed to heavily subsidised canal irrigation water (AP3, AP23, AP24). From 1980 to 2000, irrigation subsidies rose in AP from US10 million dollars to US187 million dollars per year (Reddy, 2003), and are expected to have risen further in the last nine years, although no data were available from the AP government (Palanisami et al, 2011). Measures to move in the direction of volumetric water pricing of surface water within irrigation systems are resisted by farmers, and the issue is considered as an electoral policy position tantamount to political suicide for state politicians campaigning on populist policies to secure the influential farmer vote block (AP2, AP3, AP22, AP24, AP28, AP40, AP43; Palanisami, 2011; Gupta, 2010). Interviews with ICAD officials suggest there is general unwillingness of farmers to pay volumetrically for the water they use. An ICAD official claimed that volumetric water allocation is 'an overt attempt to improve water use efficiency and is perceived by the farmers as a reduction in supply and a fear to be perpetuated, leading to permanent deprivation' (AP2; similar responses from AP3, AP7, AP17, AP22, AP23, AP24, AP28, AP40, AP41, AP46).

Water sharing between the KRB's riparian states in the context of the on-going KWDT adds another political dimension to volumetric allocation. Measuring canal (and river) flows would lead to more accurate data and understanding of how much water is actually used within large irrigation systems in AP. Politically, it serves the interests of AP state government that this figure is ambiguous, so that the riparian states of Maharashtra and Karnataka do not know exactly how much water AP is consuming for agriculture, especially in the context of adhering to the legally binding allocative decisions made by the KWDT in December 2010 (AP24, AP26). Furthermore, within the content of the continued legal negotiations of the KWDT following the 2010 allocative decision, AP often cites the need for higher allocation of the KRB water's for irrigation expansion to serve agricultural growth to improve rural livelihoods and economic growth, particularly in the poorer Rayalaseema region (AP5; AP7; AP8). The ambiguous volume of water used within canal irrigation systems by AP allows flexibility within the KWDT negotiations, with the potential for the volume of water actually used to be downscaled to suit AP's position in the legal bargaining process to claim a higher state-wise allocation within the tribunal (AP22, AP23, AP25, AP26, AP27, AP34, AP38, AP46).

The high administrative costs and logistical arrangements required to measure and monitor canal water flows throughout large scale irrigation systems, deters the ICAD. Owing to the relatively low rate of financial return on irrigation water based on the area of crops grown, which barely covers essential operation and maintenance costs, the ICAD is cautious of making heavy financial investments (AP3, AP7, AP23, AP24, AP26; Palanisami et al, 2011). Furthermore, the collection of revenue from farmers directly by ICAD at the field level also poses challenges, even with the current attempt by the ICAD to move in the direction of devolving responsibility for financial collection charges to WUAs (AP26; Bolding and Mollinga, 2004).

Another major challenge in improving irrigation efficiency, in addition to reducing the total amount of water used in agriculture, is cropping patterns within AP, which is commonly referred to as the 'rice bowl' of India (AP3, AP7, AP8, AP23, AP24, AP28; AP29, AP31, AP37, AP39, AP40; Kondepati, 2011; Palanisami et al, 2011). Rice is the staple food of the state, with irrigated production centred on the coastal and delta regions. AP is the second highest state producer of rice in India after Bengal, producing 12.7 million tonnes in the 2010 agricultural year (GoI, 2012f). Rice accounts for 65% of the total irrigated area throughout the state, consuming an estimated 91% of all irrigated surface water (GoAP, 2010a, 2009; AP28). Rice is a highly water intensive crop, requiring 1800m^3 per hectare during cultivation, considerably greater than other staple crops growth in AP[197] (Appendix 28 for water requirement of crops grown in AP). Efficiency of water use during rice cultivation is especially low (AP2, AP23, AP24, AP28). Paddy (rice) fields often receive more water than is required during the kharif season, up to 50% in most cases, especially at the top and middle sections of large irrigation systems (AP3, AP 24, AP 28). The area under rice production has steadily increased, from 254,900ha in 1955 to 438,700ha in 2009 (GoAP, 2009). Owing to rice being the staple food for internal consumption supporting the livelihoods of millions of rural farmers within AP as well as generating income through export to other areas of India, it is difficult to shift away from mass rice production throughout the state (AP2, AP7, AP23, AP24, AP28, AP29, AP40). Furthermore, in the last decade the cultivation of water intensive crops such as sugarcane and cotton has proliferated. These cash crops command high economic returns but also require large amounts of water during cultivation (AP23, AP28, AP29, AP39, AP40, AP46).

[197] The major crops grown in AP include: rice (61% of total irrigated area), groundnut (4.7%), maize (4.5%), pearl millet (4.1%), cotton (3.5%), pulses (3.3%), sugarcane (3.2%), chillies (3.0%), fruits and vegetables (2.5%), cereals (2.3%), sorghum (2.1%) and numerous other crops (5.8%) (GoAP, 2009).

The adoption of water saving technologies by farmers at the field level within irrigation systems is widely viewed as an effective means to increase irrigation efficiency (AP24, AP23, AP24, AP28). Technologies include micro-irrigation, canal lining, over-land pipe distribution systems, sprinkler and drip irrigation. However, the initial financial outlay for such technology deters some farmers from adoption, in addition to the training required for operation and maintenance (AP24, AP28, AP29, AP39, AP40, AP43).

The inequitable distribution of water within large scale irrigation systems in AP was cited by numerous respondents as a challenge to improving water efficiency and use (AP2, AP3, AP22, AP23, AP24). Top and medium sections of canal systems often receive excess water owing to the poor maintenance of weirs and gates, particularly in the kharif season, leading to inefficiency in use. Whereas the tail sections receive relatively less water, particularly in the rabi and summer seasons, often insufficient water for the cultivation of one crop annually. The inequitable distribution within irrigation system is a factor contributing to the growing irrigation gap in AP (Figure 6.4) and has been well documented in India (Chambers, 1988).

The ICAD has pioneered the WUA approach since 2005. Although the initiative does have merit in terms of devolution of tax revenue collection and operation and maintenance of irrigation systems from the ICAD to farmer organisations, it is not without it criticism. A detailed study Bolding and Mollinga (2004) concluded that the reform initiative which also aimed at increasing irrigation efficiency, was captured by the power rural elite at the local level, perpetuating embedded rural power structures by primarily benefitting the farmer elites who own large areas of agricultural land in AP (ibid; AP26, AP39, AP40, AP43, AP46). The overall performance of WUA, although acknowledged that in principal have the potential to improve irrigation management, has been criticised for not delivering on objectives and ultimately favouring powerful land owners (ND8, ND11, AP3, AP17, AP22, AP23, AP26, AP39; GoI, 2011b[198]).

7.2.1.2 Groundwater management

The AP Land Water and Trees Act 2002 calls for the regulation of groundwater withdrawal throughout the state, as well as the promotion of groundwater recharge (GoAP, 2002), supported by ICAD officials. However, enforcing the act is fraught with challenges. There is a significant political dimension to groundwater management in AP through the provision of free electricity for groundwater pumping. During the 2004[199] and 2009 state general elections, in an effort to generate votes through popular electoral politics, electoral candidates were offering free hours of electricity to the large and influential farmer vote block in AP, as well to powerful industrial and urban lobby groups (AP3, AP15, AP22). The number of free hours of electricity offered by each candidate quickly became a politically charged issue during the 2004 and 2009 state election

198 A recent report by the Planning Commission's WGWR highlights the current status of WUA in India, including lack of administrative will to share responsibilities and work together with farmers, lack of political will to fix water charges to cover at least operation and maintenance cost, lack of bulk volumetric supply of water to farmer In addition, there are reasons like enforcement of discipline in water use among water users, abuse of positions by WUA leaders, politicisation of WUAs, heterogeneous groups and lack of cooperation (GoI, 2012c).

199 The National Congress party won the 2004 AP state general election on the agenda that it would alleviate rural poverty, focusing on promoting agricultural growth and alleviating high debts of farmers. As one of the key policy decisions, the state government announced free electricity for groundwater pumping to encourage agricultural growth. This policy continued when the same party was re-elected in 2009 (AP3, AP15, AP22, AP23, AP29, AP30, AP43; Kondepati, 2011).

campaigns, with candidates out-bidding each other in the run-up to the election. The bidding topped twelve hours of free electricity promised by the eventual winning National Congress Party (AP3, AP21, AP22, AP26, AP30). Once in office both in 2004 and 2009, the Congress Party kept their election promise[200] – retracting it would be tantamount to political suicide (AP3, AP23, AP30). Since 2004, there has been a surge in electricity demand to supply tens of thousands of diffuse pumps throughout the state. This led to both a significant increase in groundwater withdrawal leading to falling groundwater levels throughout the state, particularly within inland areas (AP15); in addition to a 30% increase in inefficiency levels in groundwater use for agriculture (AP15; Kondepati, 2011). It has also generated heavy electricity demand on the distribution grid, with numerous electricity black outs in rural and urban areas as AP Transco[201] endeavoured to manage the increase in demand (AP3, AP21, AP23, AP23, AP30, AP31).

The state government departmental arrangements for groundwater regulation are poorly coordinated, with responsibility shared by two departments at four separate administrative levels of state government. At the overall state level, regulatory responsibility lies with the Rural Development department, with technical and monitoring input from the Groundwater Department, and overall strategic advice from ICAD and the Water Management Committee. However, at the three subsequent lower tiers of state administrative government - the district, divisional and mandal tiers - the Revenue Department is responsible for overseeing groundwater regulation, with charges collected for groundwater extraction by the Revenue Officer of the Revenue Department at the mandal level in rural and urban areas. Under the AP Land, Water and Trees Act (GoAP, 2002), it is the responsibility of the Revenue Officer at the mandal level to enforce the ban on unauthorised groundwater withdrawal. However, the ban is very rarely enforced at the mandal level, owing to ad hoc favours for groundwater pumping and withdrawal by locally powerful land-owing farmers, characterised by corruption and local political favours (AP15, AP29, AP30, AP39, AP40). The cross departmental and multi-tiered arrangement for groundwater regulation characterised by lack of coordination, information sharing and communication, is not conducive to enforcing the ban effectively, perpetuating the unregulated nature of groundwater withdrawal throughout the state.

The administrative costs of regulating groundwater withdrawal are considered very high in AP (AP2, AP3, AP7, AP12, AP15, AP22, AP23, AP24, AP30; AP31; AP39; Shah, 2009). Groundwater regulation would entail volumetric metering of groundwater withdrawals, including monitoring and revenue collection for tens of thousands of diffuse individual pumps and borewells throughout the state (AP15). Establishing this would require high costs in terms of the financial investment required to establish groundwater meters, logistical arrangements and administrative costs at the different levels of state administration. Considering the relatively low charge and financial recovery through volumetric metering, the state government is very cautious to pursue this strategy (AP15, AP30). Alternative methods for regulating groundwater indirectly include the installation of a separate electricity cable to serve groundwater pumps (which runs into high

[200] This policy has costs the AP state government approximately $1 billion US dollars (45 billion Indian Rupees) a year since 2009, or 4% of the total state budget (Kondepati, 2011).

[201] AP Transco or the Transmission Corporation of Andhra Pradesh Limited, is a joint public-private company that manages electricity generation and distribution throughout AP, established in 1999 by the part privatisation of the AP State Electricity Board.

transaction costs of cable installation with little relative financial return) or for the state government to change their policy of granting free electricity to framers who use groundwater more efficiently through crop rotations, drip irrigation, micro irrigation or systems of rice intensification (AP15). However, owing to the high political currency of free electricity to secure the large farmer vote block and the above mentioned factors, the policy is unlikely to be rescinded in the short to medium term (AP15, AP21, AP22, AP30, AP31, AP39, AP40; Kondepati, 2011)

With regards to farmers and individual user adoption of groundwater recharge - as advocated in the AP Land and Tree Act 2002 - the initial financial outlay required for materials, construction and maintenance training deters government investment (AP15, AP30). Furthermore, groundwater is considered as a 'common and collective pool resource' by many users, leading to a mentality and practice of maximum withdrawal and inefficiency of use (AP15, AP22, AP30).

7.2.1.3 Hydrological data and database management

The CAD's adoption of NWM Goal One focuses on digitising hydrological data for irrigation projects and establishing a hydrological database; in addition to strengthening operations in hydrological data collection, remote sensing, GIS and satellite imagery (AP2, AP3, AP17). Interviews with ICAD officials and non-government water experts in AP highlighted numerous challenges as reviewed below.

Hydrological data accuracy, availability and sharing

The accuracy of official government published hydrological data is questionable. Interviews at state level revealed that hydrological data is suspected of often being manipulated to suit project objectives, to serve wider political agendas in the expansion of large scale water supply infrastructure (AP3, AP21, AP22, AP23, AP24, AP25; AP46). An example is the claim that the LGRB has 22.5BCM of surplus water available. The accuracy and validity of this figure is crucial in justifying the Jalayagnam programme, particularly as a third (7.5BCM) of this surplus water is planned for lift irrigation and large-scale infrastructure development projects. Interviews with respondents within and close to ICAD question whether there really is 22.5BCM of surplus water within the LGRB, with respondents claiming that the figure could be significantly lower in reality (AP3, AP22, AP23, AP24, AP31, AP36, AP40, AP42), in the region of 6-10BCM (AP3, AP31). The figure of 22.5BCM surplus water originates from a report by the MWR (GoI, 1999), reproduced by the CWC (GoI, 2009a) and entrusted by the ICAD (GoAP, 2010a). There has been no independent examination regarding the amount of water available in the LGRB, with river flow and groundwater data residing within the ICAD, and requests from external organisation for historic and/or present data hydrological data refused by the ICAD (AP25, AP23, AP35, AP36; Smakhtin et al, 2007). Furthermore, the accuracy of hydrological data regarding the total amount of water stored in large, medium and small reservoirs in AP is also questioned, with no widely accepted figure available (AP21, AP22, AP23, AP31, AP39, AP42, AP43, AP46), although the CWC has published the gross volumes of the large and medium sized reservoirs in AP (Figure 4.17).

There exists a general air of secrecy within the ICAD regarding hydrological data (AP3, AP21, AP22, AP23). Although the ICAD has made some data available to the public on its website, what is revealing is the data that are not made available to the public. Total reservoir volume capacity in AP (major, medium and minor reservoirs) and volumetric river and canal flow data are not made available to the public, or shared with external organisations or individuals (AP3; AP23, AP36). This severely limits independent assessment and water accounting at the river basin and sub-basin level, as well as for irrigation projects and systems (AP3, AP21, AP22, AP23, AP25, AP46). Any hydrological data that is provided by the ICAD for independent assessments or reports, issues of accuracy remain (AP23, AP26, AP31). The lack of data availability and questions over accuracy should be understood within the wider context of the inter-state Krishna river basin, shared by riparians Maharashtra, Karnataka and AP. The Krishna Water Disputes Tribunal (KWDT) deliberated its second inter-state allocation in late 2010, upon which, at present (late 2012), is being legally contested by all three states. Data on reservoir storage capacity and actual volumes in the LKRB are cited by AP in the case of the LKRB and the other riparians to substantiate their claims for a higher proportional allocation of the Krishna basin's water resources. It is suspected that volumetric river flows and annual reservoir storage volumes are often reduced by AP and other riparian states to justify their claim for a higher allocation of shared water resources (AP3, AP21, AP22, AP25). Neither state wants the other to know exactly how much water it has or uses, with some respondents claiming an under-estimate of total water usage, to strengthen each states' claim for a higher proportion of the basin's total water resources (AP3, AP5, AP21, AP22, AP23, AP26). Similar data secrecy and accuracy findings are documented at the Indian national level (Section 5.3.4). Furthermore, data sharing between state government departments working on common water projects is limited (AP3, AP17, AP18; AP23), and competition for project- based funding from the AP Revenue Department and at the national level, limits data sharing (AP3, AP17, AP21, AP22, AP23, AP24, AP26, AP36, AP46). This is compounded by the fact that much hydrological data have been recorded in paper format, which does not lend itself to easy dissemination and sharing (AP3), and exemplifies a fragmented sectoral approach by different government departments working on common water projects (AP3, AP14, AP15, AP16, AP17, AP21, AP22, AP23, AP35, AP45, AP46).

Digitisation of data

The vast majority of hydrological data are recorded and stored on paper records within the ICAD, although since 2005 the switch over to digital format has begun (AP2, AP3). The main challenges to digitising the data, particularly historic data over the last few decades, is the large amount of time it takes and the required ICAD staff hours input (AP3). The process of digitisation is on-going within the CAD, but the process is slow and will take a significant amount of time (AP2). Data is in paper format also limits data sharing between government departments (AP2). However, the ICAD has made some progress in recent years, in the use of information technology, including GIS, satellite remote sensing and mobile technology to monitor reservoir levels, river and canal flows. A significant amount of 'non politically sensitive' data are made available for external use, primarily via the ICAD website[202], covering a wide range of parameters including river-basin physiographic characteristics, irrigation area created and utilised in AP, crops cultivated, meteorological data, surface and groundwater status of the Krishna River Basin, Godavari Rover Basin and Pennar Basin.

7.2.2 Institutional reform

7.2.2.1 Integrated Water Resources Management

As noted in Chapter 5, Integrated Water Resources Management (IWRM) has been included for the first time in state water policy (GoAP, 2008). However, although aware of the general principals of IWRM and viewing it as supporting the reform agenda initiated since 2005 (AP2, AP3), ICAD officials are uncertain how to actually operationalize the concept in realty (AP1, AP2, AP3, AP7, AP17). ICAD officials consider that on-going initiatives in demand and supply management, as well as institutional reform measures such the formation of the WMC and APWRRC, constitute IWRM. ICAD officials are not considering changing the current practices in light of IWRM, but to apply the concept to on-going operations at state level (AP1, AP3, AP7).

7.2.2.1 State government cross-departmental convergence

Numerous state government departments are involved with water management in AP (Table 4.2). Historically and to the present day, this has led to a fragmented approach, characterised by lack of coordination and communication, competition for project funds, lack of data and information sharing, and duplication on cross-cutting water programmes and projects (AP3, AP13, AP14, AP15, AP16, AP17, AP18, AP21, AP22, AP23, AP26, AP46; Saleth, 2004). The root of this lies in the specific sectoral approach by state departments, with each primarily focused on their own objectives with regards to cross-cutting water projects, ultimately serving departmental self-interests[203] (AP1, AP2). There exists a degree of inertia by departments in considering and their specific objectives in an integrated approach on common water projects (AP3, AP12, AP13, AP14, AP15, AP16, AP17, AP21, AP23, AP40, AP44, AP45). The highly bureaucratic, hierarchical and centralised structure of departments, including the ICAD, does not lend itself to an integrated approach (AP2; AP3, AP17, AP22; Bolding and Mollinga, 2004). Furthermore, undercurrents of departmental rivalry and competition, particularly to secure project funds (from government or international donors) and staff promotion, does not foster a conducive environment for collaboration and integration (AP3, AP12, AP14, AP15, AP16, AP17, AP23, AP26, AP44, AP46). Similar research in India concluded that many states have diffuse or unclear administrative and functional responsibilities unsuitable for developing an integrated approach to water management (Saleth, 2004). In this regard, the WMC was established to serve as an apex body to bring together representatives of state departments working on water management, to facilitate an overall integrated approach (AP1, AP2, AP7).

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[202] ICAD website: http://irrigation.ap.gov.in/ and http://www.apwaterreforms.in/index.html [accessed on 21 December 2012].
[203] Rivalry between the ICAD and AP Department for Agriculture was mentioned by numerous respondents as being particularly competitive (AP2, AP3, AP7, AP13, AP17, AP20, AP23, AP24, AP46).

Internal inter-play within the ICAD

The two sub-departments (or wings) of the ICAD have their own particular objectives and responsibilities. The CW focuses on the construction of infrastructure, whilst the CAD on demand management and institutional reform measures (Section 4.2.4). Although the organisational objectives are different, there is a degree of overlap on common strategic direction, particularly in support of the Jalayagnam programme. After irrigation and reservoir infrastructure are constructed by the CW, the project is passed to CAD to plan and implement operation and maintenance programmes, water efficiency and other demand management issues.

Interviews with senior ICAD officials and respondents close to the government revealed a degree of underlying tension between the CW and CAD, in terms of the differing strategic outlooks. The CW focuses on the historically established large-scale supply side operations that have been the ICAD's strategic direction since independence. Whereas the CAD, although committed to the supply side approach of the Jalayagnam programme (AP1, AP2), is endeavouring to usher in new thinking and approaches to implement effectively water demand management and reform initiatives. The exchange of information, data and communication on projects and programmes between the CW and CAD is somewhat limited, often left lacking in effectiveness (AP3, AP11, AP12, AP13, AP17, AP20, AP23, AP26, AP44, AP45). The exchange of information and data between operational units internally within the CAD is fairly effective (Figure 4.1), although 'externally' to the CW is somewhat limited and on an 'ad hoc favour basis' (AP3, AP11, AP12, AP17, AP44, AP45). Collaboration between the CW and CAD is not helped by the physical separation of their respective offices in Hyderabad, the state capital of AP. The CW office is located in the State Government secretariat building in central Hyderabad, whereas the CAD office is located a few kilometres away.

Dominance of engineering professionalism

CW and CAD officials mentioned the dominance of the 'engineer professionalism' within the ICAD department, with civil engineers seeking to retain their status, influence and ultimately their power in continuing to design and building irrigation infrastructure in the belief that it is the primary way to manage water in AP (AP1, AP2, AP3, AP6, AP7, AP9, AP10, AP11, AP12, AP13, AP17, AP18, AP20, AP44, AP45; Bolding and Mollinga, 2004). Engineer professionalism is rooted in career-long technical training in irrigation engineering, a sectoral focused conviction that infrastructure construction and supply-side approaches of the Jalayagnam programme are the most appropriate strategy to manage water scarcity and increase food production throughout the state (AP1, AP7, AP9, AP10, AP20). ICAD staff consider their prime role is to focus on their disciplinary training, that of irrigation engineering. As highlighted by the NWM policy with reference to the re-organisation of the ICAD and the fundamental orientation of staff: 'departments of the state may change from Irrigation to Water Resources or similar, but the personnel of the line department are unlikely to get unshackled from the history. Instead, they may merely lay down conditions to protect their historical responsibility towards agriculture' (GoI, 2009b:54).

