From Integrated to Adaptive: A New Framework for Water Resources Management of River Basins

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Abstract

The paper considers the theory and practice of river basin management. We examine management responses to environmental and hydrological change related to growing water scarcity in the catchment of the Great Ruaha River in Tanzania to reflect on the theory and process of creating effective and workable goals and strategies for river basin management. We find that various gaps occur in the pursuit of normative 'integrated water resources management' that can be solved by applying a focussed interpretive approach to address identified problems in the three phases of the water availability regime: 'critical water', 'scarce water' and 'bulk water'. In exploring the adaptive approach, the paper presents a framework for river basin management and considers some implications for the science of river basin management as a whole.

Introduction

The purposive, goal-orientated management of the water resources of large river basins represents a highly challenging act. As often expressed, 'water management' assembles a wide range of activities within a connected physiographic unit in order to move basin stakeholders, perhaps many thousands of them, collectively to new patterns of water use and allocation that provides for varying degrees of economic and environmental enhancement and protection. This requires the adjustment of fluctuating quantities and qualities of water supply to disparate water users whose water demand alters and tends to increase, and who derive from water a wide variety of benefits and outputs. River basin management entails complex 'project management activities' such as, amongst others; establishing visions, goals, policies and strategies; implementing decision-making frameworks; promoting participation; improving infrastructure; leveraging finances and recovering costs; and monitoring in order to make necessary changes.

Reflecting these multiple challenges, 'integrated water resources management' (IWRM), has entered the lexicon of water managers and stakeholders as the mainstream approach to water management. As explained in the paper, IWRM in an idealised form denotes a package of tools and practices designed to match and accommodate the complex and 'mosaic' nature of the problem. IWRM gives managers a long list of many activities to execute, many of them simultaneously. Reflecting this, the World Bank's influential strategy booklet in 1993, which led to projects being established, embodied this integrated thinking, termed also as a 'comprehensive approach'.

Research in Tanzania shows that Government and donor projects have attempted to represent IWRM in practice while developing operational strategies, and in attempting to represent the idealised form, we argue, key activities were omitted, part deployed, or were pursued despite being inappropriate for the locality. Clearly, these operational strategies differ from idealised integrated water management because they cannot, without considerable funding, capture the whole picture. We especially argue that for large river basins the constraints associated with scale, knowledge, logistics, variability and systemic interfaces invalidates the pursuance of full 'integrated water resources management' as commonly conceived. This emulation is captured on the left of Figure 1, which theorises that operational strategies that stem from attempts to *represent* their fuller 'idealised integrated' form result in a partial fulfilment of that task.

The geographical context of this study[1] is the Great Ruaha River Basin in the Southern Highlands of Tanzania, an area of 68,000 km^2. The GRRB contains the Upper Ruaha (synonymous with the Usangu Plains catchment, covering an area of 21,500 km^2 and forming the headwaters of the Great Ruaha River). The Great Ruaha Basin itself is a major sub-basin of the Rufiji River, and the subject of numerous studies (Danida / World Bank, 1995; FAO, 1960; USBR, 1967). The Ruaha River Basin is a good candidate for the research of the science of river basin management on the basis of its size, complexity, national significance, competing users and history of river basin initiatives (Hazelwood and Livingstone, 1978). The case study is described in a number of articles (Baur et al., 2000; Franks et al., 2004; Lankford and Franks, 2000; Lankford, 2004).

Integrated water resources management

IWRM is usually discussed by comparing *ideal IWRM* (listing principles and acts of inclusion) against *actual IWRM* (listing problems and acts of omission). This contrast affects the way in which policies attempt to reflect the ideal. In an early analysis Mitchell (1990: p 4) realised this pitfall, writing "At the strategic level, a comprehensive approach should be used to ensure that the widest possible perspective is maintained. In contrast, at the operational level, a more focused approach is needed." He went on to argue that at the operational level, attention should be directed to a smaller number of issues that account for most of the problems. After looking at ideal and actual IWRM in the next two sub-sections, the discussion returns to the issue of crafting operational strategies.

With regards to the ideal IWRM, a review of the literature shows that water management is often seen as a meta-theory; that it is multi-dimensional rather than single in nature. Water management is 'framed' within an integrated approach that constitutes many different sub-theories (one of which is that for example, water rights are required as a means of legally altering levels of water depletion). Most commentators agree that water should be approached in an integrated fashion:

"Integrated water resources management expresses the idea that water resources should be managed in a holistic way, co-ordinating and integrating all aspects and functions of water extraction, water control and service delivery so as to bring sustainable and equitable benefit to all those dependent on the resource" (EC, 1998)

The EC (1998) explains the connection between IWRM and river basins; "The river basin is seen as a means for developing an integrated approach. Its closed geographic boundary system permits various sectors and users in a basin to work together: agriculture, flood control, industry, settlements, communities". Thus a river basin authority (RBA) brings together different functions of the administrative departments that usually have responsibility for these different sectors. We take as given that the function of a river basin management is to effect a form of integrated water management, and thus in this paper, these terms are virtually synonymous.

Various contributions to water policy have explored ideal IWRM. The World Bank (1993) proposed a framework that addressed principles, calling it "A comprehensive analytical framework" (pages 10-13). Van Hofwegen (2001), as an example of the ideal examines frameworks of IWRM, and explains that 'ideal IWRM' comes from theory of IWRM and its principles (page 141), and in his paper outlines in detail the many requirements that

[1] The paper is a product of the project RIPARWIN (Raising Irrigation Productivity and Releasing Water for Intersectoral Needs), a four-year research programme funded by UK's DFID. We have used the studies conducted under the project to retrospectively deliberate on the nature of river basin management.

constitute IWRM. The act of inclusion functions at the discourse level; (Allan, 2003) argues that it integrates 5 paradigms of managing water, the first two encapsulating expansion of water utilisation being society (pre-modern), economy (hydraulic mission) while the last three relate to demand management; environmental concerns, water as an economic good and water as a social and political good.