In terms of an inter-disciplinary approach, ICAD staff are of the view that other related aspects of natural resource management (forestry, soil science, social sciences, meteorology) are the prime responsibility of another departments within state government (AP2, AP3, AP9, AP10, AP12, AP13, AP20), which in turn severely limits communication and exchange between government staff of other disciplines. This relates to earlier research findings in Pakistan, where 'caste-like' relations exist between staff of different disciplines and departments of government, characterised by a lack of communication and cross disciplinary sharing (Velde and Tirmizi, 2004). Furthermore, the ICAD is dominated by male irrigation and civil engineers, an unequal gender bias characteristic of the irrigation engineering professionalism, with little internal incentives to change staff profiles to promote human resource diversity (AP3, AP12, AP13, AP17; Bolding and Mollinga, 2004).

The scope for inter-disciplinary within the ICAD is limited and does not include wider non-water based environmental issues (AP3, AP12, AP13, AP17, AP23, AP26). Whilst sectoral technical specialisation and competence is also required in order to carry out engineering-based tasks, a degree of awareness and consideration is also required to place a particular sectoral specialist approach within the wider water and national resource management context. Facilitating and encouraging engineers to look beyond their professional career-long training is a significant challenge - particularly as there are few incentives offered by government (Bolding and Mollinga, 2004) - which requires willingness at the individual level coupled with effective training programmes and incentives (Israel, 1987). Re-training programmes in Pakistan, the Philippines and Mexico were found to be largely ineffective during the first (monthly) period of re-training, with staff members largely resisting adopting a more inter-disciplinary approach (Bolding and Mollinga, 2004). A programme designed to facilitate re-training on a long-term timescale with existing engineers along with appointing new staff with a more inter-disciplinary professional background, is more likely to promote successful and enduring reform within ICAD (AP3, AP12, AP13, AP17, AP21).

Tenure of state government positions

Under the employment system of the GoI, state government staff can apply or be transferred to different position, either within or to another state department. The average retention period for senior staff in position is five years, and up to eight in some cases. Staff can either apply for a vacant position usually in search of promotion, or can be transferred by a high-ranking staff member if considered appropriate. The issue of government tenure, particularly the relatively short residency of posts when considering that institutional reform is a long-term term process, is a limiting factor in retaining reformist actors in posts, strengthening human resource capacity and moving internally driven institutional reformist agendas forward. This is particularly the case if a reformist staff member either decides to take a more lucrative and higher paid job in a different department[204], or is transferred by a more senior staff member. The potential loss of a

[204] Different state government departments are considered more 'problematic' than others (AP1, AP2, AP3, AP7, AP12, AP17, AP20, AP44). Water management, including irrigation, is notoriously challenging, with competing requirements from a variety of users covering the multitude of disciplines that water management encompasses. 'There are so many claims and demands on water from all sectors and people in Andhra Pradesh and that is it virtually impossible to keep everyone satisfied all of the time, with many problems arising each day it is very difficult to balance everything' (AP2; similar quote from ND3 at national level). Education and health departments are generally considered the relatively least problematic and most lucrative positions in state government (AP1, AP2, AP3, AP22, AP23, AP27).

particularly dynamic reformist staff member in this manner can slow-down and deflect long term human resource development of the ICAD, and ultimately be used to deflect or resist internally-driven reform (AP3, AP17, AP22, AP23, AP26, AP44).

7.2.2.4 River basin organisations

Interviews with ICAD officials acknowledged that there exists a need for a holistic river basin organisation for the entire Krishna River basin (KRB) (AP2, AP3, AP5, AP7, AP8, AP10, AP13, AP17, AP18, AP20). However, it is considered both politically and legally unfeasible owing to on-going disputes between the three riparian states over the shared KRB's waters (AP2, AP3, AP5, AP7, AP23, AP24). After years of assessment and legal wrangling, in December 2010 the KWDT made its second formal decision on the allocative rights of each state (Section 4.3.3.1). In the years preceding the 2010 decision and at present with AP and Maharashtra legally contesting this decision, a general air of mistrust and secrecy surrounds negotiations and interactions between the states regarding allocative basin rights (AP5, AP23, AP26). A functioning river basin organisation by definition is founded on unrestrained and effective communication and coordination, data and information exchange, and joint project planning and implementation (ADB, 2009). The highly charged inter-state political and legal climate surrounding the KWDT is not conducive to establish KRB organisation (AP5, AP23, AP26). Furthermore, the KWDT legal mandate rests at the highest level in Indian jurisdiction, with the Supreme Court in New Delhi. A KRB organisation as a platform for negotiation would have no legal mandate and be largely redundant, with highly contested decisions being referred back to the Supreme Court through the KWDT (AP26).

7.2.3 Supply management

Jalayagnam programme

The ambitious Jalayagnam programme faces numerous challenges in implementation. This is witnessed in the relatively slow progress to date in completing the 86 projects originally planned in 2004. From 2004 to 2011, only 12 projects have been completed, with a further 74 on-going in various stages of design and construction. And of those 12 completed projects, they were all on-going prior to the launch of the Jalayagnam in 2004 (GoI, 2012e).

Lack of sufficient funds is a major challenge to the ICAD in pursuing all of the projects under the Jalayagnam programme (AP1, AP2, AP3, AP6, AP7, AP8, AP9, AP10, AP23; GoI, 2012e). As of April 2011, US $12.5 billion dollars[205] has been spent on the programme since 2004[206]. The state government is the principal funder of the programme, although up to 25% of costs for major and medium irrigation projects can be allocated from national government through the AIBP. From 2007 to 2011, $1.07 billion US dollars were granted to the ICAD from national government through the AIBP for 33 major and medium irrigation projects (MoWR, 2011).

[205] Equivalent to 686 billion Indian Rupees.

[206] A regional breakdown includes $4.6 billion US dollars in Telegana, $2.8 billion US dollars in Rayalaseema, and $5.1 US billion dollars in coastal AP (GoI, 2012e).

Furthermore, if the Polavaram Project is declared a national project, the ICAD will receive 2 billion US dollars to fund it. The AP state economy has witnessed a relative downturn in economic growth, linked to the wider global recession from September 2008 onwards. A recently released report by the Comptroller and Auditor General of India (CAG) states that the ICAD's decision to implement all of the Jalayagnam projects simultaneously in the immediate years after 2004 put huge financial demands on the Revenue Department, which the state finances cannot sustain[207]. As stated by the CAG report: 'the state government is saddled with a huge number of projects which are nowhere near to completion. The financial burden of these incomplete projects on the state exchequer will be felt for a long time to come' (GoI, 2012e:52). Owing to the lack of funds to finance all 74 remaining Jalayagnam projects, the Chief Minister in consultation with the State Revenue Department limited state funding to $5 billion US dollars[208] for the period 2010 to 2013. The ICAD has prioritised 43 projects (33 major and 11 medium projects) for completion in 2013, which will create an additional 1.7 million hectares of irrigated area and stabilise supply for existing projects (GoAP, 2012).

Allegations of corruption within the Jalayaganm programme have been made in recent years. On the request of the Prime Minister's Office in New Delhi, corruption allegations are being investigated, with former AP Major and Medium Irrigation Minister Ponnala Lakshmaiah called to explain certain financial mismanagement and irregularities. Corruption charges included unaccounted funds for projects, payment to private contracts for incomplete or no work completed, and the manipulation and destruction of records (Utsav, 2010). Significant funds have been lost to corruption since 2004, characterised by excessive payments for work and fraudulent claims by contractors and middle men, with a recent newspaper article referring to the Jalayagnam programme 'as the mother of all frauds' (ToI, 2012). It is estimated by a key respondent outside of government that as much as 40% of the budget for large scale infrastructure projects are lost to corruption at different levels of operations and interactions (AP26). Corruption and rent seeking behaviour of irrigation departments with regards to large scale irrigation systems has been documented by Wade (1982) and Vaidyanathan (1993) in India, and also internationally by Molle et al (2009), Briscoe (1999) and Repetto (1986). Furthermore, the CAG report finds that the ICAD awarded contracts to favoured contractors in a non-transparent manner, without any assurance of on completion of projects within the envisaged time and budget[209] (GoI, 2012e).

The energy requirements for the 31 lift irrigation projects, once fully operational, is estimated to be 9,000MW, 75% of the states current electricity supply (AP3, AP7, AP8, AP17, AP35). AP is a power deficient state, reliant on the national grid and energy imports to meet rising demands. Numerous non-government respondents were highly critical of the vast electricity requirements (AP21, AP22, A24). Either the state will not be able to fully power all of the lift irrigation projects in which case they will remain redundant once constructed, or it will have to import further energy at significant cost. This is considered as a major challenge in

[207] It is estimated that irrigation-based expenditure accounts for 10% of AP's state budget in recent years (Palanisami et al, 2011).
[208] Equivalent to 294 billion Indian rupees.
[209] The AP Irrigation Principal Secretary countered these findings, in stating that 'the report has made sweeping statements without going into the deeper ground realities. The CAG believes in a step-by-step process whereas the government believes in a parallel process' (Down to Earth, 2012).

implementation once constructed (AP2, AP3, AP7, AP17, AP21, AP22, AP23, AP28, AP31, AP35, AP36, AP39, AP40, AP41, AP42, AP44, AP45, AP46; GoI, 2012e).

The construction of new major and medium irrigation projects and reservoirs under the Jalayagnam programme should also be considered within the wider political context of KWDT. With on-going legal wrangling over the KWDT's second allocative decision in 2010, AP is very conscious that any new projects will be carefully scrutinised by the riparian states in terms of AP's allocative rights and internal use of water resources (AP3, AP5, AP23). The examination of major projects and the process of negotiation within the KWDT is time consuming, especially if concerns over the viability of new major projects are raised by the riparian states of Maharashtra and Karnataka (AP3, AP5, AP23, AP26).

National level government (MWR and CWC) has a degree of influence over state level water management and development. For all major and medium irrigation projects funded by the AIBP, upon which AP is increasingly reliant owing to financial restraints within AP, technical approval has to be sought from the CWC before finances are allocated by the Planning Commission and construction can begin. This process can be time consuming, waiting for technical clearance, which can lead to delays in project development and construction on the timescale of years (AP2, AP3, AP7, AP9, AP23).

On-going-legal disputes between AP, Orissa and Chhattisgarh over land submergence upstream of the Polavaram inter-basin transfer project have hampered and slowed down the planning and construction of infrastructure (AP3, AP7, AP8, AP12, AP17, AP20, AP22, AP44). Owing to the river basin topography, the inundation of the land within these neighbouring is difficult to avoid (AP3). Furthermore, civil society and numerous environmental NGOs in AP oppose the project owing to human displacement, environmental degradation, corruption, loss of habitat, technical and safety issues (AP21, AP22, AP23, AP25, AP31, AP32, AP37, AP38, AP39, AP40, AP41, AP42, AP43, AP46; Gujja et al, 2006).

7.2.4 Mainstreaming climate change within water management in AP

This section introduces the new challenge that ICAD faces in mainstreaming climate change within water management.

7.2.4.1 Understanding climate change impacts on water resources

The ICAD has no internal technical capacity to assess the impacts of climate change in AP, in terms of climate change models and projections. Although the ICAD has made significant progress within the realms of information technology with GIS, satellite imagery and remote sensing technology, it has not itself examined climate change projections within the state. The ICAD receives technical expertise is sought from a variety of organisations. Primarily at the Indian national level from the Indian Institute of Tropical Meteorology for meteorological models (ND22, ND23), the Indian Institute of Technology in New Delhi for surface water runoff projections and water availability at the river basin level (ND6). Furthermore, technical advice is sought and provided by international actors such as academia (University of Melbourne, AP32), the World Bank (ND24) and internal organisations such as the International Water Management Institute (AP23). It is envisaged that under the forthcoming State Climate Change Action Plan aimed to be finalised by 2018, higher resolution climate change models (25x25km) will be developed for AP (AP2, AP13), upon which scenario based planning could be undertaken; and in response to the inherent limitations this approach, the development of robust water managing practices can be deployed, as discussed in Section 6.3.6.

7.2.4.2 Incorporating climate change projections for new reservoir design

The October 2009 flood event in AP raised concern about climate change within the ICAD. Although there was no significant infrastructure failure (AP1, AP2, AP3, AP7, AP8, AP9, AP10, AP12, AP20), consideration is being given to how to design reservoirs to cope with the decadal variations in precipitation and to withstand extreme weather events.

Reservoirs under the Jalayagnam programme are designed to an average life-span of 50 years; whilst many climate change projections consider impacts over a longer time horizon, up to 80 and 100 years in the future (AP7, AP9, AP10; ND6, ND23). Such a planning timeline discrepancy in reservoir design is not conducive to encompass the long term range of climate change projections (AP10). Furthermore, the inherent uncertainty of climate change models leaves reservoir designers unsure how to proceed (IPCC, 2007), which in turn, leads to inaction and lack of long term future planning (AP10). However, the October 2009 flood event did raise the issue of incorporating climate change projections into new reservoir designs, which can be considered as a positive development. However, although the Chief Engineer of the Central Design Office in the CW admitted that he would 'consider it' (climate change), he was unsure how to take it forward in tangible design and planning, and hence would wait for further guidance from relevant organisations (AP 10). Reservoirs under the Jalayagnam project are planned for completion by the year 2020 at the latest, and some by 2013. There exists a window of three to eight years to incorporate climate change projections into reservoir design for the Jalayagnam programme, before infrastructure lock-in (Hallegate, 2010). An alternative would be to design infrastructure along the lines of robust water management approaches, specifically to include percentage storage safety margins for reservoir capacity (Section 6.3.6.1). However, at present, this is not being done whilst waiting for guidance from relevant organisations and experts (AP7, AP8, AP9, AP10, AP12).

7.2.4.3 Climate change awareness and inter-disciplinary re-training of ICAD staff

A significant challenge to inter-disciplinary training of ICAD staff is the rigid disciplinary-focused engineering professionalism (AP3, AP12, AP13, AP23, AP26). The nature of climate change impacts on ground and surface water hydrology, lends itself to a broad inter-connected system level understanding and approach to water management. Training workshops advocating a new approaches to encompass a more holistic view of water management including agriculture, drinking water, industry, forestry, soil science, meteorology, climatology and livelihoods, are being carried out by the Centre for Climate Change and Environment Advisory (CCCEA), established by the government of AP in 2010.

According to the senior capacity building trainer at the CCCEA, so far such training has met with limited success (AP 13). The vast majority of the staff at the mid to lower level of ICAD are career long established engineers (Chief Engineer, Superintendent Engineer) (Appendix 3 for top, mid and low level hierarchy of ICAD). Interviews revealed that the vast majority of the staff attending the workshops are seemingly unable or unwilling to embrace more inter-disciplinary approaches to encompass wider perspectives and linkages beyond irrigation and surface water management (AP13). Interviews with the senior workshop trainers revealed the rigid focus of many participating engineers, strongly fixed on their personal belief of the 'true value' of irrigation engineering approach in supporting agriculture and livelihoods, defined by irrigation expansion and increasing water storage capacity to increase state food production (AP12, AP13; Mollinga, 2005). According to CCCEA staff, ICAD engineers are of the opinion that other thematic areas of water management (forestry, soil science, meteorology) covered by the re-training workshops, are the concern of the appropriate staff in other state government departments, and not an issue for ICAD staff (AP13, AP12, AP18). As captured in the quote from the CCCEA trainer: 'many of the irrigation department staff at the training workshops are quite rigid in their disciplinarian belief, grounded in decades of irrigation engineering professionalism, and are unwilling to seriously consider other related and inter-connected environmental aspects that are not within the strict remit of their professional focus and job' (AP12). This confirms similar findings in Pakistan, where 'caste-like' relations between different disciplines with and between organisations limits inter-disciplinary exchanges and approaches (Velde and Tirmizi, 2004).

7.2.5 Summary

The challenges identified in implementing the demand and supply strategies, as well as institutional reform measures, are summarised in Table 7.1.

Table 7.1: Implementation challenges for the supply and demand management strategies, as well as institutional reform measures. The types of challenges are broadly classified for clarity, discussed further in Section 7.3.

WRM strategy	Challenge	Details	Type of challenge
Hydrological data and database management			
Hydrological data collection, monitoring and sharing	• Data accuracy • Data secrecy including lack of data sharing between state government departments and externally to non-government organisations and individuals	• State government departments manipulate data to suit project objectives in serving wider political agendas • Inter-state tension between riparians, data secrecy, especially regarding on-going KWDT	Political Political
	• Lack of digital hydrological data and digitisation process	• Lack of staff manpower and time process	Organisational

Irrigation efficiency			
Increase canal irrigation efficiency by 20% and halve the irrigation gap by 2020	• Lack of volumetric water allocation in large scale irrigation systems • Volumetric pricing of water allocated	• Populist electoral politics - the political importance of large farmer vote block for state elections • Relative unknown volumes of water use within large irrigation systems serve AP's political interests in KWDT negotiations • Popular politics to appease famers who are unwilling to pay full price of irrigation water. Farmers expect water to be heavily subsidised by government leading to inefficient of use in irrigation systems • High financial and logistical cost for ICAD of establishing measuring, monitoring and control water flows in canal irrigation systems.	Political Political Political Financial
	Widespread cultivation of water intensive crops with low water use efficiency, particularly rice	Dominance of rice (65% of all irrigated area and 90% of all irrigated water in AP), and move towards water intensive crops, sugarcane and cotton, in recent years.	Economic, political
	Gradual (slow) progress of framer uptake of water saving technologies	Initial financial cost and training required, social learning	Technical
Groundwater management			
Sustainable groundwater use and management	• Enactment of the AP Land, Water and Trees Act (2002) • Unregulated groundwater extraction • Lack of groundwater recharge	• Popular electoral politics - political aspect of free electricity for groundwater pumping to secure the large farmer vote in state and district elections • High financial transaction cost to monitor and regulate GW extraction throughout AP • State department uncoordinated groundwater regulation and collection of fees, fuelling corruption and political favours at the mandal (local) level • Initial cost to state government outlay of material and training for groundwater recharge structure	Political Financial Organisation, political Financial
Supply management			
Jalayagnam project overall (irrigation expansion, increasing storage, inter-basin transfer)	• Funding • Corruption • Energy requirements • Project completion • Inter-state water sharing tension • Nation government clearance for AIBP projects • Non-government opposition to inter-basin transfer	• Severe lack of state finances to fund all of the 86 projects • Mass corruption with up to half of total cost lost to fraud • Huge energy requirements for lift irrigation projects, requiring 75% of AP's entire electricity • Project construction running late owing to project mismanagement • Political tension between KRB's riparian states over shared waters, all new major projects subject to examination through the KWDT • National level (MWR/CWC/PC) control over state through funding major projects • Non-government contestation of inter-basin transfer (Polavaram) on ground of land submergence, loss of ecology and habitat, human displacement, corruption, lack of comprehensive environmental assessments, and government corruption	Political Financial Technical Project management

Institutional reform			
IWRM	IWRM concept poorly understood	Unclear how to operationalise IWRM concept. Consider on-going supply, demand and institutional reform measures constitute IWRM.	Organisational
State government convergence	• Fragmented approach of state govt departments working on water issues • Underlying tension between CW and CAD within ICAD: issues of communication, data/information sharing.	• Lack of coordination and communication • Lack of information and data sharing • Competition for project funds • Duplication on cross-cutting water projects	Organisational Political
Inter-disciplinary re-training of ICAD staff	Single sector focus of engineers, largely unwilling to consider inter-disciplinary issues	• Rigid focus on engineering approach to manage water scarcity, lack of interdisciplinary approach beyond engineering • Dominance of engineering professionalism • Government staff tenure	Organisational
River basin organisation	Inter-state political and legal tension over shared KRB water disputes	• Lack of coordination, communication and data sharing (including data accuracy) owing to on-going KWDT legal wrangling • Political tension between riparian states	Political
Climate change related challenges			
Understanding climate change impacts on WR in AP	ICAD lack of technical understanding and knowledge regarding climate change projections and hydrological models	None existent capacity within ICAD	Organisational Technical
Infrastructure planning for climate change projections	Lack of understanding how to integrate climate change projections into infrastructure design through scenario based planning	Unsure how to carry out scenario based planning in encompassing inherent model uncertainty	Technical Organisational
Climate change awareness and inter-disciplinary retraining of ICAD staff	Dominance of engineering professionalism mind-set within ICAD	Engrained professionalism	Organisational Human resources

7.3 Discussion

7.3.1 Understanding the political dimensions of policy implementation

Numerous challenges have been identified in implementing the supply and demand strategies as well as institutional reform measures advocated by the ICAD from the NWM policy. These include political dimensions, organisational inertia, financial constraints, corruption, technical limitations and the relative weak state of AP's economy.

These challenges, particularly the political dimensions of implementation, clearly indicate that policy implementation in AP operates within the realms of the interactive model. Unlike the linear policy model which conceptualises that contestation (politics) only occurs at the policy formulation stage and excludes implementation that is considered to occur automatically; the interactive model conceptualises the policy process as inherently political, with different interests contested at both the formulation and implementation stages (Grindle and Thomas, 1990; Warwick, 1982). The interactive model successfully problematises policy implementation as a political process involving a variety of policy actors in which an accommodation of interests occur (Wester, 2008:92; Grindle and Thomas, 1990). Policy implementation is a series of actions and interactions in which different individuals, groups, networks, lobbies and organisations attempt to mould the implementation to fit their agenda (Mollinga et al, 2008). Ultimately, the government is concerned with achieving politically, institutionally and economically viable outcomes (Grindle and Thomas, 1990).

The focus here is on the ICAD as the main policy actor. Political dimensions to policy implementation are discussed within the context of popular electoral state politics, water sharing between the riparian sates of the KRB, and also internally within AP state government departments and the ICAD. Many of the political challenges are rooted in an exertion of self interest and power by actors involved in the policy implementation and negotiation process, particularly the ICAD and AP state government who can be seen to be promoting their interests (Shore and Wright, 1997; Foucault, 1991). Others non-government actors can be seen to contest and resist various policy strategies that do not align with their particular interests, particularly the large and influential rural farmer constituency in AP. The process of policy implementation is characterised by complexity, negotiation in accommodating actor's interests and uncertainty in final outcomes (Grindle and Thomas, 1990; Warwick, 1982). Other (non-political) challenges are identified to policy implementation, including financial constraints, technical limitations and organisational capacity of the ICAD. These challenges align with factors identified by Grindle and Thomas (1990) in terms of bureaucratic resources required to mobilise reform measures.

Politics

As conceptualised within the 'politics of policy of sovereign states' (Grindle, 1977) with water management as a contested process (Mollinga, 2005, 2008; Mosse, 2003; Mehta, 2001), significant political challenges to policy implementation are identified in AP, consistent with the contested nature of policy implementation identified by the interactive model (Grindle and Thomas, 1990; Warwick, 1982). Political considerations can be seen to have a significant influence on the direction of implementing both supply and demand strategies. These include political aspects of water sharing between the three riparian states of the KRB and populist electoral politics in AP.

On-going legal disputes between the riparian states of the KRB within the KWDT are a significant political dimension influencing supply and demand management strategies in AP. Many of the supply strategies under the Jalayagnam programme should be considered within the context of the KWDT (AP3, AP5, AP22, AP23, AP26, AP33, AP34, AP38). The planning and construction of all major infrastructure projects has to be presented to the KWDT. Riparian states of Maharashtra and Karnataka consider the infrastructure development for the Jalayagnam programme as an overt attempt by AP to bargain for a higher allocation of the basin's shared waters (AP33, AP34, AP38). Whereas AP claims that Jalayagnam infrastructure is essential to promote rural livelihoods, agricultural security and overall state economic development (AP1, AP2, AP3, AP4, AP5, AP7, AP8, AP10, AP12, AP20, AP23, AP25, AP26, AP33, AP44, AP45). Contestation and suspicion over water availability and utilisation of the river basins and sub-basins within riparian state borders manifests in the form of hydrological data secrecy and questions of accuracy (AP3, AP5, AP23, AP25, AP26). None of the riparian states, including AP, want the other to know the exact water status or availability within their state boundaries or within large irrigation systems, with data ambiguity allowing flexibility during legal negotiations within the KWDT (AP23, AP25, AP26). This confirms earlier findings by D'Sousa (2006), who found that the selection of hydrological data for negotiations by all three states in the KWDT was determined on the basis of 'political pragmatism and opportunism', rather than a scientific representation of the facts. Infrastructure projects were positioned as neutral technological artefacts whilst all along being directed towards realising specific political outcomes' (ibid:441).

Establishing an operational Krishna river basin organisation to facilitate stakeholder communication and data exchange with regards to shared projects, is thwarted by on-going legal disputes between riparian states within the KWDT. The legal mandate of the KWDT, with decisions referred to the Indian Supreme Court as the highest legalist body in India, supersedes the envisaged authority of a river basin organisation in resolving disputes and facilitating integration and collaboration between riparian states. In summary, the lack of data availability and accuracy in addition to the support for the Jalayagnam programme could be considered as manifesting ICAD's and the Government of AP's interests to secure a higher allocative share of water within the KWDT. Riparian states contest both the data and the overall approach of the Jalayagnam project, ultimately to serve their own interests in securing a higher allocation of the basin's water.

Populist electoral politics operating within the five years state general election cycle is an influential factor in implementing groundwater regulation and irrigation efficiency strategies. It promotes a myopic view and planning approach to water management operating within a five year electoral cycle, particularly when considering that demand management strategies require long gestation periods in changing user (farmer) social behaviour and patterns of water use (Amarasinghe et al, 2009). As stated by a senior CAD official: 'there is constant pressure on political leaders and water sector managers in emerging economies to be have a short term outlook, to cater for immediate water needs at the seasonal and yearly timescale, with little planning for the long term future, especially for demand management improvement that are often politically hard to achieve' (AP2). Populist politics has been found to undermine irrigation reform initiatives launched the 1990s in both the Philippines (Panella, 2004) and Zimbabwe (Bolding and Mollinga, 2004), in serving vested national and local political interests (Merry et al, 2007).

The politicisation of water at the top level of the ICAD is witnessed in the nexus between senior ICAD officials, technocrats and state government ministers for irrigation. It is the job of senior ICAD officials to advise the Irrigation Ministers[210] on the most appropriate supply and demand management strategies, based on technical hydrological grounds and their judgement. It is then up to the Irrigation Ministers to consider if and how the hydrological and technical recommendations will play out in the wider political arena in AP. However, in reality, it is evident that senior ICAD officials are influenced by political considerations. Often senior ICAD officials pre-empt the political dimensions of supply and demand management strategies, by advocating what should be purely hydrological and technical recommendations to favour and align with the political agenda of the incumbent Irrigation Ministers (AP2, AP23, AP26, AP46, ND5, ND7, ND30). This is apparent in the overwhelming support of the Jalayagnam programme within the ICAD, especially the CW. Although there are questions regarding the availability of sufficient surplus water in the LGRB to supply the lift irrigation projects, senior ICAD officials no doubt realise the political (and financial) importance of the Jalayagnam programme (to secure votes from the large farmer vote block, as well as financial benefit from infrastructure construction projects with the potential for corruption), and therefore appear to present the programme in favourable technical and hydrological terms to the incumbent Irrigation Minister. This in turn favours the his/her agenda in aligning with popular electoral politics, both to secure his/her job within the current state parliamentary session and to increase chances of being re-elected. In turn this leads to bureaucratic job security for senior ICAD officials, with the potential to secure significant funds to finance large-scale infrastructure projects from AP state government, thereby justifying the existence of the CW in the pursuit of the state hydraulic mission.

Corruption

Charges of corruption with regards to the Jalayagnam infrastructure projects are widespread, confirmed by a recent report by the Comptroller and Auditor General of India (GoI, 2012e). The actors within the iron triangle (Molle et al, 2009) are relentlessly pushing for large scale infrastructure in order to fulfil their self-interests. The politician's interest is to secure votes on the promise of bringing irrigation to previously un-served areas, particularly the semi-arid Rayalaseema region of AP; private construction contractor's interest lie in securing large financial contracts for large scale infrastructure development; and ICAD's interest is to increase its power and control (Foucault, 1991; Shore and Wright, 1987) over water resource development throughout AP through the expansion of large-scale irrigation infrastructure. This mutually beneficial relationship serves each actor's self interest, whether it is political, financial, power or water control. There are very few academic

[210] The AP State Government Minister for Major and Medium Irrigation; and the Minister for Minor Irrigation, including groundwater development, lift irrigation and WALAMATRI.

studies on state government corruption with regards to irrigation in AP[211]. With regards to a development reform initiative focusing on health launched by the AP Government in the late 1990s, Mooji (2003) concluded that 'government corruption is an enormous problem and should not be tolerated. There are major problems in the political sphere, in the sense that there is too much politicking and too little governance' (ibid:17).

7.3.2 Organisational inertia

The highly centralised, bureaucratic and hierarchical multi-tired structure of the Indian government has been documented as a significant challenge to organisational reform (Mollinga, 2005; Saleth, 2004; Kaviraj, 2001, 1997); and is found to be a defining characteristic of the Indian hydrocracy in this thesis. Organisational challenges relating to the AP state government include lack of government department collaboration on common water projects (particularly highlighted in the case of groundwater regulation between the Rural Development department and the Revenue department); and also internally with the ICAD with regards to the dominant engineering professionalism of staff, particularly manifesting as the CW's primary focus on infrastructure development.

Historically contextualising the nature of Indian government bureaucracy helps to understand the organisational inertia and current centralised and hierarchical structure of the MWR and ICAD. India inherited the British colonial administration system after Independence, with the new Indian political leadership under Prime Minister Jawaharlal Nehru in favour of establishing a strong state: 'India inherited the colonial state's system of internal command and control, its administration ethos, its laws and rules' (Kaviraj, 1997:233). 'The bureaucracy, though now manned by Indians, was still the unreconstructed bureaucracy of the colonial state: centralised, irresponsible, unresponsive, insufficient used even to the rhetoric of serving the people' (ibid:234). The inheritance of the colonial bureaucratic India helps explain government's centralised and hierarchical approach working on a command and control administrative style, operating within a political system described as 'competitive populism'[212] (Mollinga, 2005:18). Since Independence, the government has largely retained many characteristics of the colonial administration's centralised, hierarchical structure and top-down style of governance, although now aligned to serve Indian government priorities for water management. Furthermore, during colonial rule, engineers were the dominant profession within the water sector, initiating India's hydraulic mission from the 1840s onwards through the construction of large-scale irrigation systems and reservoirs (Shah, 2009). The engineering-biased staff profile of colonial rule was retained after Independence, with Jawaharlal Nehru championing the engineering professional as 'nation builders' (Mollinga, 2002:19) in consolidation and expansion of irrigation area and reservoir construction as part of his national development strategy, acceleration India's hydraulic mission from the early 1960s (Section 4.4.1).

[211] In one of the rare studies on corruption in the water sector in AP, Davis (2004) found that the increased use of information technology for financial transactions within the urban water supply and sanitation sector in Hyderabad, the state capital AP, is considered to have increased transparency and the potential for corruption in public administration.

[212] The institutional gap between the top-down government and the local-level, or 'state-village dichotomy' in India (Mollinga, 2005:16), is considered by Kaviraj (1996) to have its roots in India's colonial history and political democracy. British colonial rule left behind a centralised, hierarchical and strong government administration, then staffed by Indians after Independence and ultimately serving the interests of political elites and the top strata of India's society operating within the boundaries of the caste system.

7.3.3 Other challenges

Various other challenges are identified in AP, which align with components identified by Grindle and Thomas (1990) in facilitating institutional reform, both internally within the bureaucratic arena (the government) and externally. These challenges include financial, technical and legal issues and issues of livelihood activity within AP. Financial constraints include the high cost of installing extensive hardware to monitor groundwater pumping at tens of thousands of borewells throughout the state. Furthermore, administrative staff costs required to monitor and regulate individual borewells particularly high considering the low rate of financial returns (AP15, AP21, AP30). A similar situation is evident regarding installing hydrological monitoring equipment throughout large irrigation systems, with the high financial outplay and low rate of return deterring government action. This is compounded by the fact that there is no great demand from the state government for entirely accurate and live hydrological data owing to farmer resistance to volumetric pricing of irrigation water (AP3, AP7, AP12, AP22, AP23, AP39, AP40). Funding constraints linked to the overall poor performance of AP state economy since 2008 have restricted the level of finances for large-scale infrastructure projects of the Jalayagnam programme (AP7, AP8). However, considering the significant sums of money allocated to the Jalayagnam programme since 2004, accounting for an estimated 10% of the state entire budget (Palanisami et al, 2011), the lack of project completion is more a function of project mismanagement, corruption, and over-ambitious planning by the ICAD than insufficient funds (AP3, AP17, AP22, AP23, AP24, AP26, AP39, AP40). Technical and human challenges exist in relation to understanding the impacts of climate change on water resources in AP, which is being addressed within the ICAD soliciting feedback from relevant organisations and national government. Human resource and technical capacity to continue the process of data digitisation was highlighted as an area of concern limiting digital data availability and sharing.

7.3.4 Understanding the hydrocracy within its wider political context

This section integrates key aspects of the political context of water policy in India to understand how and why the hydrocracy is largely permitted to continue its main focus on large scale infrastructure development. Important to this process are the vested interests of politicians pursuing populist electoral policies and infrastructure construction companies seeking to maximise financial profits. This triumvirate - consisting of the hydrocracy, politicians and infrastructure construction companies - constitutes a powerful iron triangle of actors pursuing large-scale infrastructure approaches to water management. Other key elements include the power relations between and within national and state government, the advisory nature of national water policy, inequitable distribution of water in irrigation systems, the water policy process with regards to parliamentary democracy, and the relative in-effectiveness of non-government actors to significantly influence water debates and change the hydrocracy's approach. Finally, elements more amenable to change are discussed with reference to the role of extreme events acting as windows of opportunity, and the presence of reformist actors within government.

The Indian hydrocracy is both historically and at present, through the MWR's NWM policy and ICAD's interpretation, resistant to fundamental change from its primary focus on large-scale infrastructure for water management. Such an approach is interpreted as an expression of power by the hydrocracy, in controlling surface water through a technocratic engineering approach to consolidate the hydraulic mission in line with the sanctioned 'water for food' discourse (Section 5.4.1 and 6.3.1).

Populist electoral politics is important in permitting the hydrocracy to continue its approach to water management. State and local politicians have been found to campaign on the promise of bringing surface irrigation water to previously un-served areas, through the construction of large scale irrigation systems and reservoirs, with the prospect of creating jobs and stimulating regional economic growth. The large and influential farmer constituent vote block can be decisive in state general elections, especially in AP, with an estimated 60% of the rural population involved in agricultural livelihoods (GoAP, 2010c). The victorious electoral candidate[213] in the 2004 and 2009 AP state general elections campaigned on the promise of bringing irrigation surface water to the semi-arid Rayalaseema and Telangana regions of AP, through the Jalayagnam programme, launched six months before the 2004 state general election. This was interpreted as a direct political move and is considered an important factor in electoral victory. The hydrocracy's approach is therefore championed to serve wider political interests of politicians at different level of AP's state electorate, from the Chief Minister, to Members of Legislative Assembly[214] and local politicians at the town and village level. Politicians are one of the triumvirate of actors within the iron triangle that constitute powerful coalitions, pursuing large-scale infrastructure development. Politicians implicitly support the hydrocracy's approach as it fulfils their vested interests.

Populist electoral politics is seen to restrict the effectiveness of irrigation efficiency measures, particularly volumetric pricing of canal irrigation water. Any discursive support for or practical moves towards pricing irrigation water is considered tantamount to political suicide for a state politician in AP, with farmers having become accustomed to heavily subsidised irrigation water promoting inefficiency of use and inequitable head-tail system distribution. The need to secure the influential famer block vote for electoral success cannot be over-estimated in the case of AP. The political importance of the farmer block vote is also exemplified with regards to groundwater regulation. During the 2004 and 2009 state general elections, the number of free hours of electricity for groundwater pumping became a politically charged issue, with candidates out-bidding each other in the number of hours they promised, in an overt attempt to secure the vote of farmers[215]. The levels of groundwater withdrawal have increased rapidly in India since the early 1970s, and within AP in the last decade fuelled by free electricity pumping, groundwater has dropped to critically low levels in numerous areas in the interior of the state. Populist electoral politics operating on a five-year timescale promotes a myopic approach to water management, focused on short-term political gains, particularly when considering that many WDM strategies require long-term operational timescales and to change farmer behaviour and water use practices. This is compounded by a lack of political leadership in India, failing to look beyond short-

[213] Y.S.R. Reddy of the Congress Party won the 2004 and 2009 state general elections, with a major component of his campaigns based on improving the lives of the rural and farmer population in AP.
[214] A member of the Legislative Assembly (MLA) is a representative elected by voters of an electoral district to the Legislature of Andhra Pradesh state government. AP Legislature has 295 MLAs in total.
[215] The bidding topped 12 hours of free electricity promised by the eventual victorious National Congress Party in the 2009 AP state general elections.

term political gains achieved through large scale infrastructure development, in acknowledging and planning for longer term sustainable water use and management achieved through WDM strategies and institutional reform[216]. Populist politics has also been found to undermine irrigation reform initiatives, including WDM strategies, launched in the 1990s in both the Philippines (Panella, 2004) and Zimbabwe (Bolding and Mollinga, 2004), in serving vested national and local political interests (Merry et al, 2007).

The commercial engineering and construction lobby constitutes the third group of actors within the iron triangle triumvirate pursuing large-scale infrastructure approaches. Private sector construction companies have vested interests in expanding infrastructure construction and development operations, to increase their business activity and maximise profits. Numerous large financial contracts have been awarded to private sector construction firms since the launch of the Jalayagnam programme in 2004, totalling billions of US dollars. A recently released report by the Comptroller and Auditor General of India states that contracts were awarded to 'in favour contractors', without any assurance on completion of work within the envisaged time and budget (GoI, 2012e:76).

Together these actors constitute a powerful triumvirate coalition, a mutually beneficial relationship to all involved in serving each other's vested interests, whether political, financial, power or water control[217]. The politician's interest is to secure votes; private construction contractor's interests lie in securing large financial contracts for large scale infrastructure development; and ICAD's interest is to increase its power and control over water resource development. Other actors within the web of interests - such as research organisations, consultants, business contractors, private water companies, donors, banks, farmers at the head-end of irrigation systems – lie outside but are not exclusive of the iron triangle. They are associated with the hydrocracy in various ways depending on their specific involvement, and can also be considered to benefit from and implicitly permit the hydrocracy's approach.

This thesis has also highlighted how a suite of additional actors and spheres of influence are associated within the wider political and institutional context of water policy and management in India. These are outlined below.

Fragmented power relations between and within national and state government is an important factor in understanding why the hydrocracy is permitted to continue its approach. Inter-state water disputes between riparians in India are characterised by legal contestation and power struggles over shared water resources. Legal contestation over the KRB's water resources began after independence and continues to this day, even after the 2010 KWDT allocative declaration. The construction of large-scale reservoirs and canal irrigation infrastructure in AP is considered as a political manoeuvre to claim a greater allocative share of the KRB's

[216] The lack of political leadership with regards to environmental issues was remarked upon by Jimmy Carter, the former President of the USA, in the late 1970s: 'acknowledging the physical realities of our planet does not mean a dismal future of endless sacrifice. In fact, acknowledging these realities is the first step in dealing with them. We can meet the resource problems of the world - water, food, minerals, farmlands, forests, overpopulation, pollution - if we tackle them with courage and foresight.

[217] The iron triangle is considered as a synergistic relationship between the actors in which 'the ways flows of water are created or modified by water infrastructure are intertwined with flows of power and influence, often manifested in the form of political or financial benefits, whether private or collective' (Molle et al, 2009:336).

waters within the legal negotiation process of the KWDT. Considering the Jalayaganm programme within the wider inter-state water sharing context reveals the wider political importance of further construction of large-scale infrastructure in order to negotiate a higher share of the KRB's water resources. The general air of secrecy between riparian states, characterised by lack of communication and data sharing, is rooted in the political and legal negotiation process of the KWDT, with each state not wanting the other to know exactly how much water lies within its state boundaries.

Within government, fragmented power relations between different ministries and state departments working on water issues is manifest in a disjointed institutional approach. This is characterised by a lack of effective communication and sharing of data, competition over funds and an uncoordinated cross ministry and departmental approach to water management. This has led to ministries and departments focusing on their specific organisation mandates, which over time has tended to support the hydrocracy (MWR and ICAD) in its primary focus on large-scale infrastructure. The limited effectiveness of inter-disciplinary re-training of career-long engineers within the MWR and ICAD further compounds the hydrocracy's approach.

The advisory nature of national water policy is important particularly at state government level, in permitting ICAD's continued focus on large-scale infrastructure. National water policy does not impose legally binding management approaches to state government. Under the Constitution of India, water management is an independent issue for state government (GoI, 1952). National water policy acts in an advisory capacity, recommending approaches for state governments to consider and implement under their state legislative jurisdiction. The adoption of national water policy recommendation at the state level varies significantly throughout India, with some states more progressive than others. As can be witnessed by ICAD's interpretation and implementation of the NWM policy (e.g. primarily adopting large scale infrastructure approaches) state governments are free to 'pick and choose' from national water policy to suit their agendas. The fragmented power relationship and legal arrangements between national and state government are exemplified by the advisory nature of national water policy. At present, there are no plans to change the advisory nature of national water policy[218]. Legal amendments to the Constitution would entail lengthy legal negotiations which would likely be opposed by numerous state governments on the grounds of infringing their legal sovereignty.

The unwillingness of the hydrocracy to effectively implement WDM strategies and reform measures such as PIM and WUA, that essentially decentralise power away from the ICAD, perpetuates the inequitable distribution of water within canal irrigation systems and associated social inequity. Politically unfavourable WDM strategies and reform measures are also resisted by politicians who prefer to maintain the mutually beneficial status quo of power relations between the hydrocracy and powerful land owning farmer elites. The unequal distribution of water within large scale canal irrigation systems in India was first documented in detail by Chambers (1989) and subsequently by Ramamurthy (1995), Mollinga (2003), Bolding and Mollinga (2004), and Nikku (2006), and also confirmed in this research with regards to AP. Social inequality, characterised by

[218] As discussed in Section 5.3.6.5, the PC's WGWR has recommended the establishment of a National Water Commission to 'name and shame' poor performing state government departments involved in water management.

locally entrenched 'water elites' at the head sections of canal distribution systems, use disproportionately high volumes of water hence depriving the tail sections of sufficient water, particularly in the rabi and zaid (summer) cropping season when water is relatively less abundant (Bolding and Mollinga, 2004; Mollinga, 2003; Chambers, 1989). Water elites consist of relatively rich land owning farmers who primarily cultivate water intensive crops such as sugarcane for high economic returns. Owing to the political sensitivity of volumetric water pricing and the large subsidies for irrigation water, efficiency of use is especially low at the head section of a canal distribution system, closest to the surface water source. The tail section of the irrigation distribution system is characterised by smaller agricultural plots (less than one hectare) owned by farmers, who often do not receive sufficient irrigation water owing to the excessive use within the head and middle sections (Mollinga, 2003; Chambers, 1989). Such non-agriculturally productive areas add to the irrigation gap; the area within a canal irrigation system that does not receive sufficient water to cultivate one crop per year. As illustrated in India and AP (Figures 5.4 and 6.4), the irrigation gap has been steadily widening since independence. The effectiveness of PIM and WUA has been found to be limited, with the reform measures captured by economically and politically powerful rich farmers and party members, perpetuating social inequality within irrigation systems (Bolding and Mollinga, 2004). Vested political interests within the hydrocracy and at the local field level have been found to severely limit the overall effectiveness of PIM and WUA (ibid), with the ICAD regaining much of its lost control through amendment of the original PIM Act in 1997 that was the basis for the reform (Nikku, 2006). This finding was confirmed by a recent report by the Planning Commission, which criticised the effectiveness of the WUA approach citing the politicisation and manipulation of WUAs by powerful elites in order to retain their social and economic status and power (GoI, 2012c).