However, idealised IWRM is rarely the de facto practice. Even the World Bank's comprehensive approach in 1993 acknowledged that "the complexity of the analysis would vary according to the country's capacity and circumstances, but relatively simple frameworks can often clarify priority issues" (p 10). Mitchell (1990) believed maintaining a full approach, which he termed 'comprehensive', creates difficulties. Tapela (2002) felt that IWRM needs to relate to context: "the prospects for river basin institutions achieving the envisaged outcomes of IWRM are more strongly determined by the embedded contexts than by institutional conformity to a given set of organizational criteria."

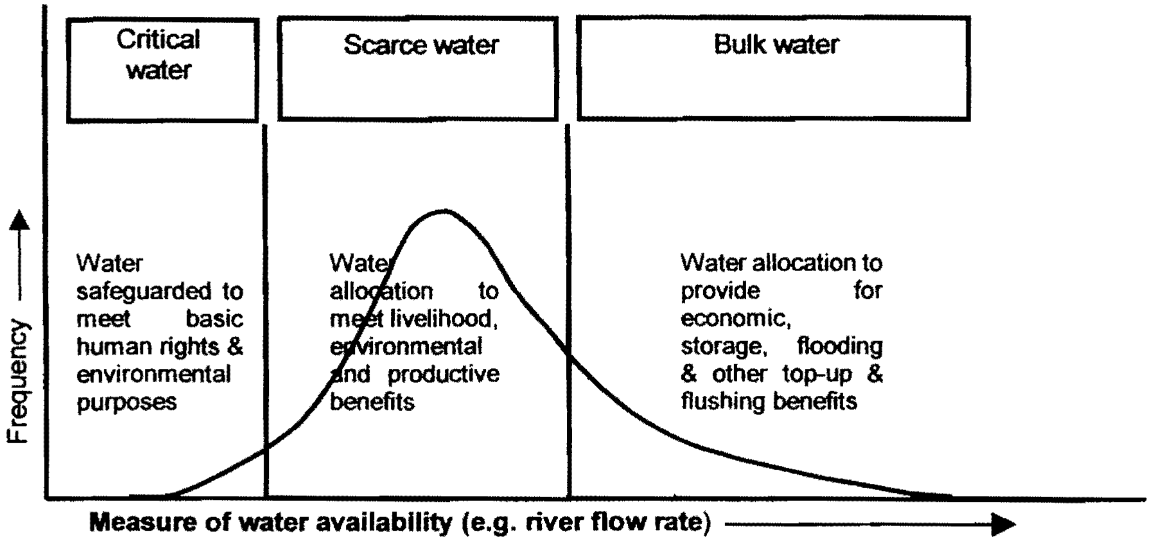
On a more critical note, analysis of actual IWRM operations manifests itself as critiques of water management or of specific and generic concerns regarding the appropriateness of river basin institutions to developing countries. For example Shah, et al (2001) and Carter (1998) are concerned with the applicability of river basin management to resource-poor situations, and conclude that there are many risks in copying normative, fully-fledged IWRM to local situations. In the follow up to the 1993 strategy, the World Bank 2002 review (Pitman, 2002) identifies shortcomings in rolling out IWRM, however this reads more as an eclectic list of 'lessons-learnt' rather than being grounded in a theory of how to generate meaningful operational strategies.

Interpretive Water Management

Water resource managers are interested in effective water management – moving towards focussed operations that recognise constraints and expedite solutions. Key to this is the process of developing those operations. It should be stated that although there are formulations of strategies of water management, few papers explicitly examine the process by which operational river basin activities are developed from the 'potential template' that IWRM constitutes.