The inability of NGOs and other non-government actors to exert collective and consistent influence on the electoral system by influencing policy debates is another factor issue. Water policy discourse is polarised in India; entrenched in two camps, with non-government actors generally advocating small-scale decentralised community-based approaches' to water management, and the government focused on large-scale infrastructure approaches. Although the civil society sector is vociferously opposed to the government's approach, the large number of NGOs and activists in India advocate numerous and diverse approaches to water management, set within often local or regional water and river basin contexts. Even though non-government actors appear to be more united in opposition to the ICAD's Jalayagnam programme, there still exists no collective and coordinated perspective in advocating a clear alternative approach. Non-government actors contest both the NWM policy formation process, its content and policy implementation in AP state. This is consistent with the inter-active model of policy processes which states that water management is politically contested, with actors endeavouring to exert their power in pursuit of their particular approach (Grindle and Thomas, 1990; Warwick, 1982). Furthermore, the variety of WDM strategies advocated by non-government actors are relatively more difficult for local and state politicians to sell to the electorate during election campaigns. Many of the WDM strategies promote efficiency and reduction in water use, and in some cases, volumetric allocation and pricing of canal irrigation water. Such policies are considered as political suicide, particularly with regards to securing the influential farmer block vote in state elections. However, the relative lack of influence over debates and action regarding the MWR's policy formation process and the ICAD's Jalayagnam programme, should be considered within the context of decision making processes within the hydrocracy. The NWM policy was formulated by a handful of senior MWR officials with limited non-government stakeholder participation, interpreted as a direct manoeuvre by the MWR to control and exert their influence over the strategic direction of the policy. In AP, the Jalayagnam programme was initiated and planned by a handful of senior ICAD officials and top-level politicians, with decisions made at the top levels of government without wider consultation with non-government actors. There is a disconnect between the water policy process and the resulting decisions made by the hydrocracy, and representative parliamentary democracy in India. Once politicians are elected, often having campaigned on the mandate of bringing irrigation water to previously un-served areas as a political strategy to aid their election, the subsequent decision making process within the hydrocracy is largely non-transparent and non-participatory; with decisions made by senior government officials and top-level politicians behind closed doors with limited accountability to the electorate. The disconnect between the water policy processes and democratic accountability coupled with the relative ineffectiveness of non-government actors to influence the water policy debate, is a significant factor in understanding why the hydrocracy does not face a more significant challenge to its approach to water management.

Nevertheless, some elements of the hydrocracy are more amenable to change. This can be witnessed by the occurrence of extreme or crisis weather events triggering change, acting as 'windows of opportunity' during which significant political and institutional momentum is generated to develop appropriate operational, management and policy responses (Kingdom, 1984). The first NWP in India in 1987 was developed in direct response to a nation-wide drought earlier in the year, characterised by crop failure, migration from rural areas and loss of human life. The political momentum generated during and immediately after the drought galvanised the MWR into action in developing the first NWP. Similarly, the October 2009 flood event in AP led to a direct operational response and organisational learning within the ICAD. Immediately after the flood, the ICAD established a programme of dam safety checks, dam break analysis and established a year-round flood control centre, none of which were in operation prior to the flood. The operational responses of the ICAD can be considered a positive development, an example of institutional learning, helping to build resilience against future flood events as well as strengthening anticipatory flood planning. The flood event also raised awareness of the possible impacts of climate change in AP state, and considerations of how to plan infrastructure to cope with projected changes in precipitation and river flow.

Reformist actors are highlighted as a key ingredient for lasting institutional change, particularly within the hydrocracy (Merry et al, 2007; Mollinga et al, 2007; Israel, 1987:4). The head of the PC's WGWR within national government and a handful of senior CAD officials in the ICAD are identified as reformist actors within government. They are considered as 'agents of change' (Sutton, 1999:6), who consider reform as an opportunity and not a threat (Teskey, 2005; Israel, 1987:4). Within national government, the PC WGWR under the leadership of a charismatic senior official, is endeavouring to facilitate the implementation of water demand strategies and institutional reform measures advocated by the NWM. Similarly, a small group of senior CAD officials within the ICAD are focusing on operationalising water demand strategies and institutional reform measures. The existence and initiatives of these reformist actors within government is especially pertinent, as based on the analysis of thirty years of reform initiatives in the water sector, Merry et al (2007) concluded that successful and lasting reform will require the government, particularly the hydrocracy, to play a leading and instrumental role; whilst at the same time, paradoxically, it is itself in need of significant reform (ibid).

In conclusion, the Indian hydrocracy is not an all powerful agency that can impose its will, for example, through the construction of large-scale water infrastructure. The hydrocracy's approach is permitted within the context of the wider political context in India. The vested interests of others actors closely align with the hydrocracy's approach, particularly politicians and infrastructure construction companies, who constitute a powerful triumvirate of actors pursuing large scale infrastructure approaches to water management. Furthermore, other additional actors and spheres of influence within the wider political and institutional context of water policy and management in India permit and facilitate the hydrocracy in its approach.

7.3.5 Conclusions

This chapter has identified numerous challenges to policy implementation in AP. Of paramount importance is the politically contested nature of water management, with the 'pervasiveness of politics' (Warwick, 1982:91) illustrated by populist electoral politics in AP and the on-going KWDT, which is seen to impinge on policy implementation, particularly demand management strategies and institutional reform measures. Furthermore, organisation inertia of the AP state government, rooted in the inheritance of colonial administrative systems and largely continued since Independence, is seen to restrict internal reform measures within the ICAD and water-related departments more generally.

The politically contested nature of policy implementation in AP confirms that the implementation process in India operates within the realms of the inter-active policy model (Grindle and Thomas, 1990; Warwick, 1982), which problematises policy implementation as a political process involving a variety of policy actors in which an accommodation of interests occur (Wester, 2008:92). Findings confirm a number of assumptions upon which Warwick (1982:181-184) characterises the inter-active model (Section 2.7.3). For instance, that the NWM policy is important in establishing the parameters and directions of strategies and actions, but it does not determine the exact course of events, with implementation subject to on-going negotiation and accommodation of actor's self interests. Furthermore, as illustrated by the diverse range of implementation challenges contested by numerous actors on different grounds, implementation is inherently dynamic and complex, characterised by an on-going exertion of actors self interests in negotiating a politically manageable outcomes. And finally, the wider socio-political and economic context clearly influences implementation, as can be seen with regards to the lack of government funds linked to the relative weak state of AP's economy, the rural economies reliance on rice as the staple crop for food production (consuming large volumes of water at a low efficiency rates), and the five year cyclic timescale of state general elections. Policy implementation challenges identified by this research confirm earlier findings regarding AP state government's heath reform policy initiative launched in the late 1990s, in so much that 'policy implementation was vigorously contested, characterised by manipulation and corruption in many different ways' (Mooji, 2003:21). Furthermore, Mooji also concluded the impinging nature of popular politics linked to corruption and incompetence of government: 'politics of populism should be replaced by politics of development, with politics become more respectable and dissociated from corruption and incompetence' (ibid:17-18). Cleary implementing demand management strategies and institutional reform measures cannot be considered on their technical or organisational merit alone. They operate in a politically contested arena with government and other actors exerting their self interests; and within centralised and hierarchical government structures resistant to change, inherited from colonial times and largely continued by Indian civil servants and engineers.

With many of the 'politically low cost' demand management and institutional reform strategies already in various stages of implementation since 2005 under the initiatives of the CAD. The challenges identified in this chapter represent politically higher cost challenges, many of which essentially challenge the status quo of government and other actor's vested interests, and are also rooted in the inertia of government's centralised and hierarchical structures. Chapter 8 discusses the possibility of negotiating such challenges, led by reformist actors at the margins of national and AP state government.

The wider political context within India, particularly the alignment of vested interests between the hydrocracy with politicians and infrastructure development companies constituting a powerful triumvirate of actors, largely permits the hydrocracy to continue its approach set within a wider web of actors. However, some elements of the hydrocracy are more amenable to change. The role of extreme events acting as windows of opportunity and the presence of reformist actors within government offer a suitable approach to initiate and develop lasting institutional change from within the hydrocracy.

8.0 Conclusion

8.1 Introduction

This chapter presents the findings and draws conclusions in answering the fifth research question: what does the Indian water policy experience tell us about the use of water policy to respond to climate change? This chapter also addresses the overall research objective of this thesis. Are there times of change within the Indian hydrocracy? What insights can be gained from government's policy and water management practice response to climate change? Findings and insights from the national and state government in relation to theory are structured around six main themes in addressing the fifth research question (Section 8.2-8.7). Section 8.2 discusses the alignment of interests between the MWR and ICAD in continuing the hydraulic mission. Section 8.3 discusses the MWR's policy and ICAD's water management practices specifically in response to climate change. Section 8.4 draws on the NWM policy formation process and policy implementation challenges identified in AP to discuss the nature of the Indian water policy process. Section 8.5 discusses the hydrocracy within the wider political context to understand why it is largely permitted to continue its approach. Section 8.6 offers an assessment of the current status of institutional water management in India. Section 8.7 discusses the reformist agenda at the margins of government, and potential approaches to overcome the challenges identified. Section 8.8 draws together these insights to provide an overall summary of whether there are times of change within the Indian hydrocracy. Sections 8.9 and 8.10 discuss policy relevance and areas of further research.

8.2 The national and state hydrocracies appropriation of climate change in continuing the hydraulic mission

The MWR and the AP ICAD are using the policy response to climate change primarily to continue their national and state hydraulic missions, in response to meeting water demands, particularly to serve rising agricultural requirements. The sanctioned 'water for food' discourse at national and state government defines what approaches are politically feasible, that of large-scale infrastructure development to expand the area under canal irrigation and to increase reservoir storage capacity.

The MWR's policy formation process was an internal government affair, written primarily by MWR officials, with limited and largely ineffectual non-government participation and stakeholder consultation. This confirms Horowitz's (1989) theoretical reflections that governments in developing countries are inordinately more influential than non-government actors in the policy formation process. However, findings are contrary to Grindle and Thomas' (1990) conclusion that in developing countries policy formation is largely state-centric owing to the absence of an active civil society sector, which is not the case in India which has an active civil society and NGO sector. The internal nature of the NWM formation process characterised the MWR's resistance to change its policy consultation process (Molle et al, 2009), largely deflecting criticism and alternative water management approaches proposed by non-government actors, both at the national and state level in AP. The sanctioned discourse in government can be seen to be 'constraining those who may wish to speak or think outside of the discursive hegemony' (Allan, 2002:182). Although the NWM recommends a large numbers of supply and demand strategies as well as institutional reform measures as 'statements of government intent' (Saleth, 2004:12), the policy primarily focuses on large-scale infrastructure-based supply strategies. This is demonstrated by the ambitious national irrigation expansion and reservoir storage capacity targets, as well as explicit support for the National River Linking Project. The MWR's policy support of large-scale infrastructure-based supply strategies within the NWM confirms findings in 2005, that 'at the level of formulation of new public policy, the symbolic and discursive faithfulness to the old paradigm (e.g. large-scale supply management) is very strong' (Mollinga, 2005:6). The supply strategies advocated in the NWM ultimately represent an exertion of power by the MWR, aiming to increase its control of water through the construction of large-scale infrastructure, in line with the 'water for food' sanctioned discourse within the MWR (Allan, 2002; Foucault, 1991; Shore and Wright, 1987). The policy space that climate change created through the Prime Ministers Action Plan on Climate Change appears to have largely been appropriated by the MWR through the NWM policy to consolidate the national hydraulic mission.

At the state government level in AP, the ICAD primarily adopted the NWM's irrigation expansion and reservoir storage capacity targets to support the Jalayagnam infrastructure programme. Furthermore, ICAD officials can be seen to be appropriating climate change impacts as 'further justification' for large-scale infrastructure supply strategies, to increase water supply to meet agricultural demands in line with ICAD's 'water for food' sanctioned discourse, thus consolidating the state hydraulic mission. The ICAD's choice of water management strategies at the river basin is found to be driven primarily by political considerations to serve vested political and financial interests of the 'iron triangle' actors (state and local politicians, ICAD and private infrastructure construction companies, through the construction of Jalayagnam infrastructure projects. This is likely to lead to further over-building of the Lower Krishna and Pennar river basins, with political considerations found to over-rule what is considered as rational hydrological planning.

It is apparent that there exists an alignment of strategic interest between the MWR and the ICAD (particularly by the CW) to continue the national and state hydraulic missions. This is based on the MWR advocating supply strategies particularly irrigation expansion and increasing reservoir storage targets in the NWM policy, and by the ICAD primarily adopting these strategies to support the Jalayagnam programme in AP. Funds from national government for the construction of major irrigation projects through the AIBP, as well as the ICAD endeavouring to declare the Polavaram inter-basin transfer project as a 'national project' to secure 90% from national government, demonstrates the financial and practical dimensions of this mutually beneficial relationship.

Two explanatory factors are offered to understand why the MWR and ICAD are using climate change to continue the national and state hydraulic missions: the plasticity of climate change and the fundamental resistance of the Indian hydrocracy to change. The plasticity of climate change, in terms of the multiple framings through which impacts are understood and rhetorically deployed to serve vested interests, has been documented by Hulme (2009) within the environmental sector[219]. MWR and ICAD officials are mobilising the plasticity of climate change, citing a variety of climate change hydro-meteorological impacts as 'further justification' within the current water discourse to support supply side approaches at the national level and the Jalayagnam programme in AP. Furthermore, the policy space that climate change created through the Prime Minister's Action Plan on Climate Change has been used by the MWR to primarily advocate supply strategies through the NWM policy. However, the underlying reason is their fundamental resistance to change from a primary focus on infrastructure-based supply strategies that consolidate the hydraulic mission. The ICAD, particularly CW officials, clearly realise that the multitude of climate change hydro-meteorological impacts can be deployed to further support their agenda for supply strategies of the Jalayagnam programme. However, owing to the uncertainty of climate change projections and impacts, none of the supply strategies are advocated solely in response to climate change impacts, but instead to secure food production in line with the sanctioned 'water for food' state discourse (Allan, 2002).

Critical in understanding the MWR and ICAD motivations is their ambition to increase control of water resources through irrigation expansion and reservoir storage capacity. Increasing water control manifests the hydrocracy's ambitions to consolidate and expand its power, particularly to serve vested political and financial interests of the iron rectangle of actors (Molle et al, 2009; Mollinga, 2005; Allan, 2003; Foucault, 1991; Shore and Wright, 1987). Furthermore, the total irrigation area created since Independence is often cited by MWR and ICAD officials as an indicator of 'success' for their approach to water management. However, the irrigation gap has steadily widened both nationally and in AP since Independence (Figures 5.4 and 6.4), owing to the government's relentless pursuit of large scale infrastructure, compounded by inefficiency of (irrigation) water use and demand management implementation challenges. The marginal increase in the canal irrigation area utilised for agriculture is significantly under representative of the huge sums of money spent on large-scale infrastructure construction, particularly in recent decades.

The resistance of the Indian hydrocracy to fundamental change confirms earlier findings internationally in Mexico (Wester, 2008), Indonesia (Suhardiman, 2008), Thailand (Molle and Floch, 2008) and the Philippines (Panella, 2004). Within India, Mollinga (2005) documented that the Indian hydrocracy have been 'extremely resistant to change', and that 'so far the Indian hydrocracy has been largely successful in ignoring the societal demands for new and different approaches to water management, and has been able to keep itself to its main professional orientation, the planning, design and construction of water infrastructure – preferably large-scale' (ibid:5). Results from this research confirm these findings seven years on that the Indian hydrocracy's resistance to change is still as strong and dogmatic as ever, with its main professional orientation still primarily focused on large-scale infrastructure projects.

[219] Climate change plasticity is attributed to a number of factors. These include the complexity of the physical phenomenon itself; the interweaving of natural and anthropogenic climate change; the multi-scale nature of the phenomenon (global to local level impacts); the cultural filters through which climate change is viewed in order to search for meaning and significance (e.g. the cultural histories that exist around weather and climate); the contested and ideologically shaded arguments about scientific claims; and the many different value-systems which get mobilised when viewed through the lens of economics and social systems (Hulme, 2009).

8.3 Are the water policy and management practices specifically in response to climate change?

The NWM strategies have been developed primarily to manage water demand, particularly agriculture requirements in line with the sanctioned 'water for food' discourse. Although the NWM recommends further assessment of climate change impacts in India, results from the ICAD illustrate that water is not being directly managed in the context of climate change. No mid to long-term water management strategies[220] are planned in direct response to climate change impacts by the ICAD. This is due to the uncertainty of climate change projections in AP, leaving water managers unsure how to plan accordingly through a scenario-based approach (IPCC, 2007). Instead, ICAD officials can be seen to be using climate change within their discourse as 'further justification' for both supply and demand strategies. However, some short-term water responses[221] can be directly attributed to the October 2009 flood in AP, as a past event of climate variability. Direct organisational learning within the ICAD can be attributed to this event, as detailed in Chapter 6, confirming Kingdom's (1984) 'window of opportunity' hypothesis. The organisational learning represents a bottom-up management approach to climate change (Wilby, 2010), an appropriate adaptation response to climate change at the present time, especially considering the uncertainty of scenario-based planning. The strategies adopted by the ICAD from the NWM policy are in line with the IPCC, which recommends a mixture of supply and demand strategies to manage climate change impacts (IPCC, 2008). However, the infrastructure-based supply strategies of the Jalayagnam programme are relatively less robust adaptations to climate change projections than demand management strategies, primary owing to their irreversible and inflexible infrastructure 'lock-in' (Hallegate, 2009; IPCC, 2008; UKCIP, 2003).

In summary, the NWM policy and ICAD's water management strategies are still operating within the boundaries of stationarity (Milly et al, 2008), continuing existing approaches that have been developed within the known envelope of historical hydro-meteorological variability. This resonates with findings by Pittock (2011), in which an assessment of nine countries water and environmental policy responses to climate change found that climate policies were adopted and operationalised before the impacts of climate change were fully understood. Furthermore, findings of this research support another key finding by Pittock (ibid), who concluded that many of the nine countries proposed further research and monitoring to understand climate change impacts within their polices, but 'without more meaningful actions' (ibid:25).

[220] Termed tactical and strategic by the water management decision making framework detailed in Section 6.3.6.2.
[221] Termed operational by the water management decision making framework detailed in Section 6.3.6.2.

8.4 Indian water policy processes

This thesis reflects the politically contested nature of water policy processes in India (Mollinga, 2008, 2005; Mosse, 2003 Mehta, 2001), within the domain of the 'politics of water policy in sovereign states' (Grindle, 1977). Results indicate that the water policy process in India operates within the realms of the inter-active model, with both policy formulation and implementation politically contested[222] (Grindle and Thomas, 1990; Warwick, 1982). Throughout the policy process, the MWR, ICAD and other non-government actors exert their power in negotiating the modalities of societal governance and consolidating this into institutional and organisational arrangements, water projects and programmes (Mollinga, 2008). Furthermore, non-government actor's contestation highlights the polarised nature of Indian water discourse at the present time (2012).

The NWM policy formation process was contested by non-government actors on grounds of limited stakeholder consultation and transparency, as well as the strategies advocated by the MWR. Contestation is also witnessed internally within national government, between the MWR and the Planning Commission's Working Group on Water Resources (PC WGWR) seeking to pursue a reformist agenda. The politically contested nature of the NWM policy formation process is consistent with both the linear and inter-active policy models (Grindle and Thomas, 1990; Warwick, 1982). The internal nature of the NWM policy formation process and the strategic direction of the policy, primarily focusing on large-scale supply strategies, are direct exertions of power by the MWR to serve the political agenda to continue the national hydraulic mission.

Policy implementation in AP is contested by various actors on a number of grounds, as discussed in Chapter 7. Government and non-government actors are negotiating the outcomes of implementation within which accommodation of interests occurs. Non-government actors contest the supply and demand strategies advocated by the ICAD. Significant political challenges are identified, particularly state electoral politics and on-going legal disputes between riparian states of the KRB, which can be seen to limit the implementation of demand management strategies and institutional reform measures. Contestation is evident by non-government actors, for instance, by famers opposed to volumetric water allocation and pricing. Internal contestation within the ICAD is also apparent, with a handful of senior CAD officials focusing on demand management and institutional reform measures. Organisational challenges rooted in the centralised and top-down hierarchical structure of government, such as competition between state government departments and particularly the ICAD's inertia to change are highlighted, in addition to financial constraints and technical limitations to policy implementation.

Limitations of the government's institutional approach

The government's institutional approach is largely inadequate to address the contested nature of the water policy process in AP, operating within the realms of the inter-active model. It does not offer a viable

[222] Contestation is an inherently political process through which politics is understood as the set of activities through which balances of power that shape water resource use are exerted by actors and re-negotiated (Bolding and Mollinga, 2004:241).

institutional approach or mechanism to address the political and organisational implementation challenges. The MWR's approach through NWM policy and ICAD's adoption and implementation of strategies highlights the current status of institutional water management in India[223]. The NWM policy essentially offers top-down 'policy as prescription' recommendations to state governments, as 'statements of government intent' (Saleth, 2004)[224] or statements on desired outcomes (Shah, 2006; Mollinga, 2005; Iyer, 2003), regarded by government to automatically lead to implementation, as conceptualised by the linear model (Grindle and Thomas, 1990; Warwick, 1982). The MWR and ICAD are operating within the realms of the linear model, without offering a suitable policy, appropriate organisational mechanism and integrated institutional framework to over-come the implementation challenges[225] (particularly the political contestation and government organisational inertia) to accommodate the interactive model in policy design and implementation. This fits with earlier findings by Mollinga (2005), who found that the Indian hydrocracy policy approach largely operates within the limits of the linear model policy model; and by Saleth (2004), who stated that 'although water institutions in India have undergone significant changes in recent years, these changes fall short of the new and emerging institutional requirements of the water sector' (ibid:1)[226].

The relative lack of progress regarding institutional water reform over the last thirty years has been attributed to the dominance and longevity of the social engineering paradigm, with government approaches operating within the realms of the linear model, characterised by policy prescriptions without fully considering specific socio-economic and political contexts and policy implementation (Merry et al, 2007) (Section 2.6.4). Particularly relevant in the case of India and confirmed here, is that policy makers are reluctant to admit that the process of institutional reform is inherently complex, uncertain, slow and politically contested (ibid; Mollinga, 2005). MWR policy makers and ICAD officials prefer to focus on technical issues of water management and infrastructure development and construction, increasing the area under canal irrigation. As opposed to confronting and negotiating the political challenges of reform, particularly implementing 'politically high cost' demand management and institutional reform measures in AP (Mollinga et al, 2007). The linear model suits MWR policy makers who consider policy implementation the job of state government departments (Wester, 2008; Clay and Schaffer 1984). It also suits ICAD officials who consider institutional reform and demand management strategies of secondary importance, both owing to the significant political and organisational challenges in implementation, and the vested financial and political interests embedded in the Jalayagnam programme. The handful of CAD officials advocating and endeavouring to operationalise demand management and reform strategies are a minority within ICAD, operating at the margins of government.

223 Mollinga (2005) considers that the inter-active model facilitates an examination of water management and governance practices with themes like democratisation, decentralisation, transparency, privatisation and public good functions.

224 As noted by Saleth (2004) 'water policy relates to the declared statements as well as the intended approaches of national and state governments for water resource planning, development, allocation and management' (ibid:12).

225 A lack of sufficient political at the top echelons of national government was also highlighted as being inadequate to exert sufficient political pressure for significant change (ND5, ND31).

226 Saleth (2004) considers policy statements do signify the beginning of the long-term process of institutional change, although it is acknowledged that the policies may not mean much unless they are implemented on the ground (ibid:13).

8.5 Understanding the hydrocracy within its wider political context

The hydrocracy is not an all powerful agency that can impose its will through the construction of large-scale water infrastructure. The hydrocracy's approach is permitted within the wider political context in India. The vested interests of others actors closely align with the hydrocracy's approach, particularly politicians and infrastructure construction companies, constituting a powerful triumvirate of actors pursuing large-scale infrastructure approaches to water management. Other actors within the web of interests - such as research organisations, consultants, business contractors, private water companies, donors, banks, farmers at the head-end of irrigation systems – lie outside but are not exclusive of the iron triangle. They are associated with the hydrocracy in various ways depending on their specific involvement, and can also be considered to benefit from and implicitly permit the hydrocracy's approach. The wider political and institutional context in India facilitates the hydrocracy's approach, characterised by fragmented power within and between government ministries and departments, and the advisory nature of national water policy within the legal arrangement of the Constitution of India. Politicians pursuing populist electoral polices and approaches serving their vested interests severely limits the effectiveness of WDM strategies and reform measures such as PIM and WUA, perpetuating social inequality and equitable distribution of water within large-scale irrigation systems, further increasing the irrigation gap. Populist electoral politics operating on a five-year timescale promotes a myopic approach to water management, focused on short-term political gains, particularly when considering that many WDM strategies require long-term operational timescales and to change farmer behaviour (social) and water use. This is compounded by a lack of political leadership in India, failing to look beyond short-term political gains achieved through large scale infrastructure development, in acknowledging and planning for longer term sustainable water use and management achieved through WDM strategies and institutional reform. A lack of challenge to the hydrocracy's approach is witnessed in the inability of non-government actors to effectively influence the water policy debate and hold the hydrocracy accountable though the democratic process in India. This compounds the polar nature of water discourse and management practice within India, with both sides entrenched in their different views and approaches. All of these factors set within the wider political context in India cumulate to permit the hydrocracy to resist fundamental change and continue its approach to water management. However, elements of the hydrocracy are more amenable to change. Crisis events such as floods and droughts act as window of opportunity in which a degree of change has occurred within the hydrocracy. The presence of reformist actors within government acting as agents of change provides the grounding upon which lasting institutional change can be developed internally within the hydrocracy over time (Section 8.7).

8.6 Insights to institutional water management in India – towards an adaptive approach?

In order to manage the challenges of increasing water demand with population growth and economic development, along with climate change impacts, governments are urged to move towards Adaptive Water Resource Management (AWRM) approaches (Pahl-Wostl, 2007 (Section 2.4.3.3). Gleick (2003) calls for a fundamental shift from 'management as control' to 'management as learning', in pursuing a soft path[227] to build greater flexibility to manage the challenges facing institutional water management (ibid:525).

The MWR's policy response to climate change and the strategic direction of the NWM, as well as the ICAD's adoption of large-scale supply strategies and with the implementation challenges identified, provide insight into the current status of institutional (government) water management in India. Insights from this research can be gauged against the AWRM criteria, to provide an overall assessment of how adaptive the government's institutional approach to water management is (Table 8.1). At one end of the AWRM scale is 'prediction and control' (second column), considered the most common institutional approach to water management (Pahl-Wostl 2002); and at the other end of the scale is 'integrated and adaptive' (third column), considered to be the most appropriate institutional approach (Pahl-Wostl, 2007). Results and insights from this thesis are presented in the fourth column of Table 8.1.

Table 8.1: How adaptive is India's institutional water management status? (adapted from Pahl-Wostl, 2007)

Indicator	Prediction and control	Integrated and adaptive	Evidence from national and AP state government (MWR and AP ICAD)
Management paradigm	Hydraulic mission; construction of large-scale infrastructure Prediction and control based on a mechanistic systems approach	Operational reflexive modernity stage, including demand management and institutional reform measures Learning and self-organisation based on a complex systems approach	MWR and ICAD still intent on continuing hydraulic mission as the primary management paradigm and water management approach Reformist actors at margins of government (PC WGWR and CAD) endeavouring to operationalise reflexive modernity stage (Allan, 2003), including demand management and institutional reform.
Governance	Centralised, hierarchical, top-down and multi-tiered government organisational approach; narrow and limited stakeholder participation	Polycentric, horizontal and integrated government organisational approach; broad stakeholder participation and consultation process (government, civil society and private)	Top-down, centralised and hierarchal national and state government organisational structure and approach to water management. Increase water control through large-scale supply-side infrastructure approaches, procedures and projects. Limited stakeholder consultation during NWM policy formation process. Involvement of non-government actors (NGO/civil society) for watershed development programmes and groundwater management. Private sector involvement limited to infrastructure construction and ad hoc consultancy.
Sectoral integration	Government sectors operating in isolation; separately	Cross sectoral operation and analysis identifies emergent	National ministries and state government departments uncoordinated and fragmented approach operating in centralised and hierarchal organisational structures. Competition within

[227] Gleick (2003) expands on what constitutes a sort path as 'one that complements centralised physical infrastructure with lower cost community-scale systems, decentralised and open decision-making, water markets and equitable pricing, application of efficient technology, and environmental protection' (ibid:525).

	analysed resulting in policy conflicts and emergent chronic problems	problems and integrates organisations and policy implementation	national ministries and state departments for funding and performance, characterised by limited communication and data sharing for common water projects. Dominance of engineering professionalism and approach within ICAD.
Information management	Lack of hydrological understanding and fragmented approach; gaps and lack of integration and sharing of information and data	Comprehensive hydrological understanding by transparent and effective sharing of information and data, that fill the gaps in assessment and facilitates integration of government departments and water projects	Limited sharing of sensitive hydrological data and information between national minsters and state departments, and to non-government actors. Political considerations of trans-national and inter-state water sharing disputes and competition between ministries and departmental, severely limits data integration and sharing. Questionable data accuracy owing to political dimensions in serving vested political and financial interests in water projects, particularly large-scale infrastructure development projects. Hydrological assessment at the macro river basin level fairly comprehensive across India, although relative less hydrological coverage and monitoring at the sub-basin and local level
Infrastructure (water supply management)	Massive and centralised infrastructure; single sources of design	Infrastructure at appropriate scale and decentralised. Diverse sources of infrastructure design	MWR and ICAD primary focus on large-scale infrastructure based approach to expand the irrigation area and increase reservoir capacity to continue national and state hydraulic missions. Infrastructure designed by government officials with limited ad hoc input from private sector and/or international organisations.
Water demand management	Limited operational effectiveness of demand management strategies; largely symbolic in policy as 'statements of intent' with little operational value	Demand management fully operationalise, with effective and efficient use of water within and across all sectors, including irrigation efficiency. Decentralised and locally managed, complementing supply management approaches	MWR and ICAD (particularly the CW) consider demand management strategies of secondary importance to that of large-scale supply approach. Demand management primarily operates as 'statements of policy intent' with limited and ineffective implementation. ICAD (CAD) implementing 'politically low cost' demand strategies in AP since 2005. Significant political challenges and organisational inertia identified to implement other 'politically high cost' demand management strategies, serving wider political and financial vested interests. Reformist actors in CAD pushing to operationalise demand management strategies but with significant dimensions to implementation in challenging wider political and financial interests.
Finance	Financial resources concentrated in structural protection (sunk costs) (e.g. large-scale infrastructure)	Financial resources diversified using a broad set of private and public financial instruments distributed even across multi-scale supply and demand strategies, and institutional reform measures.	Vast majority of AP government and ICAD funds for large-scale supply infrastructure, allocated to Jalayagnam infrastructure (10% of state budget in 2011). Large sunken costs within irrigation and reservoir large-scale infrastructure. Minute fraction of total funds allocated to demand management and institutional reform measures.
Transboundary scale of analysis and operation	Transboundary water sharing characterised by conflict and suspicion between riparians; limited effective allocation and collaboration. Problems emerge when river sub-basins are the	Transboundary issues addressed by multiple scales of analysis and management. Conflicts between riparians resolved by effective negotiation platform and enforcement of water sharing declarations	Political dimensions of legal disputes within Krishna Water Disputes Tribunal leads to climate of mistrust and suspicion between riparians with each pushing for higher allocative share of the KRB waters, characterised by hydrological data secrecy and questions of accuracy. Construction of large-scale infrastructure as an attempt to strengthen legal case for higher allocative share. Limited communication and sharing of hydrological data between riparian states, apart from add hoc reasons such as the October 2009 flood event between AP and Karnataka. Proposed River Basin Organisations ineffective to facilitate better

	exclusive scale of analysis and management		coordination between riparians as KWDT supersedes in legal authority.
Environmental factors	Minimal environmental flow allocation in river basins; only quantifiable variables can be measured easily	Sufficient environmental flow allocation in river basins; qualitative and quantitative indicators of whole ecosystem well-being	ICAD environmental flow allocation (eg. sufficient water for river basin delta region) largely disregarded. Strategy to capture and utilise all of river basins waters for irrigation purposes has witnessed the closure of the Lower Krishna and Pennar river basins in last decade. Current strategy to capture of Lower Godavari river basins' surplus waters will lead to reduction in river flows and to water to the delta region of Godavari river.
Climate change risk management	Non-existent or limited consideration or planning for projected climate change impacts. Reactionary approaches to disaster management (floods and droughts)	Understanding and application of robust no or low regrets water management adaptation strategies, including safety margins and irreversibility. Comprehensive monitoring and hydrological assessment, along with data sharing. Anticipatory programmes for disaster management	MWR established Indian Network on Climate Change Assessment, in addition to soliciting feedback from expert organisations to further understand hydro-metrological impacts of climate change. ICAD not integrating climate change projections for mid to long term water strategies, owing to uncertainty of scenario-based planning approach. CW officials considering how to integrate climate change projections for new reservoir design of the Jalayagnam, but no action taken at present owing to model uncertainty. Large-scale infrastructure projects of Jalayagnam programme less robust to climate change impacts characterised infrastructure 'lock-in' and irreversibility, relative to demand management strategies. ICAD officials largely resistant to re-training to consider inter-disciplinary aspects of water management including climate change impacts. Significant ICAD organisational learning attributed to the October 2009 flood event, in moving towards anticipatory management practices as bottom-up climate change adaptation.

India's current water institutional approach appears to lean heavily towards prediction and control. It is rather inadequate in its overall institutional adaptive approach and capacity based on the AWRM criteria. The Indian hydrocracy is found to be resistant to change from its primary focus on large-scale supply side approaches, in moving towards a more adaptive institutional approach to managing climate change impacts and increasing water demand. As discussed in Section 8.2, the Indian hydrocracy's resistance to change is rooted in its ambitions to increase its control of water resources though large-scale infrastructure construction to continue the hydraulic mission, manifesting deeper intentions to consolidate and expand its power to serve vested political and financial interests. The wider implications of an inflexible, predictive, controlling, centralised and hierarchical institutional approach to water management are likely to lead to further over-building and closure of river basins throughout India. This is approach will likely result in the 'hard landing' of river basins in India within future years (Falkenmark and Molden, 2008), characterised by over-abstraction of surface and groundwater, increased water scarcity and competition between sectors, inequitable sharing of benefits, loss of ecosystems services and habitat, in addition to increasing vulnerability to future climate change impacts[228].

[228] As Charles Darwin considered, it is not the strongest of the species that survive, nor the most intelligent, but the ones most responsive to change.

8.7 Reform agenda at the margins of government

A secondary result of the NWM policy and climate change is that it is also being used by certain actors within government to promote a reformist agenda, entailing a paradigm shift, moving beyond the hydraulic mission to the reflexive modernity stage of water management (Allan, 2003). Within national government, the PC WGWR under the leadership of a charismatic senior official, is endeavouring to facilitate the implementation of water demand strategies and institutional reform measures advocated by the NWM, discussed in Chapter 5. Similarly, a small group of senior CAD officials within the ICAD are focusing on operationalising water demand strategies and institutional reform measures, discussed in Chapter 6. There exists an alignment of interests between the PC WGWR and these CAD officials, with the group acting as 'agents of change' (Sutton, 1999:6), who consider reform as an opportunity and not a threat (Teskey, 2005; Israel, 1987:4). The presence of such reformist actors within government has been identified as a key ingredient in promoting enduring institutional change (Merry et al, 2007; Mollinga et al, 2007; Israel, 1987:4). The existence and initiatives of these reformist actors within government is especially pertinent, as based on the analysis of thirty years of reform initiatives in the water sector, Merry et al (2007) concluded that successful and lasting reform will require the government, particularly the hydrocracy, to play a leading and instrumental role; whilst at the same time, paradoxically, it is itself in need of significant reform (ibid).

Theory highlights that institutional reform is inherently complex, uncertain, slow, context specific and politically contested by numerous actors (Merry et al, 2007; North, 1990; Ostrom, 1990). Water reforms are essentially a political process (Merry et al 2007; Mollinga et al, 2007; Bolding and Mollinga, 2004; Perry, 1995), with the PC WGWR and CAD officials challenging the interests of the MWR and particularly the CW in continuing infrastructure development projects. The MWR and CW, along with politicians and infrastructure construction companies, represent powerful 'iron triangle' groups of actors, intent on retaining the status quo to serve their financial and political interests (Molle et al, 2009). The challenge of reforming the hydrocracy from within government is substantial, as the reformist actors within national government and the ICAD are very much in the minority by number, existing at the margins of governments, operating within the highly centralised, bureaucratic and hierarchical structure of national and state government (Mollinga, 2005; Saleth, 2004; Iyer, 2003; Kaviraj, 1996).

Policy implementation challenges identified in Chapter 7 cover a range of issues. The political dimensions of water management, particularly in the context of populist state electoral politics and on-going legal water disputes between riparian states in the KRB, represent difficult 'politically high cost' challenges in AP. The reformist actors will have to take the lead in balancing the complex and political nature of these challenges, in negotiating an arrangement that is politically feasible for all actors involved. Theory identifies a number of approaches to initiate and sustain reform (Section 2.6.6), essentially requiring an analysis of options, vested interests, potential cost and benefits, as well as potential allies and opposition in building effective collations[229] (Merry et al, 2007; Mollinga et al, 2007). Building coalitions along lines of mutual interests, both within government and with non-government actors, particularly the NGO and civil society sector in exploring decentralisation (Wester, 2008; Allan, 2003; Saleth, 2000; Smith, 1985) and private sector involvement to improve performance (Davis, 2004; Shah, 2000), could help facilitate long-term enduring reform in AP (Merry et al, 2007). However, the Indian hydrocracy has been found to be resistant to decentralisation in the past, as it essentially involves a loss of power and control of water resources (Molle et al, 2009; Wester, 2008; Bolding and Mollinga, 2004; Smith, 1985).

Organisational inertia is a significant challenge in AP state government, both between departments and internally within ICAD, characterised by highly centralised, bureaucratic and hierarchical government structures (Saleth, 2004; Iyer, 2003; Kaviraj, 1996). This research confirms the nature of the Indian hydrocracy, as large and powerful agencies controlled by a single civil engineering professionalism, who endeavour to retain their status and organisational focus on large-scale infrastructure development, even during times of increasing demands from all sectors and climate change. An interdisciplinary re-training programme has met with resistance from ICAD staff, unwilling to look beyond their professional engineering approach. The CW is also intent on pushing large-scale infrastructure projects through the Jalayagnam programme, resistant to change its organisational pursuit of the hydraulic mission (Molle et al, 2009; Mollinga, 2005). Other challenges identified (Section 7.3.3) are relatively easier to overcome, if sufficient bureaucratic resources are allocated, including sufficient funds, equipment and training programmes (Grindle and Thomas, 1990). Strengthening human resource capacity has been identified as an important component to promote institutional reform (Merry et al, 2007). Financial constraints could be mitigated if sufficient funds are made available; however, considering the relative poor performance of AP's economy, it is unlikely that all of the funding requests by state government officials will be met.

[229] Mollinga et al (2007) offers a number of questions in negotiating the political feasibility of reform: 1) What will be the benefits of institutional and policy reform and how will these benefits be distributed? What will be the costs and who will bear them? 2) Who will be the bearers of institutional transformation: who will constitute the coalition of interest groups to push forward and implement the change? 3) Around which issues can such efforts be organised most productively? 4) How can these coalitions be supported? 5) What can realistically be done to adapt the enabling and constraining conditions for this institutional transformation? 6) How can knowledge producers and processors such as academics, consultants, and reflective practitioners play a more active role in this process? (ibid:706).

8.8 Times of change?

This thesis concludes that climate change is being largely integrated into government policy and water management practices to continue the hydraulic mission in India. The Indian hydrocracy is found to be resistant to changing its strategic approach to water management, using the plasticity of climate change to continue support for its historic approach. Insights into the water policy process highlight numerous challenges to policy implementation of demand strategies and institutional reform measures, paramount are the political nature of water management and the centralised hierarchical structure of government. The hydrocracy is largely permitted to continue its approach within the wider political context in India, with other actors implicitly supporting and benefiting from large-scale water infrastructure. However, although the Indian hydrocracy is found to be resistant to fundamental change, it is apparent that change is occurring at the margins of government, with the PC WGWR and CAD endeavouring to operationalise the reflexive modernity stage of water management through demand management strategies and institutional reform measures. Both continuity and change co-exist within the Indian hydrocracy. The fundamental resistance of the Indian hydrocracy endures, whilst at the same time, certain reformist actors in government are intent to navigate the complex and uncertain nature of institutional reform in India.

8.9 Policy implications

The results offer an insight to water policy processes in India. The government operates within the realms of the linear policy model, with the NWM policy acting as statements of intent, but without offering a suitable institutional mechanism or approach to negotiate implementation challenges, many of which are politically contested and rooted in organisational inertia. At the present time (late 2012), the MWR is in the process of developing a revised version of the National Water Policy 2012. This was due to be finalised in 2012, but the consultation process is still on-going with the draft residing with the MWR before being recommended to the National Water Resources Council for approval. Some of the policy orientated findings of this research, particularly the contemporary implementation challenges in AP, are relevant to the development of this policy. These include the importance of developing an appropriate institutional mechanism and approach to address the politically contested nature of water management and over-coming organisational inertia. Understanding the processes and mechanisms of institutional reform is especially relevant. This could include facilitating a negotiation platform to find a middle path in balancing actors' interests, particularly the government; as well as incentives to encourage integration between national ministries and state government departments, and internally between the CAD and CW within the ICAD.

8.10 Further research

The internal workings of the hydrocracy are still relatively unknown. It remains a relatively under-researched area worldwide, as noted by Molle et al (2009). However, gaining complete and transparent access to the inner workings and circle of the Indian hydrocracy can be problematic, even with good contacts inside and outside of government, particularly for a non-Indian national who is unable to understand or speak fluent Hindi or Telugu. Investigating the nature of the relationship between the iron triangle of actors is especially sensitive, owing to the significant political and financial vested interests of those involved, requiring a delicate approach in enquiry and gaining the trust of those 'in the know'. Deconstructing the centralised and hierarchical bureaucratic structure and procedures of national and state governments, requires patience, access to government officials and unpublished government documents and reports. Both of these topics, particularly the actors and dynamics within the iron triangle and those beyond who benefit from large scale infrastructure, would make interesting if not challenging avenues of further investigation. Understanding the process of internal reform within the hydrocracy also warrants further research, particularly the role of reformist actors or policy entrepreneurs (Huitema et al, 2011) operating within and using 'windows of opportunity' to negotiate and facilitate lasting institutional change.

Further research is required to further understand climate change impacts in India and AP state. This includes changes in the Indian summer monsoon, of crucial importance to agriculture and rural livelihoods throughout the country; along with changes in surface water runoff and water availability within river basins across India. The Indian Institute of Technology in Delhi has pioneered this approach, with climate model input from the Indian Institute of Tropical Meteorology and other relevant international organisations. Further work is required to downscale a number of climate models to a higher resolution and then to model hydrological runoff for future years. However, the limitations of scenario-based planning for water management are highlighted in this thesis, characterised by inherent uncertainty leaving water managers unsure how to plan specifically. A more realistic approach to increase the adaptive capacity of government to deal with climate change as an increase in the intensity and frequency of extreme weather events, would be to focus on strengthening bottom-up adaptation approaches to recent floods and droughts, moving from reactionary to anticipatory planning. Further research is required in this area, to understand the institutional learning process and effectiveness of these responses and strategies put in place during and immediately after such events. Water policy development and water management in the context of climate change is still in its relative infancy in many countries, as detailed by Pittock (2011). The findings of this thesis can hopefully go some way to inform other countries who are considering how to manage water in adapting to climate change, particularly those still pursuing their hydraulic mission.