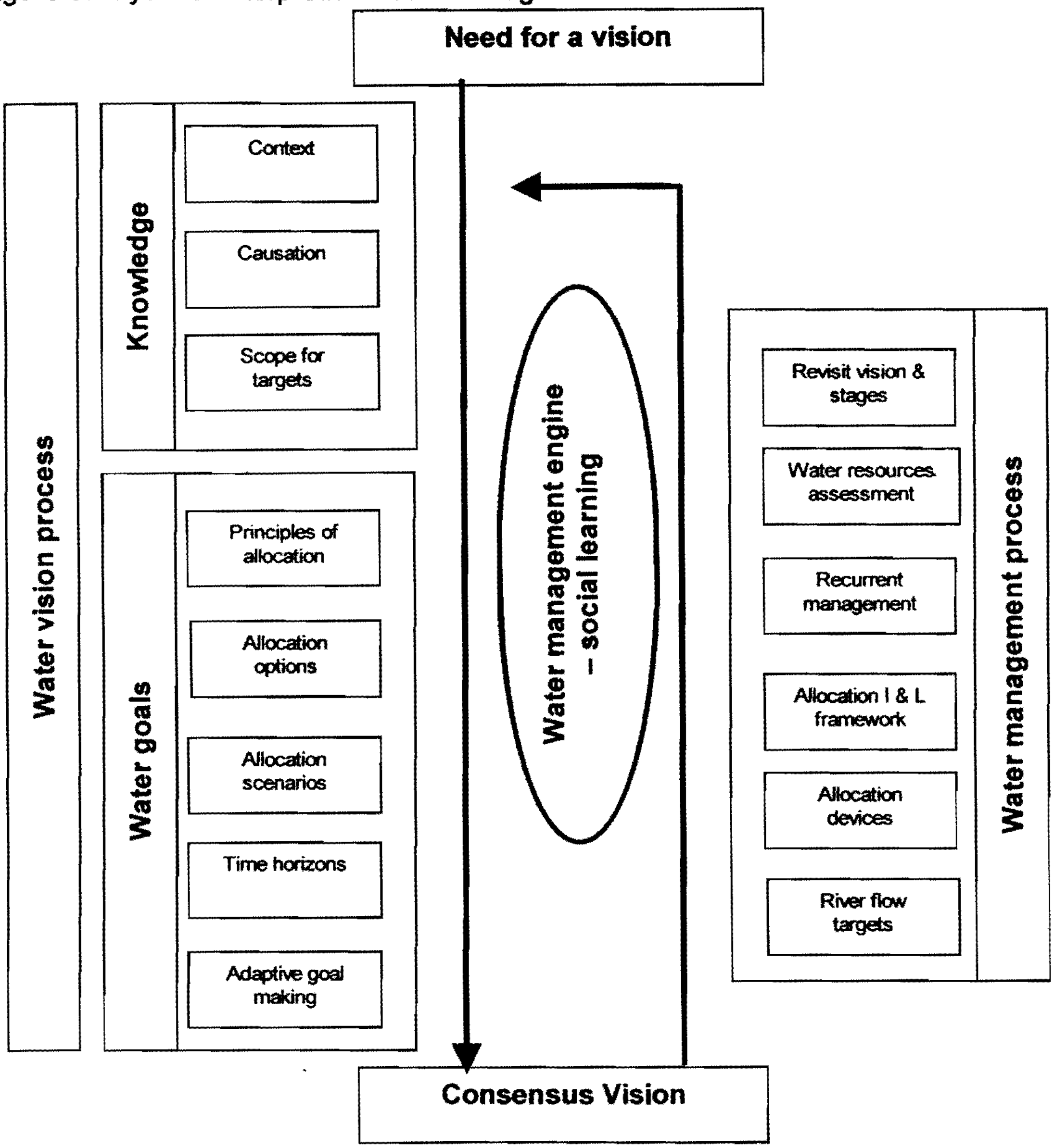
Figures 2 and 3 and Table 1 propose a new interpretive approach to developing a water management programme. Figure 2 combines with Figure 3 to give the matrix in Table 1, the latter being the proposed framework. In Figure 2, we argue that basin water is divided into three water phases; 'critical', 'scarce' and 'bulk', noting that the *y* axis is frequency and the *x* axis is a measure of a water availability, such as river flow rate, respectively. This allows us to understand the situation of, and specify goals for, each phase, and as will be seen later on, to generate phase-specific activities to fulfil these goals. Critical water is for vital lifeline needs required in arid situations for health and domestic purposes. Scarce water, notable during dry season and dry years, has to be shared between a number of sectors, including the environment and agriculture. Bulk water, which occurs during the wet season, provides ample amounts of water for a variety of purposes, including topping up of natural and artificial storage bodies. Table 1 explains in more detail the nature of the three phases. Figure 3 is the cycle of management that applies to each of the three phases in Figure 2 to ensure goals, needs and problems arising in different sectors are met.

Figure 2. The three-phase challenge of creating goals and managing river basins



In Figure 3, the cycle of interpretive water management is divided into four main stages, (discussed below). In keeping with our critique of the science of river basin management, these four translate into a science of understanding; a science of establishing goals; and a science of developing a management response to those goals, and a science of generating activities that lead to and drive those three steps. We have grouped the first two into a 'vision process', because in Usangu we noticed that consensus in understanding the cause of hydrological change is linked with a consensus on solutions and a vision of future water allocation. Figure 3 puts the fourth, the water management engine, at the centre of the other three. This is a critical part of how goals and responses are derived, and although is the fourth stage, it might easily have been discussed first or as part of the second stage. Figure 3 emphases an iterative cycle of development – it would be a mistake to see these components working in a linear manner. In particular, it would be incorrect to see the visioning, management response and engine being separate issues because the latter generates information that can be used in the former and because participatory processes are required throughout.

Figure 3. Cycle of interpretive water management



Part 1. Precursor integrated understanding

We argue that to pursue interpretive water management requires an understanding of the context that draws from integrated water resources guidelines. In other words, normative IWRM forms a template background to analyse the situation.

Context

Briscoe (1997) argues that "context matters (a lot!)" when tailoring water management to a given situation. Context covers an understanding of the biophysical nature of the challenge. The Ruaha River Basin reflects some biophysical conditions found within Sub-Saharan Africa. These conditions have been noted by other authors (Carter, 1998) as posing special risks for the application of IWRM. The size of the sub-basin (68,000 km^2) poses logistical problems for managing water by formal rights alone that require monitoring and policing. Multi-point, dispersed monitoring of both supply and demand is expensive, and to reduce these costs and to manage conflicts at the sub-catchment scale suggests that meaningful forms of subsidiarity are required. The basin experiences a single rainy season (600-1000 mm depending on climate and altitude). Rivers swell during this period, but shrink during the dry season between May and November, a period that suffers from water scarcity and conflict. In addition, the area experiences climate variability typical of Sub-Saharan Africa giving rise to periodic floods and droughts. This dissimilarity in water availability and associated dynamics suggests that flexibility is critical; that the three phases of critical, scarce and bulk water exist here; and that the dry season needs special care when there is insufficient water to cater for all sectors. In addition, the lack of aquifer buffering and re-routing in Usangu does not enable downstream users to access water that is used in inefficient ways upstream.

As well as the physical attributes of a river basin, its 'political economy' can have a major influence on water management. Formulating an effective response shows up inevitable gaps between legislation, institutions, organisations and desirable outcomes of water management – this has long been understood in river basin management. For example (Moss, 2004) examines institutional gaps in river basin management with particular argument that strategies should recognise that land use affects the water use. As economic development continues layers of complexity can be added. In Chile (Bauer, 1998), the trade-off in uses is between irrigation and HEP, arguably relatively straightforward compared to balances to be found between water pollution, protection of minimum flows, inter-basin transfer and groundwater management.

Further, if IWRM strategies are to address issues that are of importance "locally", this can only be achieved by understanding the socio political context and especially the conflicts that characterize the area. These conflicts are driven by the departure of objectives and interests peculiar to the different stakeholders. The latter represent all the issues that matters to the different stakeholders and can be defined as "values" (Keeney and Summer 1994). As stated by Hermans (2001), "if these values are not characterized, analysis efforts by hydrologists and other experts are likely to have very little impact on actual decision making". It is by defining the values that motivate different actors in each of the three flow phases that alternatives can be generated when defining articulated water goals and therefore lead to an adaptive response.

Table 1. Framework for adaptive water management of river basins

Stage of water management cycle	Sub-stage & aspects	Regime phase of water		
		Critical water	Scarce water	Bulk Water
Precursor understanding	Main supply function of this phase	Meet living & drinking needs	Meet agricultural, livelihood & eco-logical needs, protecting minimum flows	To top up storage bodies (artificial, natural, surface, sub-surface), to flush systems,
	Main period during year	Throughout year, but dry season is critical	Dry season	Wet season
	Sectors associated with phase	Domestic, urban	Agriculture, industry, environmental	Agricultural, hydropower, environmental,
	Amounts of water	Very small amounts of water, 20-300 l/day/pp	Small streamflows, 10 to 1000 litres/second	Medium to large flows >500 l/sec
	Timeliness & timing	Required daily	Daily to weekly	Seasonally important

	Quality of water	Highest quality required	Medium to high quality	Medium quality, sediments in flood water
	Change & causality	Investigate trends of water supply and demand, and study of driving factors within each phase		
	Scope for further change	Investigate scope for productivity and efficiency gains within each sector in each phase		
Setting adaptive goals	Principles that steer allocation	Water as a human/domestic right	Water as an environmental and productive right	Water as an environmental, productive and economic good
	Examples of scenarios	Pro-poor connection	"Pro-agriculture, pro-environment"	Pro-industry, pro-agriculture
	Examples of water goals	"80% of rural users connected"	"Aim for year round flow"	"Ensure a 50 cumec cap on irrigation abstraction"
Water management response	Routing the water	Amounts of water required at a given time	Cascading scarce water	Cascading bulk water
	Type of cap	Volumetric, set by capacity of supply infrastructure	Proportional abstraction cap	Total volumetric abstraction cap
	Infrastructure associated	Village boreholes, pipes, taps, bowsers	Irrigation intakes, boreholes, weirs, dividers & control structures	Intakes, dams, barrages
	Allocation institutions	Village borehole committee, water company or NGO	Irrigation water user assoc. + Sub-catchment WUA	Catchment & basin WUA
	Type of rights closely associated with phase	Customary agreements (village & household related)	Customary agreements / rights (proportional, time schedule basis)	Formal water permit (volumetric)
	Economic instruments	Payment for drinking water is a possibility	No payment for proportional share	Fixed payment for water right tend to be found
Water management engine	Institutional connections, participation & deliberation	Autonomous units around the infrastructure supplying water	Intake to Intake representatives of irrigation water user associations plus outside mediation	Basin Office facilitates and mediates basin negotiations
	Other tools of decision-making	Village and user level decisions	Field- and office based decision aids	Reservoir operation, office decision-aids

N.B. Some of the points made in this table refer to Usangu only

Causation – examining hydrological change

Related to the previous section on characterising the environment of river basin management, is the role of research in determining and isolating the factors affecting water distribution so that appropriate policies may be crafted. The research we envisage goes beyond water resources assessment (WRA) which is part of river basin management but which often inconclusively monitors flows without making that exercise explicitly part of 'problem-orientated' vigilance. This is explains the fact that although the Ruaha River dried in the early 1990's, the causality of that change could not be explained until the SMUWC project began its work in 1999. In addition, the responses to the problems, perceived and real, are illustrative of the need to arrive at a consensus understanding of the causes of the changes (Lankford et al., 2004b).

SMUWC and RIPARWIN found that the main reason for hydrological change was the increased abstraction of water into irrigation intakes during the dry season to meet livelihood needs but also leading to much non-beneficial depletion. The ability to abstract more water arose from the increasing number of intakes constructed and changes in the design of intake (Lankford, 2004). This causality however conflicted with other theories about hydrological change, some of which play a minor role. Good science was critical here; and although it need not be highly sophisticated it should at the very least be underpinned by field observations. Spending a few days on the Plains with flow-gauging equipment, satellite imagery and a GPS was enough to pinpoint where the main losses of water were occurring on the rivers; something that until that moment, remained conjecture.