Appendices

Appendix 1: Description of SRES storylines to economic development (Nakicenovic and Swart, 2000)

Scenario A1	Scenario A2
Very rapid economic growth with increasing globalisation, an increase in general wealth, with convergence between regions and reduced differences in regional per capita income. Materialist–consumerist values predominant, with rapid technological change. Three variants within this family make different assumptions about sources of energy for this rapid growth: fossil intensive (A1FI), non-fossil fuels (A1T) or a balance across all sources (A1B).	Heterogeneous, market-led world, with less rapid economic growth than A1, but more rapid population growth due to less convergence of fertility rates. The underlying theme is self-reliance and preservation of local identities. Economic growth is regionally oriented, and hence both income growth and technological change are regionally diverse.
Scenario B1	**Scenario B2**
Same population growth as A1, but development takes a much more environmentally sustainable pathway with global-scale cooperation and regulation. Clean and efficient technologies are introduced. The emphasis is on global solutions to achieving economic, social & environmental sustainability.	Population increases at a lower rate than A2 but at a higher rate than A1 and B1, with development following environmentally, economically and socially sustainable locally oriented pathways. In terms of climate forcing, B1 has the least effect, followed by B2.

Appendix 2: Key informant interviews at national and state level

Reference code	Fieldwork period	Location	Job role and organisation	Number of interviews
National level				
ND1	1st	New Delhi	Senior water policy adviser; National government, MWR	2
ND2	1st	New Delhi	Senior water policy advisor on technical aspects; National Government, CWC	1
ND3	1st and 2nd	New Delhi	Senior water policy advisor on technical aspects; National Government, CWC	2
ND4	1st and 2nd	New Delhi	Senior water policy adviser; National government, MWR	1
ND5	1st and 2nd	New Delhi	Water specialist; International organisation	5
ND6	1st	New Delhi	Water and climate change specialist; Indian academic	3
ND7	1st	New Delhi	Water specialist and activist; Indian NGO	2
ND8	1st	New Delhi	Water policy advisor; National government, Planning Commission	1
ND9	1st	New Delhi	Water specialist; International donor	1
ND10	1st	New Delhi	Water, climate and energy specialist; International NGO	1
ND11	1st	New Delhi	Groundwater specialist; International organisation and National Government, Planning Commission	3
ND12	1st	New Delhi	Climate change specialist; National government, MFE	1
ND13	1st	New Delhi	Climate change specialist; International organisation	2
ND14	1st and 2nd	New Delhi	Water specialist; International organisation	3
ND15	1st and 2nd	New Delhi	Water specialist; International organisation	3
ND16	1st	New Delhi	Water specialist; Indian NGO	1
ND17	1st	New Delhi	Water specialist; International organisation	1
ND18	1st	New Delhi	Water specialist; International private sector	1
ND19	1st	New Delhi	Water and agriculture specialist; National government, MoA	2
ND20	1st	New Delhi	Water and irrigation specialist; International organisation	1
ND21	1st	New Delhi	Disaster management specialist; Natio0nal government, MHA	1
ND22		New Delhi	Senior water policy advisor to National government; International research organisation and formerly with national government, MWR	1
ND23	1st	New Delhi	Climate change specialist; Indian academia	1
ND24	1st	New Delhi	Climate change specialist; Indian academia	2
ND25	2nd	New Delhi	Water specialist; international donor	1
ND26	2nd	New Delhi	Water specialist; international donor	1

ND27	1st	New Delhi	Water specialist; Indian academia	3
ND28	1st	New Delhi	Water and climate change specialist; international organisation	3
ND29	1st and 2nd	New Delhi	Water specialist; international organisation	2
ND30	1st	New Delhi	Water policy advisor and manager; national government, MWR	1
ND31	1st and 2nd	New Delhi	Water specialist; retired formerly with national government, MWR	2
ND32	1st	New Delhi	Water specialist; international organisation	1
ND33	1st	New Delhi	Water specialist; national government, Planning Commission and international academia	1
ND34	1st	New Delhi	Groundwater specialist; national government, MWR	1
ND35	1st	New Delhi	Climate change scientist; Indian academia	1
ND36	1st and 2nd	New Delhi	Water specialist; international academia	4
ND37	1st	New Delhi	Water specialist; international organisation	1
ND38	1st	New Delhi	Senior water policy advisor; international organisation and retired national government, MWR/CWC	1
ND39	1st	New Delhi	Water specialist; international NGO	2
ND40	1st	New Delhi	Water specialist; international academia	1
ND41	1st	New Delhi	Water specialist; independent consultant	1
ND42	1st	New Delhi	Water specialist; international organisation	1
ND43	1st	New Delhi	Water specialist; international organisation	1
ND44	1st	New Delhi	Senior Water policy advisor national government, CWC	1
ND45	1st	New Delhi	Water specialist; Indian NGO	2
ND46	1st	New Delhi	Water journalist; National Press Paper	1
ND47	1st	New Delhi	Water and agriculture specialist, Indian NGO	1
Andhra Pradesh state level				
AP1	1st and 2nd	Hyderabad	Senior water policy advisor and manager; AP government, ICAD (CAD)	2
AP2	1st and 2nd	Hyderabad	Senior water policy advisor and manager; AP government, ICAD (CAD)	2
AP3	2nd	Hyderabad	Senior water policy advisor and manager; AP government, ICAD (CAD)	3
AP4	2nd	Hyderabad	Senior Engineer; AP government, ICAD (CW)	1
AP5	2nd	Hyderabad	Senior Engineer; AP government, ICAD (CW)	1
AP6	2nd	Hyderabad	Senior Engineer; AP government, ICAD (CW)	1
AP7	2nd	Hyderabad	Senior Engineer; state government, ICAD (CW)	2
AP8	2nd	Hyderabad	Senior policy advisor and manager; AP government, ICAD (CW)	2
AP9	2nd	Hyderabad	Senior policy advisor and manager; AP government, ICAD (CW)	2
AP10	2nd	Hyderabad	Senior Engineer; AP government, ICAD (CW)	1
AP11	2nd	Hyderabad	Retired senior engineer, AP government, ICAD (CW)	1
AP12	2nd	Hyderabad	Water specialist; state government, Human Resource Development	2
AP13	2nd	Hyderabad	Trainer; state government, Human Resource Development	2
AP14	2nd	Hyderabad	Water specialist; AP government, WALAMATRI	1
AP15	2nd	Hyderabad	Groundwater specialist; AP government, DoGW	1
AP16	2nd	Hyderabad	Water specialist, AP government, retired (ICAD)	1
AP17	2nd	Hyderabad	Water specialist; AP government, ICAD (CAD)	1
AP18	2nd	Hyderabad	Senior Engineer; AP government, ICAD (CAD)	2
AP19	2nd	Hyderabad	Climate change specialist; AP government, Human Resource department	1
AP20	2nd	Hyderabad	Senior Engineer; AP government, ICAD (CW)	1
AP21	2nd	Hyderabad	Water policy advisor; international NGO	2
AP22	2nd	Hyderabad	Water specialist; international organisation	1
AP23	1st and 2nd	Hyderabad	Water and irrigation specialist; international organisation	5
AP24	1st and 2nd	Hyderabad	Water specialist; international organisation	3
AP25	2nd	Hyderabad	Water specialist; international organisation	2
AP26	1st and 2nd	Hyderabad	Water specialist; international academia	4
AP27	2nd	Hyderabad	Water specialist; independent consultant	1
AP28	2nd	Hyderabad	Water and agriculture specialist; Indian academia	1
AP29	2nd	Hyderabad	Agriculture specialist; international organisation	1
AP30	2nd	Hyderabad	Groundwater specialist; international organisation	3
AP31	2nd	Hyderabad,	Water specialist; international NGO	1
AP32	2nd	Hyderabad	Water specialist; international academia	2
AP33	2nd	Hyderabad	Senior water policy advisor; Maharashtra government, Department of water resources	1
AP34	2nd	Hyderabad	Water specialist; Indian NGO	1
AP35	2nd	Hyderabad	Water specialist; international organisation	1

AP36	2nd	Hyderabad	Water specialist; international organisation	2
AP37	2nd	Hyderabad	Agriculture l specialist; international organisation	1
AP38	2nd	Hyderabad	Water specialist; Indian NGO	1
AP39	1st and 2nd	Hyderabad	Agriculture specialist; Indian NGO	3
AP40	2nd	Hyderabad	Farmer organisation leader; Indian NGO	2
AP41	2nd	Hyderabad	Water specialist; Indian academia	1
AP42	2nd	Hyderabad	Water specialist; Indian NGO	1
AP43	2nd	Hyderabad	Water specialist; Indian academia	1
AP 44	2nd	Hyderabad	Retired Engineer, AP government, ICAD	1
AP45	2nd	Hyderabad	Retired Engineer, AP government, ICAD	1
AP 46	2nd	Hyderabad	Water specialist, Indian NGO	1

Appendix 3: Staff organisational hierarchy of the Irrigation Department (adapted from Wade, 1985)

	Position	Job role
Top level	Minister for irrigation	Political direction
	Secretary for Irrigation (four in total)	Policy formulation, strategic water management direction
	Commissioner	Strategic water management direction
	Chief Engineer	Policy, operational and technical operations
Mid level	Superintending engineer in charge of circle	Technical
	Executive engineer in charge of division	Technical
	Assistant engineer in charge of subdivision	Technical
Field level	Supervisor in charge of section	
	Foreman	Construction
	Construction and maintenance workers	Construction
	Bankers	Revenue collection

Appendix 4: Conferences, meetings and workshops attended during fieldwork periods

Event title / focus	Description	Date and location
Extreme Weather Events, British Council	Conference	November 2007, New Delhi
2nd Aqua Conference on Water Management in India	Conference	November 2008, New Delhi
Climate change and Water Resources in Andhra Pradesh, Norwegian donor conference	Workshop	February 2009, Hyderabad
Climate change scenarios and impacts in India, IITM	Workshop	March 2009, Pune
National Research Conference on Climate Change	Conference	March 2009, New Delhi
National River Linking Project, IWMI	Workshop	April 2009, New Delhi
Australia-India Workshop on the Future of Water Security under Climate Change	Workshop	New Delhi, September 2010
NWM policy consultation workshop organised by the MWR	Workshop	October 2010, New Delhi
Climate Change and Agriculture, CGIAR	Workshop	November 2010, New Delhi

Appendix 5: Field visits undertaken during fieldwork

Location	Date	Location	Issues examined
Upper Bhima river basin, Maharasthra	March 2009 Three days	Upper Krishna river basin, Maharasthra	Hydrology, land use practices, agriculture (surface and groundwater irrigation). Watershed development programmes
Mahabubnagar	April 2009 Two days	Lower Krishna river basin, Andhra Pradesh	Rainfed agriculture, watershed development
Nagarjuna Sagar reservoir and left bank canal irrigation system	October 2010 Three days	Lower Krishna river basin, Andhra Pradesh	Reservoir infrastructure, storage capacity, conveyance canal systems. Agricultural practices in command area, crops cultivated

Appendix 6: Interview consent form

Consent form

Introduction

My name is Matthew England. I am a PhD researcher student at the School of International Development Studies, University of East Anglia, UK. For my fieldwork period in India, I am hosted by the International Water Management Institute, part of the Consultative Group on International Agricultural Research, who have offices in New Delhi and Hyderabad.
Focus of my research
My research is examining the Government of India's policy and water management practise response to climate change. It focuses on the National Water Mission policy response of national government, and makes a case study of Andhra Pradesh state.

Confidentiality
The information you provide will be used primarily for writing my PhD thesis. Findings of my thesis have the potential to be used in reports, academic papers and books. You are guaranteed complete anonymity as a respondent; your name shall not appear in my thesis or other relevant publications. Any information or data you provide will be treated in the strictest confidence, held in secure format (electronically and/or on paper), and will in no way be attributed to you as an anonymous respondent in the thesis or subsequent publications.

Participation in the research and the right to refuse
If you are willing to participate in this research as an interview respondent, then I can meet you at a convenient time and location. On your full consent, the interview can be recorder by an audio divide. You are free to decline this method of audio recording prior, or at any time during the interview. If during the interview you wish to stop or retract any comment or statement, you are completely within your right to do so. Any information you have given will be discarded immediately (either electronically deleted or destroyed in paper format) and not used in the research.

Questions
You are welcome to raise any issues of concern or otherwise at any time, either prior to the interview, during or after. I am contactable on the phone number: 0091 9834533543. Or con be contacted at the IWMI office: 2nd Floor, CG Block C, NASC Complex DPS Marg, Pusa, New Delhi 110 012, India

Agree to participate and have meeting digitally recorder
The research information and interview purpose was explained to me clearly in written format and/or verbally. Anything I did not understand was explained, with all my questions answered to my complete satisfaction. I understand that I have the right to withdraw my participation at any time, with all responses destroyed completely and not used in the research.

I………………….. agree/disagree to participate in the research, and agree to have the meeting digitally recorded.

Signature of respondent

Date

Signature of researcher

Date

Appendix 7: MWR organisational structure and programmes (GoI, 2012a).

Organisations under Ministry of Water Resources	
Attached offices	Central Water Commission Central Soil & Materials Research Station
Subordinate Offices	Central Ground Water Board Central Water & Power Research Station Bansagar Control Board Sardar Sarovar Construction Advisory Committee Ganga Flood Control Commission Farakka Barrage Project Upper Yamuna River Board
Statutory Bodies	Narmada Control Authority Tungabhadra Board Betwa River Board Brahmaputra Board

Registered Societies	National Water Development Agency National Institute of Hydrology
Programmes implemented	
National level	Ground Water Management and Regulation River Management Activities and Works related to Border Areas Flood Forecasting Hydrology Project Investigation of Water Resources Development Scheme Indo-china Cooperation India-Bhutan Cooperation
State level	Accelerated Irrigation Benefits Programme Flood Management Programme Command Area Development and Water Management Programme Dam Rehabilitation and Improvement Programme Repair, Renovation and Restoration of Water Bodies

Appendix 8: State map of India

Appendix 9: District map of Andhra Pradesh

Appendix 10: Regional map of Andhra Pradesh: Telegana, Rayalaseema and Coastal AP.

Appendix 11: Organisational operations of the Construction Wing and Command Area Development (ICAD department) (GoAP, 2012, 2010a)

	Objectives and activities	Details
Construction Wing	Construction of new major and medium irrigation infrastructure projects	• Major irrigation projects – 31 construction projects • 5 Electrical and Mechanical operation • Medium irrigation – 7 project for construction and management
Command Area Development	**Operation & Maintenance unit** Statistics Administration Geographical Management Information system Water Use Efficiency Capacity building	**Cells and operations in O&M sub-wing** • Participatory Irrigation Management Cell – for management of irrigation projects and irrigated agriculture through farmers' organizations. The cell organizes the capacity building of the farmers' organizations and their management; • Water Policy Research Cell – to provide support to the Water Management Committee and • Operation and Management Cell – for cost recovery and plough back of tax revenue for maintenance of the irrigation projects; • Water Audit and Benchmarking Cell for coordinating the WUA wide annual water audit and benchmarking through the respective Chief Engineers; • Technical Cell - for providing technical support for the above listed agenda and for externally aided projects. • Remote Sensing and Geographical Management Information System Cell
	Minor Irrigation Wing	• Creation of new and revival/restoration of minor irrigation projects. • 10 Minor irrigation circles
Notes of irrigation area classification Major irrigation: >10,000 ha total command area; Medium: 2500-10,000 ha command area; Minor: <2500 ha total command area; 1ha=100mx100m (10,000m2). 1 hectare (ha) = 2.471 Acres		

Appendix 12: AP Legislative Acts (GoAP, 2012a)

Legislative Act in AP	Description of Act objectives and scope
River Conservancy Act – Madras Act VI, 1884	Basic modalities of defining rivers and river systems, methods of conducting surveys to determine river course and tributaries, setting limits on river beds and drainage systems. Establish authority of conservator of rivers to establish rules and regulations on granting permission of buildings, construction, plantations, grasses and trees on land adjacent to the river. Power of conservatory of rivers, resulting in penalties and punishment.
AP Irrigation Utilisation and Command Area Development Act, 1984	Provides constitution for the constitution of the Command Area Development Authority (CAD). Laws down functions and powers, including specifying command area under jurisdiction of the Commissioner, species command areas for systematic land development, construction of field channels, and preparation of land records. Empowers Irrigation officer for governing supply of irrigation water for one or more crop, settling disputes, regulation of cropping patterns. CADA Act paved way for establishing CAD department.
AP (Krishna, Godavari and Pennar Delta Area) Drainage Cess Act, 1985	Extending to all lands in the Krishna, Godavari and Pennar rivers deltas, establishes rules governing levy and collection of drainage cess which is laid to be levied and collected by the state government, for a period of five years.
AP Water Tax Act, 1988	Establishes water tax for each crop, proving guidelines for raising of water tax demand and the rationalisation of the levy and collection of water tax. Elaborates power of state government to levy and collect taxes from all government sources of irrigation. Details the manner of determining water tax, rules of governing revision and exemption, jurisdiction of powers to make rules and amend schedules relating to water taxes.

AP Groundwater – Regulation for Drinking Water Purposes Act, 1996	Regulate exploitation of groundwater and protection of public drinking water resources, laying down rules and licensing requirements. Creates appropriate centres of authority and organisations authorised for enactment.
AP Farmers Management of Irrigation Systems, 1997	Promotes the involvement of farmers in irrigation management, with ultimate aim to transfer irrigation management from the state to farmers. Act details working rules and regulations governing organisational structure, area operations, composition, membership criteria, functions and resources to farmer organisations. Envisages transformation of government from direct service provider to facilitator or guarantor of services, with transferring rights and responsibilities to farmer organisations. Functions include reorganisation of organisations for maintenance and rehabilitation, new methods for cost recovery, new participatory approaches, and capacity building. The act delineates Water User Associations on a hydraulic basis, with all water users in an area given membership with voting rights. Organisational structure of farmer organisations to be determined on size of the irrigation scheme. Function of WUA: secure distribution of water amongst users, maintenance of irrigation system, optimisation of agricultural productivity, protection of environment and ecological balance. Farmers organisation entrusted with maintenance of systems, water budgeting and promotion of efficiency water use.
AP Water, Land and Tree Act, 2002	Enacting the promotion of tree cover, regulation exploitation of surface and groundwater, strengthening private sector involvement. Empowers authority to control registration of all wells and water bodies, prohibition of pumping, granting permission to sink wells near drinking water surfaces, regulate exploitation of groundwater resources, protection of public drinking eater, registration of drilling rigs, and guidelines for appropriate rainwater harvesting structures. Surface water quality monitoring and enforcing of standards, protection of surface water bodies, guidelines for sand mining.
AP Water Resources Regulatory Act, 2009	This act established the formation of the AP Water Resources Regulatory Commission (APWRRC). The objective of the APWRRC is to facilitate the efficient, sustainable and scientific management of water resources of the state for drinking, agriculture, industrial and other purposes (ICAD, 2010, p33). Specific functions include determining the water requirement of various users of irrigation water including water user associations, municipal, rural drinking water and industry; determine the adequate operation and maintenance cost of irrigation and multi-purpose water projects; to promote efficient management of irrigation water by providing guidelines; regulate efficiency within all sectors involved in water use; and to assist the state government to implement the AP Water Policy 2008 by providing oversight and guidelines (ICAD, 2010, p34). The APWRRC consists of a chairperson and experts from irrigation engineering, groundwater, agriculture, economics and finance/revenue.

Appendix 13: Water resource status of river basins in India (Amarasinghe et al, 2005)

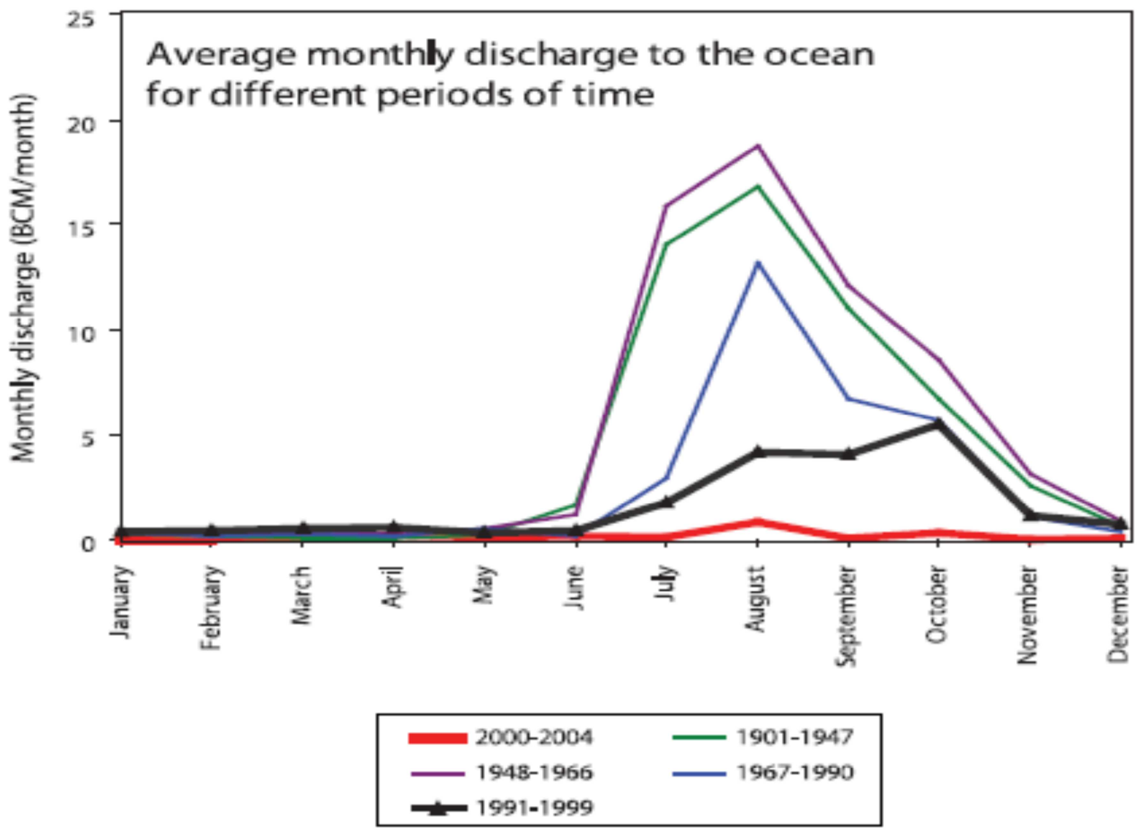
	Catchment Area[i]	Length of the river	Population			Total Renewable Water Resources (TRWR)	Potentially Utilizable Water Resources			Per capita Water Resources	
River Basin			Total[ii]	Density	Rural - % of total[iii]		Surface	Ground water[v]	Total	RWR/pc	PUWR/pc
	Km^2	Km	Million	No. people/ km^2	%	Km^3	Km^3	Km^3	Km^3	m^3	m^3
All basins	3,190,819		932	282	73	1887	690	343	1033	2011	1130
Sabarmati	21,674	371	6.0	521	54	3.8	1.90	2.90	4.8	239	302
Subernarekha	29,196	395	15.0	347	76	12.4	6.80	1.70	8.5	1216	833
Mahi	34,842	583	6.7	324	77	11.0	3.10	3.50	6.6	973	584
Meghna	41,723	-	10.0	160	82	48.4	1.70	8.50	10.2	7224	1522
Brahmani&Baitarani	51,822	1164v	16.7	204	87	28.5	18.30	3.40	21.7	2689	2047
Pennar	55,213	597	14.3	189	78	6.3	6.30	4.04	10.9	601	1040
West flowing rivers 1[vi]	55,940	-	58.9	425	72	15.1	15.00	9.10	24.1	478	763
Tapi	65,145	724	17.9	245	63	14.9	14.50	6.70	21.2	931	1325
Cauvery	81,155	800	32.6	389	70	21.4	19.00	8.80	27.8	676	878
East Flowing Rivers 1[vi]	86,643	-	19.2	293	74	22.5	13.10	12.80	25.9	946	1089
Narmada	98,796	1,312	17.9	160	79	45.6	34.50	9.40	43.9	2868	2761
East Flowing rivers 2[vi]	100,139	-	39.0	484	60	16.5	16.70	12.70	29.4	340	605
Mahanadi	141,589	851	27.2	202	80	66.9	50.00	13.60	63.6	2331	2216
Brahmaputra	194,413	916	33.2	161	86	585.6	24.30	25.70	48	17108	1529
Krishna	258,948	1,401	68.9	253	68	78.1	58.00	19.90	77.9	1186	1183
Godavari	312,812	1,465	76.7	186	85	110.5	76.30	33.50	109.8	1877	1865
Indus	321,289	1,114	48.8	140	71	73.3	46.00	14.30	60.3	1611	1325
West flowing rivers 2[vi]	378,028		51.9	166	57	200.9	36.20	15.60	51.8	3184	821
Ganga	861,452	2,525	370.2	449	75	525.0	250.00	136.50	386.5	1353	996

i - Source: CWC 1993. (Reassessment of Water Resources Potential of River basin
ii - Source for total population (UN 1998)
iii - Source for Renewable and potentially utilizable water resources is CWC 2000
iv - Potentially utilizable ground water resources is the ground water replenished from normal natural recharge
v - The length of Brahmani river itself is 799 km
vi – West Flowing rivers 1 includes rivers Kutch & Saurastra Including Luni; West flowing rivers 2 includes rivers south of Tapi, East flowing rivers 1 includes rivers between Mahanadi and Pennar and East flowing rivers 2 includes rivers between Pennar and Kanayakumari.

Appendix 14: Future water demand projections for India (Shah et al, 2007)

Sector (year)	**2000**	**2025**	**2050**
Irrigation	605	675	637
Domestic	34	66	101
Industrial	42	92	161
Total (BCM)	**680**	**833**	**900**

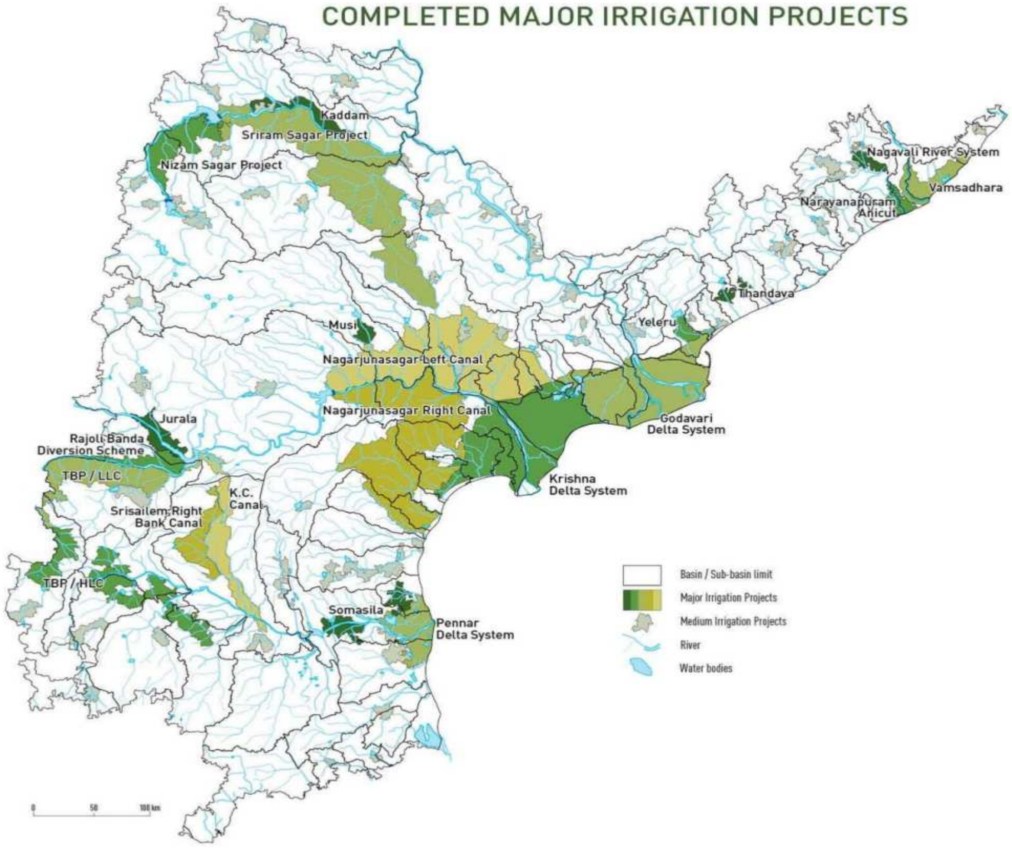
Appendix 15: Krishna river average monthly discharge to the ocean, 1901-2004 (Venot et al, 2007)



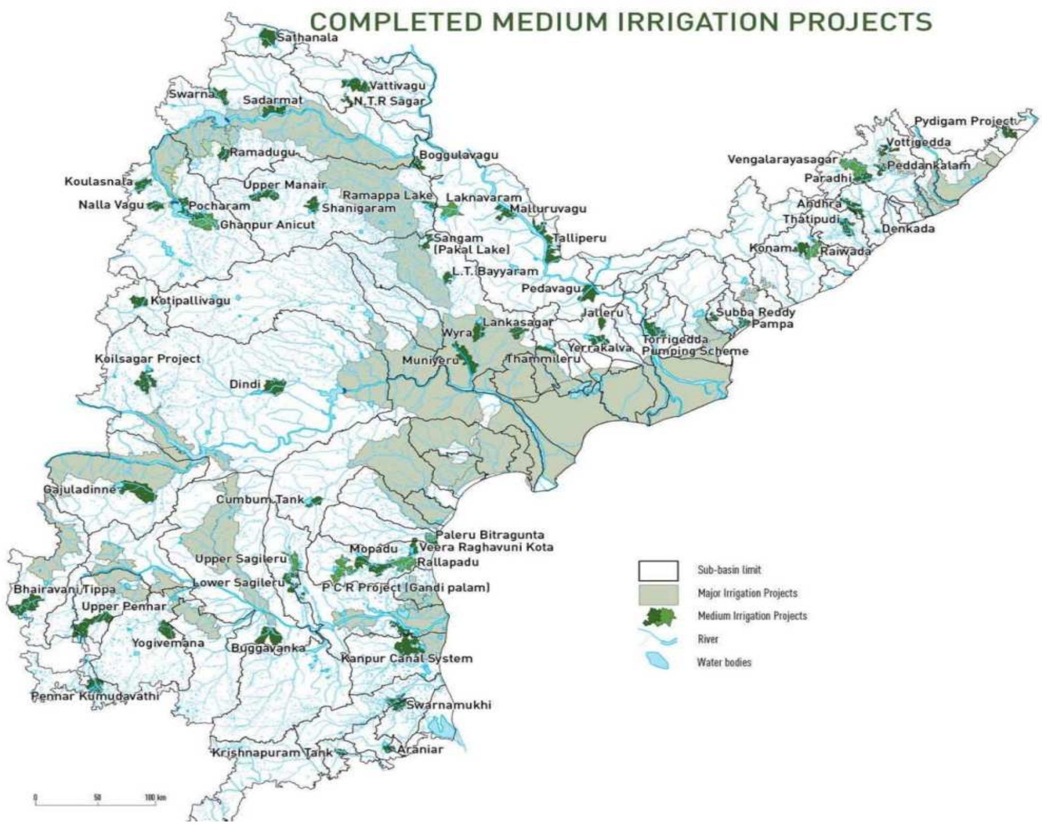
Appendix 16: Future sectoral water demands for 2025 for AP (GoAP, 2012)

Sector	2001 Utilisation (BCM)	2025 Projected requirement (BCM)	Increase in BCM (and % of the total)
Irrigation	64.2	108	43.8 (91.6%)
Domestic	0.6	3.5	2.8 (5.8%)
Industry	0.2	1.4	1.2 (2.5)
Power generation	0.028	0.056	0.028 (0.05%)
Total	**65.1**	**112.9**	**47.8**

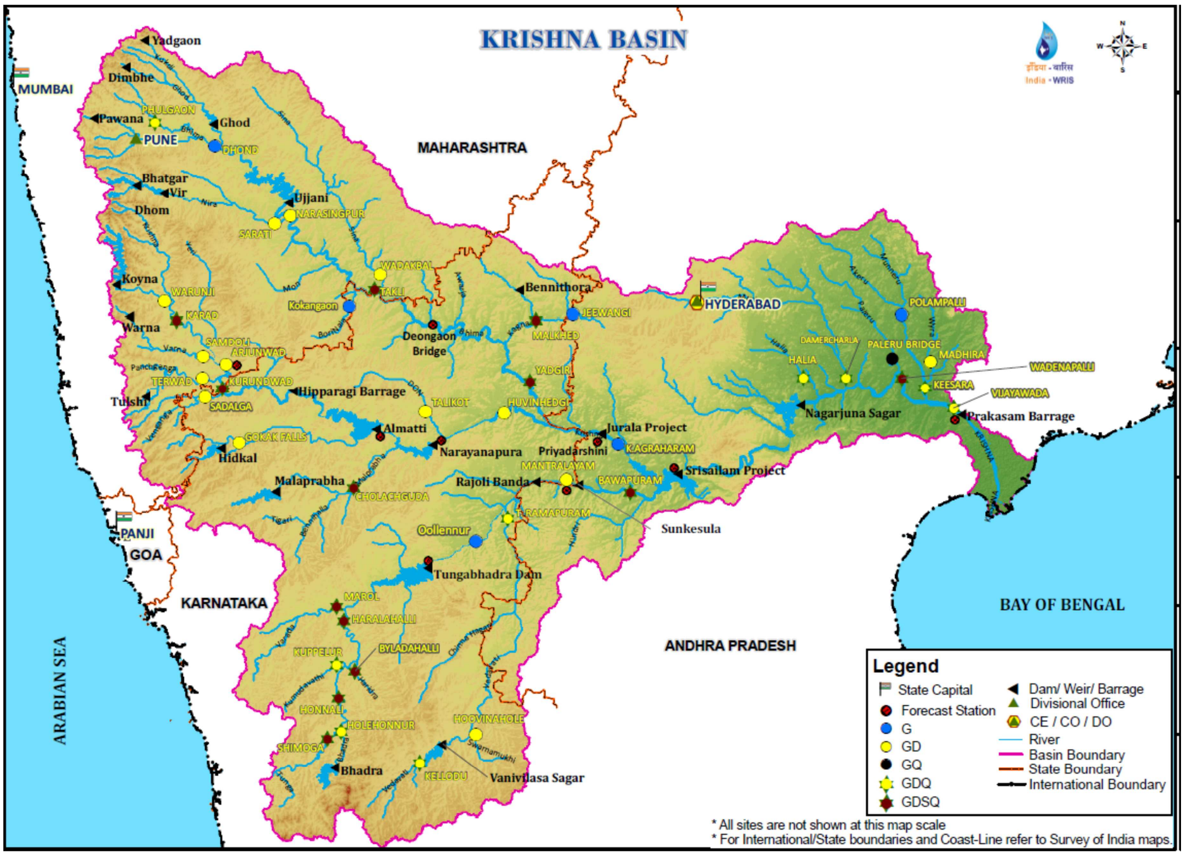
Appendix 17: Major Irrigation Projects in AP (India Water Portal, 2012)



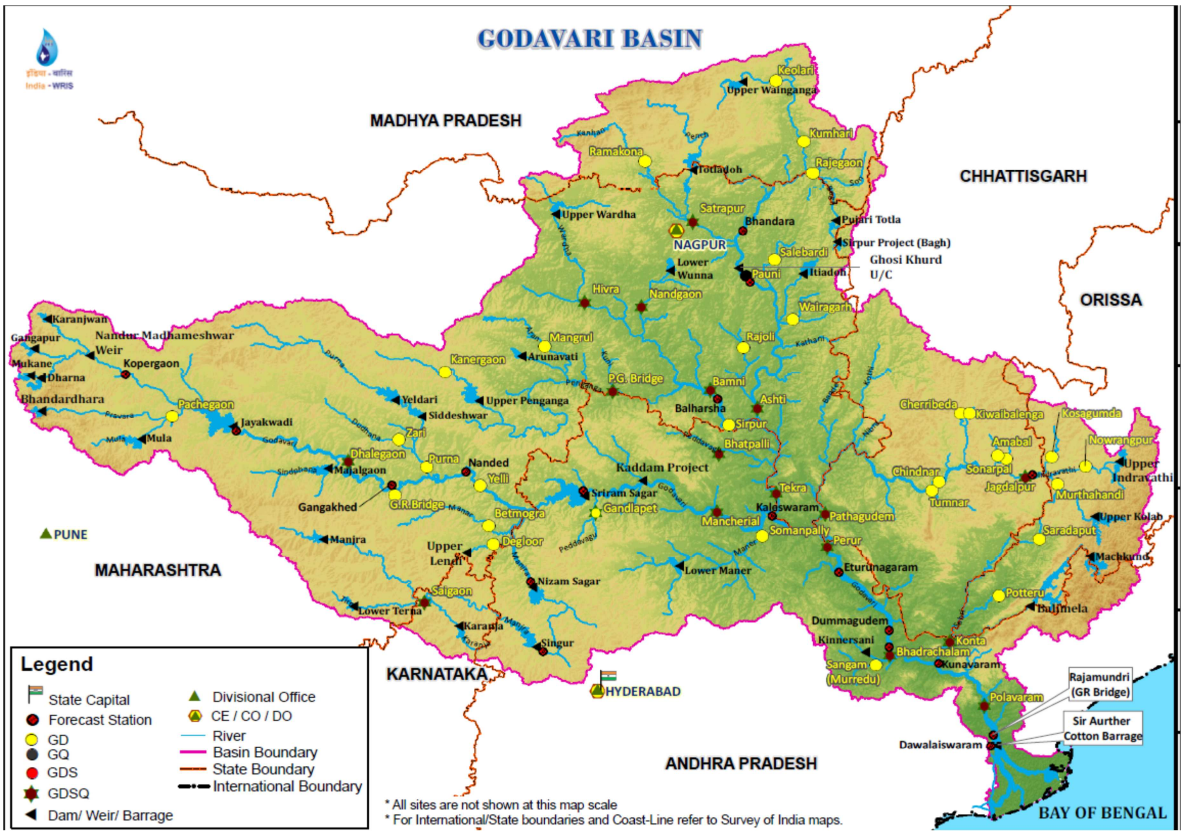
Appendix 18: Medium Irrigaiton Projects in AP (India Water Portal, 2012)



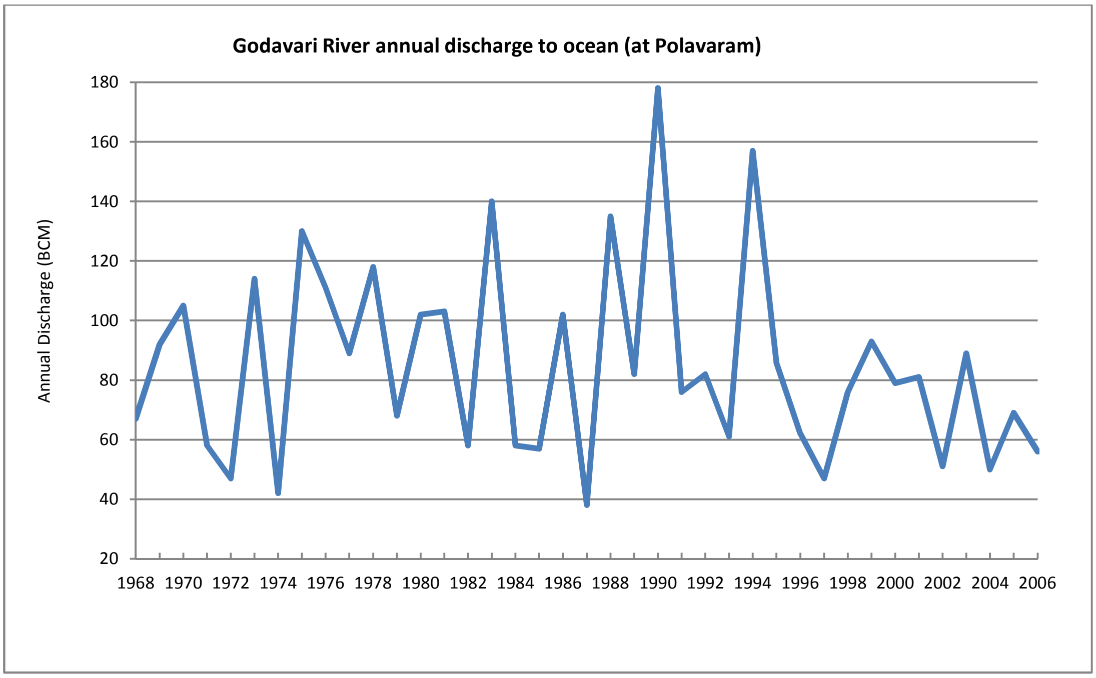
Appendix 19: Physical map of the Krishna River Bain (Venot et al, 2007)



Appendix 20: Physical map of the Godavari river basin (Venot et al, 2007)

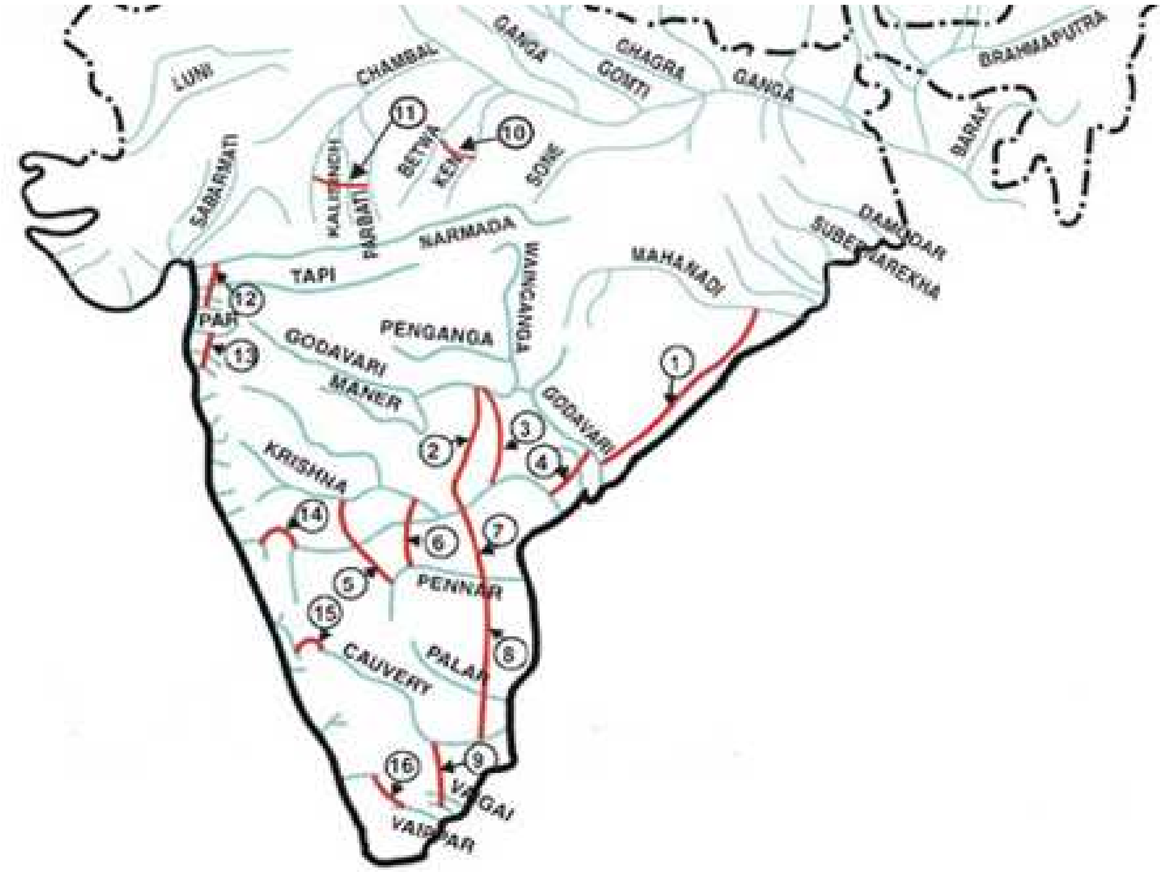


Appendix 21: Godavari River outflow, 1968-2006 (GoI, 2009a)