Scope for reallocation – efficiency, productivity and storage

Moving to a consensus on how water is provided and shared requires knowledge of whether water is 'available' either within the hydrological record for storing[2], or within a water sector for saving and reallocation. Water availability is not only assessed from the hydrograph of supply against consumption but also from developing a picture of where water is working 'hardest', in other words, productivity and efficiency. Thus, the visioning process is partly informed by a 'productivity maximisation'.

An important precursor is to determine whether water exists to be allocated on the basis of subtracting from the net needs of water of a donor sector or from savings made within the gross water usage of that sector. The science underling the 'scope' for reallocation is critical – it is this that the experienced water manager is attempting to ascertain. In irrigation, a commonplace theory is that efficiency is low enough and gross volumes of water used high enough for there to be ample room to provide water to other sectors. This logic is not certain, not least because the theory of irrigation efficiency is dependent on boundary conditions and its detailed measurement rare. Conceptual work by IWMI (Molden, 1997; Perry, 1999) shows that local losses need not be seen as consumptive losses from the basin. In other words, the real efficiency of irrigation may already be high, and savings are unlikely to be forthcoming. Furthermore, even if possible, the outcome of transferred water is not guaranteed because of social costs involved and because local irrigators may recapture 'spare' water.

The case study in Usangu provides an example of the errors in scientific understanding of irrigation efficiency. The RBMSIIP project (World Bank, 1996) believed that their project would raise efficiency from 15% to 30% allowing substantial reallocation of water, as the following quote from page 42 explains, and that this would be effected by improving intakes and training farmers. Yet closer measurement indicates that effective efficiency was probably in the region of 45% to 65% precisely because of re-use of drain water by

[2] *Storage is a reallocation device, and expands the opportunities for reallocation between sectors. Storage holds water that otherwise would generate environmental goods in providing a range of natural flows downstream. The 'donating' sector in this case is the environment.*

tailenders. The errors shown in this quote are that a) the efficiency was very low and b) the losses were depleted from the basin, and c) improving intakes would reduce losses.

"In order to illustrate this effect, the "savings" in water which result from the improvement of some 7,000 ha of traditional irrigated area under the project (this includes both basins) are valued using their capacity to generate electricity in the downstream turbines. An average "in the field" requirement of 8,000 m3 of water, for one ha of rice production, implies withdrawal of 53,300 m3 from the river, with an irrigation efficiency of 15 percent. Following improvements in irrigation infrastructure, and an increase in irrigation efficiency to 30 percent, the withdrawal requirement from the river drops to 26,700 m3 per ha. This releases some 26,700 m3 for every ha of improved irrigation, to be used for hydropower generation downstream. For this exercise, the water is valued at 5 US cents per m3, the valuation for residential electricity use (34 percent of all electricity use, and intermediate point between the two alternate values)". World Bank RBMSIIP Appraisal Report page 42.

Part 2. Development of adaptive water goals

The second part of the framework generates goals of water allocation. The question is whether in a covertly (or overtly) political process, there is a science of creating visions for water allocation? By making this an open question, key problems can be addressed. Firstly, breaking 'goal-making' into stages provides us with a more transparent knowledge-based approach. Secondly, the stages reveal where the all-too-dominant 'principles of IWRM' reside in this process. Thirdly, we can articulate goals that might give us operable water management strategies but which might, interestingly, be quite disassociated with the earlier stage of expressing principles of allocation. This *step-change* problematic that comes from moving from principles of allocation to water goals, is solved by iteratively formulating adaptive water goals, as is explained.

Principles of allocation

The wide and conflicting range of principles of water allocation, and the priority and scale that they best apply to, make goal-articulation difficult – often it is not easy to discern what criteria are being pursued. Yet at the same time, being aware of these principles, even *ad hoc* historical legacy types, is an important part of the debate about river basin management objectives. Table 2 gives a number of drivers and principles in tension and lists the numbers of ways in which goals of water allocation can be argued for, including the commonly held notion that water should flow to users that generate the highest economic utility for the water used. The paper contends that these principles do not lend themselves to a more refined articulation of goals, rather they shore up goals that have been otherwise derived and then applied to different phases of the water supply regime.

Table 2. Principles of water allocation visions within river basins

Factor	Explanation and definition
As before	A priori rights determined by historical legacy may affect water use. This principle is behind riparian rights that allowed users to claim water by dint of their location close to a river. "Grandfather rights" meant that water rights could not be revoked unless new water laws were passed.
Precipitation-based	The Helsinki protocol states that water may be allocated in accordance with rainfall amounts found within parts of the river basin.
Higher economic utility (Principle of water as an economic good)	Often cited to be the main reason for re-allocation, water should flow to its highest value user to maximize economic utility for the river basin/nation. An example is of water allocation out of agriculture (a low value user), and into industry or power

	generation (a high value user). A similar case, or sub-clause, is that water is re-distributed to ensure higher water productivity.
Drinking, health and sanitation, and scalar effects (Principle of water as a basic need)	The principle that water is vital for life is often enshrined in domestic water rights that usually have the highest priority call on available water. Growing domestic demand from town and cities scale up this demand requiring rebalanced allocation.
Higher or wider livelihood utility (Principle of affordability)	A concept arguing that water should be safeguarded for poverty-focused productive livelihoods; e.g. water for irrigated agriculture. The argument is that poorer sectors cannot afford expensive water or a lack of water yet poverty results in high social externalities and costs. Also, higher value sectors are better placed financially to afford more expensive water-saving or water-finding solutions.
Environmental needs (Changing functional or value priorities and principle of societal values)	Humans determine changing priorities of water use. The clearest example here is of the supply for environmental needs, which in the last 10-15 years has come to be recognized as an important if not priority demand for water. Thus a river basin need not be closed in order for re-allocation to be required.
Conflict resolution	A class of change in priorities mentioned above, has special mention because of increasing occurrence, significance and need for resolution. Here lie a complex interaction of behaviour, fears and norms surrounding perceptions of demand, needs, wants, costs and benefits.
Principles of equity (Fixed vs proportional, and value derived)	Issues related to scarcity of water and nature of the water body. Physical division according to supply or value associated with the use of water. Or division according to proportions of available water (%'s)