Appendix 22: Himalaya component of the National River Linking Project (GoI, 2012b)

Appendix 23: Peninsular component of the National River Linking Project (GoI, 2012b)



Appendix 24: National Water Mission policy (GoI, 2011a)

National Water Mission policy		
Goal 1	**Comprehensive water data base in public domain and assessment of impact of climate change on water resource**	1.1. Review and establishment of network for collection of additional necessary data 1.2. Development of Water Resources Information System and development of Web enabled Ground Water Information System and placing them in public domain 1.3. Development / implementation of modern technology for measurement of various data 1.4. Developing inventory of wetland 1.5. Research and studies on all aspects related to impact of climate change on water resources including quality aspects of water resources with active collaboration of all research organizations working in the area of climate change 1.6. Reassessment of basin wise water situation 1.7 Projection of the impact of climate change on water resources - Projection of water resources availability as a result of impact of climate change which would inter-alia include the likely changes in the characteristics of water availability in time and space.
Goal 2	**Promotion of citizen and state action for water conservation, augmentation and**	2.1. Empowerment and involvement of Panchayati Raj Institutions, urban water bodies, Water Users' Associations and primary stake holders in management of water resources with focus on water conservation, augmentation and preservation (capacity building) 2.2. Promote participatory irrigation management 2.3. Sensitization of elected representatives of overexploited

	preservation	areas on dimensions of the problems and to orient investment under MNREGP towards water conservation 2.4. Provide incentives for water-neutral and water-positive 2.5. Encourage participation of NGOs in various activities related to water resources management, particularly in planning, capacity building and mass awareness 2.6. Involve and encourage corporate sector / industries to take up, support and promote water conservation, augmentation and preservation within the industry and as part of corporate social responsibility
Goal 3	**Focused attention to vulnerable areas including over-exploited areas**	3.1. Expeditious implementation of water resources projects particularly the multipurpose projects with carry over storages benefiting drought prone areas and rain deficient areas 3.2. Promotion of traditional system of water conservation - expeditious implementation of programme for repair, renovation and restoration of water bodies in areas / situations sensitive to climate change by (i) Increasing capacity of minor tanks, and (ii) Rehabilitating water bodies, with changed focus. 3.3. Physical sustainability of groundwater resources 3.4. Intensive program for ground water recharge in overexploited, critical and semi critical areas 3.5 Conservation and preservation of wetlands 3.6 Intensive programme for addressing the quality aspects of drinking water particularly in rural area 3.7 Promotion of water purification and desalination 3.8 Systematic approach for coping with floods
Goal 4	**Increasing water use efficiency by 20%**	4.1. Research in area of increasing water use efficiency and maintaining its quality in agriculture, industry and domestic sector 4.2. Incentivize recycling of water including waste water 4.3. Development of Eco-friendly sanitation system 4.4. Improve efficiency of urban water supply system 4.5. Efficiency labeling of water appliances and fixtures 4.6. Promotion of water efficient techniques and technologies 4.7. Undertake Pilot projects for improvement in water use efficiency in collaboration with States. 4.8. Promote Water Regulatory Authorities for ensuring equitable water distribution and rational charges for water facilities 4.9. Promote mandatory water audit including those for drinking water purposes 4.10. Adequate provision for operation & maintenance of water resources projects. Provision for operation and maintenance of the projects to be appropriately enhanced 4.11. Incentive through award for water conservation & efficient use of water. 4.12. 12Incentivize use of efficient irrigation practices and fully utilize the created facilities
Goal 5	**Promotion of basin level integrated water resource management (IWRM)**	5.1. Review of National Water Policy 5.2. Review of State Water Policy 5.3. Guidelines for different uses of water e.g., irrigation, drinking, industrial etc particularly in context of basin wise situations 5.4. Planning on the principle of integrated water resources development & management 5.5. Inter-basin integration particularly for augmenting water by converting surplus flood water into utilizable water – Expeditious formulation of the projects for utilization of surplus flood water for beneficial use of the society and implementation of projects after evaluating costs and land acquisition problems. 5.6. Ensuring convergence among various water resources programmes

Appendix 25: Irrigation system efficiency of six major irrigation systems in AP (MWR, 2011c)

Irrigation project	**Cultivatable command area (Ha)**	**Conveyance efficiency (%)**	**On farm application efficiency (%)**	**Overall project use water efficiency (%)**
Godavari delta system	410108	83	54	45
Krishna delta system	529000	87	46	40
Nagarjuna Sagar	889000	56	39	22
Srisaliam	59000	50	34	17
Tungabhadra high level canal	45800	81	58	47
Tungabhadra low level canal	61163	72	45	32
Average	**N/a**	**71.5**	**46**	**34**

Appendix 26: NWM goal adoption by AP ICAD

National Water Mission Goals and strategies		Adopted by CW and/or CAD	Previously on-going or NWM specific	ICAD initial strategies
Goal 1 **Comprehensive water data base in public domain and assessment of impact of climate change on water resource**	1.1. Review and establishment of network for collection of additional necessary data.	Yes CAD	On-going	Existing programme of hydrological data collection. No plan for collection of further data in relation to climate change.
	1.2. Development of Water Resources Information System and development of Web enabled Ground Water Information System and placing them in public domain	Yes CAD	On-going	ICAD website with limited hydrological data and project information.
	1.3 Development / implementation of modern technology for measurement of various data.	Yes CAD	On-going	Remote sensing, GIS and satellite imagery.
	1.4. Developing inventory of wetland	No	-	No plans
	1.5. Research and studies on all aspects related to impact of climate change on water resources including quality aspects of water resources with active collaboration of all research organizations working in the area of climate change	Yes CW & CAD	NWM specific	Input of external organisations (national and international) to further understand climate change impacts in AP.
	1.6. Reassessment of basin wise water situation.	No	-	No plans
	1.7 Projection of the impact of climate change on water resources - Projection of water resources availability as a result of impact of climate change which would inter-alia include the likely changes in the characteristics of water availability in time and space.	Yes CW & CAD	NWM specific	Input of external organisations (national and international) to further understand climate change impacts in AP.
Goal 2 **Promotion of citizen and state action for water conservation, augmentation and preservation**	2.1. Empowerment and involvement of Panchayati Raj Institutions, urban water bodies, Water Users' Associations and primary stake holders in management of water resources with focus on water conservation, augmentation and preservation (capacity building).	Yes CW & CAD	On-going	Promotion of Water User Associations to promote irrigation efficiency.
	2.2. Promote participatory irrigation (PIM) management	Yes CAD	On-going	Promotion of PIM since passing Act for AP Farmers Management of Irrigation Systems (1997)
	2.3. Sensitisation of elected representatives of overexploited areas on dimensions of the problems and to orient investment under MNREGP towards water conservation	No	-	No plans
	2.4. Provide incentives for water-neutral and water-positive.	No	-	No plans
	2.5. Encourage participation of NGOs in various activities related to water resources management, particularly in planning, capacity building and mass	No	-	No plans

	awareness.			
	2.6. Involve and encourage corporate sector / industries to take up, support and promote water conservation, augmentation and preservation within the industry and as part of corporate social responsibility.	No	-	No plans
<u>Goal 3</u> **Focused attention to vulnerable areas including over-exploited areas**	3.1. Expeditious implementation of water resources projects particularly the multipurpose projects with carry over storages benefiting drought prone areas and rain deficient areas. The creation of 9Mha of additional irrigation area and 64BCM of storage through completion of 205 major and medium projects by 2012. Implementation of inter-basin transfers as part of NRLP to fully utilise water resources.	Yes CW	On-going	Jalayagnam programme. Creating of additional 4Mha of irrigation area (by 2020) and 7.5BCM reservoir storage by 2020. Carry over storage design for 20% in new infrastructure. Polavaram and Dummudgen inter-basin transfers.
	3.2. Promotion of traditional system of water conservation. Expeditious implementation of programme for repair, renovation and restoration of water bodies in areas / situations sensitive to climate change by Increasing capacity of minor tanks, and rehabilitating water bodies, with changed focus.	Yes CAD	-	No plans
	3.3. Physical sustainability of groundwater resources	AP Groundwat er dept with CAD	On-going	Monitoring GW levels; efforts to implement groundwater regulation to slow down high levels of GW withdrawal.
	3.4. Intensive program for ground water recharge in overexploited, critical and semi critical areas.	AP Groundwat er dept with CAD	-	Responsibility of AP Groundwater department
	3.5 Conservation and preservation of wetlands.	No	-	No plans
	3.6 Intensive programme for addressing the quality aspects of drinking water particularly in rural area	N/a	N/a	Outside of ICAD's objectives
	3.7 Promotion of water purification and desalination	N/a	-	Outside of ICAD's objectives.
	3.8 Systematic approach for coping with floods	Yes CW and CAD	On-going	Monitoring with flood management committee housed in CAD.
<u>Goal 4</u> **Increasing water use efficiency by 20%**	4.1. Research in area of increasing water use efficiency and maintaining its quality in agriculture, industry and domestic sector	Yes CAD	On-going	CAD research initiatives through performance management (water audits, benchmarking, agricultural water saving technology) and user groups (WUA, PIM). Research input from relevant state, national and international organisations.
	4.2. Incentivise recycling of water including waste water	No	-	No plans
	4.3. Development of Eco-friendly sanitation system	N/a	-	Outside of ICAD's objectives

	4.4. Improve efficiency of urban water supply system	N/a	-	Outside of ICAD's objectives
	4.5. Efficiency labelling of water appliances and fixtures	N/a	-	Outside of ICAD's objectives
	4.6. Promotion of water efficient techniques and technologies	Yes CAD	On-going	Performance management techniques (water audits, benchmarking, water saving technology such as micro irrigation.
	4.7. Undertake Pilot projects for improvement in water use efficiency in collaboration with States.	No	-	No plans
	4.8. Promote Water Regulatory Authorities for ensuring equitable water distribution and rational charges for water facilities.	Yes	On-going	APWRRC 2009 Act passed 2009. Still to be established (as of late 2012).
	4.9. Promote mandatory water audit including those for drinking water purposes	Yes CAD	On-going	Water audits since 2005 for irrigation system efficiency.
	4.10. Adequate provision for operation & maintenance of water resources projects. Provision for operation and maintenance of the projects to be appropriately enhanced.	Yes CAD	On-going	CAD operation and maintenance of irrigation systems through PIM and WUA.
	4.11. Incentive (financial) through award for water conservation & efficient use of water.	No	-	No plans
	4.12. Incentivize use of efficient irrigation practices and fully utilize the created facilities.	Yes CAD	On-going	CAD irrigation efficiency operations, and efforts to utilise irrigation area created.
Goal 5 **Promotion of basin level integrated water resource management (IWRM)**	5.1. Review of National Water Policy	N/a	-	N/a
	5.2. Review of State Water Policy	No	-	No plans to review AP SWP 2008
	5.3. Guidelines for different uses of water e.g., irrigation, drinking, industrial etc particularly in context of basin wise situations.	No	-	No plans
	5.4. Planning on the principle of integrated water resources development & management.	Yes CAD	On-going	ICAD on-going initiatives and WMC, although implementation of IWRM principles poorly understood at management and operational level.
	5.5. Inter-basin integration particularly for augmenting water by converting surplus flood water into utilizable water – Expeditious formulation of the projects for utilization of surplus flood water for beneficial use of the society and implementation of projects after evaluating costs and land acquisition problems.	No	-	No plans
	5.6. Ensuring convergence among various water resources programmes.	Yes CAD	On-going	CAD input into WMC since 2007.

Appendix 27: Adaptation screening of ICAD supply and demand strategies (1=positive; 0=negative; - = N/a).

	Autonomous	No regrets	Low regrets	Reversibility	Safety margin	Robustness
Reservoir storage	1	0	1	0	-	Partially
Irrigation expansion	1	0	1	0	-	Partially
Carry-over capacity	1	0	1	0	-	Partially
Inter-basin transfer	1	0	1	0	-	Partially
Flood management	0	1	0	1	-	Yes
Data mmgt monitoring	1	1	0	1	-	Yes
Irrigation efficiency	1	1	0	1	1	Yes
Groundwater	1	1	0	1	1	Yes

Appendix 28: Water requirement of principal crops cultivated in AP (GoAP, 2009)

Crop	Water requirement (millimetre)
Rice	1800
Wheat	450
Bajra	550
Jowar	500
Maize	500-600
Ragi	500-550
Cotton	850
Sugarcane	1950-2800
Pulses	350
Groundnut	650
Sugarbeet	600
Soyabeen	600
Onion	500
Pearl Millet	400
Pea	600
Banana	1600-1800

Appendix 29: Ethics consent application and approval forms

Official use only – ref. number		

UNIVERSITY OF EAST ANGLIA, INTERNATIONAL DEVELOPMENT RESEARCH ETHICS COMMITTEE

APPLICATION FOR ETHICAL APPROVAL

PART A – to be completed by the applicant(s)

Name of applicant:	**Matthew England**			
Student ID no. (if applicable)	**3825108**			
Project Title:	**Water Resource management in the context of climate change and variability in the Krishna river basin, India.**			
Project Funder*:	**N/a**			
Submitted by (✓)*	**SSF**		**ODG**	

*for DEV/ODG faculty or ODG research associate applications only.

Date of submission of application:	8 September 2008

Name(s) of all person(s) submitting research proposal (including main applicant)	Position(s) held (student/research associate/faculty) Students please specify your course	Department/Group/ Institute/Centre
Matthew England	PhD researcher	DEV

Address for correspondence relating to this submission:
School of Development Studies University of East Anglia Norwich NR4 7TJ

In the case of undergraduate and postgraduate research please give details of supervisor(s):	
Name	**Position held**
Dr Declan Conway	Senior Lecturer at DEV
Dr Bruce Lankford	Senior Lecturer and Head of DEV School

1. OVERVIEW OF THE STUDY: Describe the purposes of the research proposed. Detail the methods to be used and the research questions. Provide any other relevant background which will allow the reviewers to contextualise your research (400 words).

Overall Research Aim
Generate insights into how water resources are managed in the context of climate change and variability in the Krishna river basin, India.

Research objectives
A. To understand how government institutions interpret the challenges posed by climate change and variability, and how they manage water resource accordingly in a water scarce river basin.
B. To examine climate change and variability as a direct hydrological driver in the water scare Krishna river basin.

Research questions
A. To understand how government institutions interpret the challenges posed by climate change and variability, and how they manage water resource accordingly in a water scarce river basin.
A2. Have previous 'shock events' *associated* with climate change and variability in the Krishna river basin?
A3. Is climate change/variability *used* (as a 'shock' event or not) within the water policy narrative by state government institutions and/or certain actors to justify further water supply expansion (dams, inter-linking of rivers) at the expense of demand management responses such as re-allocation and conservation?
A4. What is the opinion of government water resource planners regarding the relative importance of climate change when compared against other water demand drivers?
A5. What are the implications for the river basin trajectory in light of the water strategy adapted to climate change?

B1. What are the future implications of climate change on rainfall rates and water resource availability in the (lower) Krishna basin? And what is the significance of changes in rainfall (CV) for the river basin supply/demand balance, when compared against increasing water demand from water demand drivers (urbanisation, industry, etc).

Methods
Objective A – Qualitative data
Primary data from interviews with state government officials in Andhra Pradesh. Possible interviews with representative from other actors in the water sector, including private sector, civil/NGO and international donor communities.
Secondary data from current and historic policy documents (state and national), relevant research reports, and news/opinion articles.

Objective B
Secondary hydrological data on rainfall levels and variability at national and river basin level, in addition to river flow data where available.

2. SOURCES OF FUNDING: The organisation, individual or group providing finance for the study.

Economic and Social Research Council – ESRC +3 PhD studentship

3. RISKS TO PARTICIPANTS: What risks to the subject are entailed in involvement in the research? Are there any potential physical, psychological or disclosure dangers that can be anticipated? What is the possible benefit or harm to the subject or society from their participation or from the project as a whole? What procedures have been established for the care and protection of subjects (e.g. insurance, medical cover) and the control of any information gained from them or about them?

The only risk envisaged is the sensitivity of data from respondents. However, anonymity of responses and interviewees identities is guaranteed. Potentially sensitive data will be stored in secure electronic and hard copy manners. Any potentially sensitive secondary hydrological data collected during the study will be carefully secured and shared with no third parties whatsoever.

4. RECRUITMENT PROCEDURES: Is there any sense in which subjects might be 'obliged' to participate – as in the case of students, prisoners or patients – or are volunteers being recruited? If participation is compulsory, the potential consequences of non-compliance must be indicated to subjects; if voluntary, entitlement to withdraw consent must be indicated and when that entitlement lapses.

Interviewee's participation is entirely voluntary. Entitlement to withdraw consent will be indicated at the onset of the interview, and when/if voluntary participation entitlement lapses. Anonymity of interviewee's identities and/or particular quoted or unquoted responses will be guaranteed and adhered too throughout.

5. PARTICIPANTS IN DEPENDENT RELATIONSHIPS: Specify whether subjects will include students or others in a dependent relationship.

N/a

6. VULNERABLE INDIVIDUALS: Specify whether the research will include children or people with mental illness, disability or handicap. If so, please explain the necessity of involving these individuals as research subjects.

N/a

7. PAYMENTS AND INCENTIVES: Will payment or any other incentive, such as a gift or free services, be made to any research subject? If so, please specify and state the level of payment to be made and/or the source of the funds/gift/free service to be used. Please explain the justification for offering payment or other incentive.

No payments or incentives will be offered. Interviews will be carried out on an entirely voluntary basis.

8. CONSENT: Please give details of how consent is to be obtained. A copy of the proposed consent form, along with a separate information sheet, written in simple, non-technical language MUST accompany this proposal form.

The interviewee will be asked his/her preference of gaining consent, either orally or in formal writing. Consent will be obtained orally and recorded with a voice recorder, if this is the preferred method of the interviewee. Or if the interviewee prefers, a consent form will be signed before the interview begins (see consent form).

The interview will not proceed until after consent has been agreed between both parties. Regarding sensitive issues, the anonymity of interviewees identifies and/or their specific response will be offered and agreed upon during the interview.

9. CULTURAL, SOCIAL, GENDER-BASED CHARACTERISTICS: Comment on any cultural, social or gender-based characteristics of the research participants which have affected the design of the project or which may affect its conduct.

Consideration and sensitively will be duly given to cultural, social and/or gender based issues. Social issues such as caste, cultural issues such as the sanctity of water in Hinduism, and gender issues notably of water access will be considered throughout the fieldwork period. It is expected that interviews with government officials will take a more formal arrangement, whereas interviews with member so the civil/NGO could potentially take a more informal manner.

10. CONFIDENTIALITY: Please state who will have access to the data and what measures which will be adopted to maintain the confidentiality of the research subject and to comply with data protection requirements e.g. will the data be anonymised?

I will have sole access to and responsibility for all the qualitative and quantitative data collected. The dissemination and/or sharing of data with third parties is entirely in my hands. Data will only be shared with a third party after (a) having made the data anonymous and (b) having reduced the data where needed to ensure that respondents cannot be identified straight forwardly (unless the respondent has explicitly agreed to this).

Data will be saved in a secure electronic manner, in addition to hard copy where appropriate. Data will be securely kept both during the fieldwork period and upon return to the UK.

Data will be anonymised in a systematic fashion both electronically and in hard copy, notably with regards to anonymity of respondents identifies and/or specific responses.

11. THIRD PARTY DATA: Will you require access to data on research subjects held by a third party? In cases where subjects will be identified from information held by another party (for example, a doctor or school) describe the arrangements you intend to make to gain access to this information.

N/a

12. PROTECTION OF RESEARCHERS: Please state briefly any precautions being taken to protect the health and safety of researchers and others associated with the project (as distinct from the research subjects).

Full health insurance will be taken out for the duration of the fieldwork period, in the case of emergency and/or illness.

13. MONITORING OF RESEARCH: What procedures are in place for monitoring the research (by funding agency, supervisor, community, self etc.)

Regular communication will be established with my UEA supervisor (Declan Conway and Bruce Lankford) throughout the fieldwork period. This will occur at regualr time intervals, on a weekly and/or monthly basis as required.

14. ANTICIPATED USE OF RESEARCH DATA ETC: What is the anticipated use of the data, forms of publication and dissemination of findings etc.?

The primary use of the data is to examine the research questions noted above. After completion of the PhD, data could be used in subsequent publications/presentations as appropriate. The process of anonymity of interviewee and/or responses will be continued both during and after completion of the thesis, in the form of possible post-PhD publications.

15. DURATION OF PROJECT	
START DATE	1st fieldtrip: 1 November 2008 2nd fieldtrip: 3 June 2010
END DATE	1st fieldtrip: 30 May 2009 2nd fieldtrip: 17 December 2010

16. PROJECT LOCATION(S): Please state location(s) where the research will be carried out.
India

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PART B – Review report and decision.

To be completed by the applicant:

Name of applicant:	**Matthew England**
Student ID no. (if applicable)	**3825108**
Project Title:	**Water Resource management in the context of climate change and variability in the Krishna river basin, India.**

To be completed by the Ethics Committee:

Reviewer's recommendation (✓):

Accept	✓
Request modifications	
Reject	

Reviewer's Comments
The changes required have been made.

Committee's recommendation:
Ethical approval granted.

Signature (Chair of the International Development Ethics Committee)	
Date	27th October 2008

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