Table 3. Options for water re-allocation

Option	Explanation
River basin or water body boundary	The river basin is the unit of management or alternatively, a given aquifer is the unit of management
Sub-basin	Part of a hydrological body is the unit of management
Political boundary unit	A political boundary (e.g. region or district) is used as the unit of management; this may cut across river basins (international rivers) or be part of a river basin.
Sectoral approach	Cross-user management is absent in favour of a sectoral emphasis, e.g. irrigation development in the 60's is an example of a sectoral emphasis
Active reallocation mode	In cross-sectoral allocation, water is actively moved out as a result of employment of allocation devices
Passive 'capture' reallocation	Water allocation changes as a result of de-facto growth of allocation to one sector without forward planning
Total reallocation	Water is moved completely from one sector to another
Partial reallocation	A proportion of water is moved out of one sector to another
None	Despite demand for re-allocation, none is effected
User-relocation	The user relocates in order to find water, thereby acquiring it.
Local supply solution	The user obtains water from the hydrological cycle; desalinization; boreholes, reservoirs – often this involves using water that was stored that in the longer run might have played an environmental role

Allocation options
River basin science also requires an explicit definition of the allocation options to assist the process of creating the vision for water allocation. Table 3 provides some of the allocation options, including basin wide allocation. Classifying allocation in Usangu, we could argue that it a basin-wide approach in assessment terms, but implemented in sub-basins and sub-catchments. It seeks a return to year round flow via partial reallocation amongst sectors in an active reallocation mode, employing basin and local solutions.
Allocation scenarios
Allocation categories or scenarios can encapsulate in words new arrangements or visions of water use. One scenario is 'status quo' or 'business as usual', while another is 'ad hoc'. Shin (1999) developed a scenario-consequence analysis, based on economic growth forecasts, to assess alternatives for water management. The Ruaha Decision Aid (RUBDA) will generate three main scenarios for the year 2010. These are termed 'Balanced' (ensuring year round flow through the Ruaha National Park, but also allowing water for rice and hydropower), 'Hydropower' (providing more water for Mtera-Kidatu) and 'Irrigation' (favouring upstream irrigation to the detriment of downstream flows).

It is important to note a disassociation between principles allocation and scenarios; the latter generally do not appear to draw on the former in an explicit fashion, although principles can be retrofitted to an allocation scenario. Allocation scenarios therefore provide a series of 'future options' where the main emphasis is on influencing economic patterns in the basin that lead from the current economic pattern rather by formulating a water distribution that strictly adheres to safeguarding principles of water allocation.

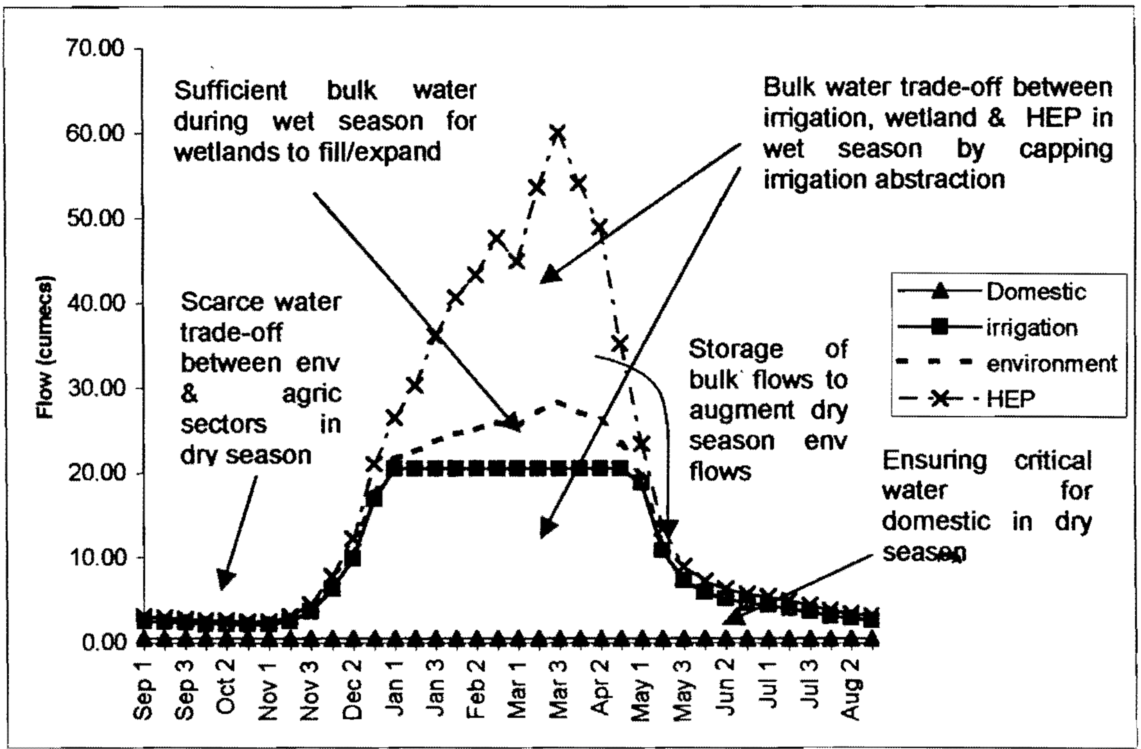
Time horizons
A review of the literature reveals that few scenarios are placed within a time frame. For the Ruaha, the target of year round flow has been set politically at 2010 (see next section). Time horizons necessarily provide stimulus for action. Working backwards, the authors believe stakeholders in the Upper Ruaha Basin are able to develop an explicit long-term (5-10 year) strategy for water management to meet this goal.

Adaptive goal making - three phase water management
In Ruaha, the agreed priority water allocation goal is to return the river to year round flow. This relates to the statement by the Prime Minister of Tanzania, Frederick Sumaye, in London, (6th March 2001), for the Rio+10 Summit[3]. Yet, how have the principles, options and scenarios translated into this articulated goal? Its difficult to see the linkages here, but the notion of adaptive goals seems to answer this if we break down river basin management into three phases (Figures 3 and 4). Adaptive goal making in the case of Ruaha functions by fitting goals to the likelihood of success in altering patterns of water use within each phase, and by finding that across all three phases, niches of water demand exist that cater for various principles and scenarios of water allocation. Thus, achieving year-round flow is seen as a 'scarce' water goal that meets Tanzania's new environmental laws but need not jeopardise agriculture and hydro-electricity production (HEP) because it is predominantly a dry season goal. As Figure 4 shows, the return to year round flow means that the substantial use of non- or low-beneficial water in dry season agriculture has to be curtailed, something that is possible given the predominant rice-fallow cropping pattern. It is possible to articulate other goals and related principles; in the dry season, critical water, meeting the principle of water as a basic right, would come from a programme of boreholes and piped supplies; while in the wet season, ample water could be apportioned between agricultural needs, the latter

[3] "I am delighted to announce that the Government of Tanzania is committing its support for a programme to ensure that the Great Ruaha River has a year round flow by 2010. The programme broadly aims at integrating comprehensive approaches towards resources planning, development and management so that human activity does not endanger the sustenance of the Great Ruaha ecosystems." *(N.B. 'Programme' here refers to government and non-government initiatives).*

giving water as a pro-poor livelihood right, and environmental needs and hydropower storage, the latter fulfilling the principle of water as an economic good.

Figure 4. Adapting water goals to fit water supply and demand patterns



Part 3. The expedient response – water management

In this section, and following Figure 2, under a number of headings, we exemplify the expedient response by developing a multi-stage strategy for managing the Ruaha River Basin according to the vision of returning the river to year round flow.

River flow targets – routing the water

Having derived adaptive goals of water distribution in the basin it is necessary to move to breakdown of how this can be achieved. For each subcatchment, this means specifying how much water is required in volume, time and place for a particular use/user. In this discussion, we use only scarce water during the dry season as an example.

This exercise is termed here 'routing the water', and involves mapping out a 'cascade map' to ensure water physically moves thróugh the landscape from donating to recipient sectors (Table 4). In order to provide a year round flow for the Ruaha through the national park, target flows for the supply of the wetland in upstream perennial subcatchments have been identified for each month of the dry season. Working backwards, this gives the allowable irrigation abstraction from the supply of water running off the high catchment. The same exercise can be conducted for a dry or wet year of rainfall, and for the wet season, if flows downstream for the hydropower reservoirs are required. The river basin decision-aid RUBDA (Cour et al., 2005) based on hydrological modelling (Kashaigili, 2005) is ideal for this target creation for a given scenario.

Table 4. Target flows in rivers and allowable abstractions to meet Ruaha vision

		June	July	Aug	Sept	Oct	Nov	Dec
Upstream river supply (cumecs)	N	4,68	1,38	1,38	1,38	1,38	1,38	1,38
	M	6,98	5,51	4,37	3,46	2,64	2,86	6,83
	K	2,24	1,46	1,11	0,90	0,75	0,72	3,57
	R	4,83	3,64	2,86	2,38	2,25	2,19	6,08
	T	**18,74**	**11,98**	**9,73**	**8,12**	**7,01**	**7,15**	**17,86**
Allowable irrigation abstraction (cumecs)	N	0,94	0,28	0,28	0,28	0,28	0,28	0,28
	M	1,40	1,10	0,87	0,69	0,53	0,57	1,37
	K	0,45	0,29	0,22	0,18	0,15	0,14	0,71
	R	0,97	0,73	0,57	0,48	0,45	0,44	1,22
	T	**2,78**	**1,67**	**1,37**	**1,15**	**0,95**	**0,99**	**2,36**
Target downstream flow (cumecs)	N	3,75	1,10	1,10	1,10	1,10	1,10	1,10
	M	5,59	4,40	3,50	2,77	2,11	2,29	5,46
	K	1,79	1,17	0,89	0,72	0,60	0,58	2,86
	R	3,86	2,91	2,29	1,91	1,80	1,75	4,87
	T	**14,99**	**9,59**	**7,78**	**6,50**	**5,61**	**5,72**	**14,29**
Per-river losses in wetland (cumecs)	N	2,89	0,93	0,99	1,04	1,05	1,05	0,85
	M	4,30	3,72	3,16	2,61	2,01	2,18	4,22
	K	1,38	0,99	0,80	0,68	0,57	0,55	2,21
	R	2,98	2,46	2,07	1,80	1,71	1,67	3,76
	T	**11,55**	**8,10**	**7,02**	**6,13**	**5,34**	**5,44**	**11,05**
Per-river contribution to Ruaha in RNP (cumecs)	N	0,86	0,17	0,11	0,06	0,05	0,05	0,25
	M	1,28	0,68	0,34	0,16	0,10	0,11	1,24
	K	0,41	0,18	0,09	0,04	0,03	0,03	0,65
	R	0,89	0,45	0,22	0,11	0,09	0,09	1,10
	T	**3,44**	**1,48**	**0,76**	**0,37**	**0,27**	**0,28**	**3,24**

Notes: N = Ndembera, M = Mbarali, K = Kimani, R = Ruaha, T = Total

Table 3 shows us that in order to maintain a flow in the Ruaha National Park, we need to release approximately 5 to 7 cumecs below the irrigation intakes during the dry season. Two factors relate to this. Firstly, this is partly dependent on whether the wetland can be kept topped up during the later part of the wet season, and therefore canal regulation is also important in this season. Secondly, this table allows us to determine whether storage is required to capture excess wet season water to augment dry season flows.

Allocation management framework

In the previous section, a routing exercise indicated where and how much water was required. This *quantifies* the water goals. In this section, we explore a number of ways in which those goals can be met. We argue that rather than defining these in the normative language of IWRM, it is more relevant to build a response adaptively and in keeping with the three phases of water flow.

Key rivers in key periods

An initial step is to identify key rivers where activities can lever as much benefit as possible (Lankford, 2001). In 2001, the Rufiji Basin Water Office initiated an intake regulation programme designed to ensure a reduction in dry season abstraction from the three key rivers feeding the wetland. To this end, negotiations with three main state farms reduced their water during the dry season to give enough water for domestic use rather than for irrigation of fields that were visibly not producing crops of any type. This clearly focussed on a 'scarce water' problematic. Lately, the RBWO has regulated intake flows during the latter part of the wet season to help keep the wetland topped up; a focus on 'bulk water' with a knock-on effect on the dry season.

Infrastructure for river basin management

Water allocation is strongly mediated by the presence of infrastructure, often playing a multiple roles in augmenting supply for one sector and reducing demand from another sector. For example on the Usangu Plains, village boreholes are a supply solution for domestic use but, in reducing the need to abstract water through the canals, they are also a demand solution for irrigation which leaves more water for in-stream environmental benefits. In a problem-focussed water management, infrastructure is added, removed or adjusted within sub-catchments to meet the water-routing goals. This is framed within each of the three phases of water supply, as Table 5 explains. For example, in Usangu, there are few sites for cost effective capture of bulk water using large reservoirs, yet one case might be on the Ndembera river for water to the Ruaha National Park during the dry season, which is a water scarce period. Thus, bulk water is taken from the wet season and reallocated during the dry season to the environment.

The design of irrigation intakes by RBMSIIP and programmes (UVIP, 1993; WER, 1993) influences water allocation. Downstream users are subjected to extreme low flows in the dry season as a result of upstream 'blocking weirs' taking all the water. These conventional types of intake aggravate a delicate situation where dry season flows of only 100-200 l/sec have to be shared between intakes and in-stream users. The aim here is adjust the intakes' design so that, firstly, the total volumetric cap allows excess, 'bulk' water to flow downstream during the wet season, and secondly, the proportional cap allows sharing of scarce water during the dry season (Lankford and Mwaruvanda, 2005).

Organisational and institutional set up

A pragmatic approach indicates that institutional design should be questioned and refined. Although handing over to the correctly identified group, invoking the principle of subsidiarity, is seen as an integral part of integrated water management – the *manner* in which this group is supported and is provided with institutional space is critical to the success of that provision. Tanzania proposes to establish Apex Bodies (the term for sub-catchment water user associations) to decide how water should be shared within the catchment and released downstream. One model (MOWLD, 2004) represents an ideal by giving a river level to each institutional body. However, disadvantages come from the requirement for four layers; basin, subcatchment forums, sub-catchment WUA's and irrigation WUA's. In addition, user fees are required to support these institutions. Instead, it is more relevant to consider which of the tiers of are most necessary, and how water management should be encapsulated formally at this chosen level, allowing that group to determine its institutional design and relationships with other organisations.

Table 5. Classification of river basin infrastructure

Water flow phase	Examples and sub-types	Definitions and notes
Critical flows	Technology for poverty focussed water acquisition (taps, pipes, boreholes, rainfall harvesting)	This class of infrastructure attends to critical flows that meet and safeguard poverty and environmental objectives. Although the amounts of water are small amounting to less than a litre/second the cost of installing the technology can be disproportionally high.
Scarce flows	Irrigation intake design for water sharing, proportional capping.	Water acquisition and sharing of scarce flows between intakes

	In-stream weirs	In-stream and storage environmental protection
Bulk water flows	Irrigation intake design for volumetric abstraction cap.	Capping of maximum amount of water taken by irrigation
	Large reservoirs	Reservoirs capture floodwater for storage and release for beneficial use during scarce or critical water periods.

Legislative framework
A review of the water policy, strategy and legislation of Tanzania seems to indicate there is a possible tendency for water legislation to put into 'legalese', or to encode, the notions and principles of water management without examining how water is actually managed. Thus the policy-strategy-law continuum is coherent but somewhere in that process the stresses and strains that water rights and fees places on the governance of surface water management are not recognised. For example, institutional space given to informal water rights is provided but not in sufficient detail so that their relationship to and precedence over formal water rights is explained. Adaptive water management seeks much greater traction here and encourages local users to formulate bye-laws and customary agreements to minimise conflict and to effect intra and inter-sectoral allocation. The scalar challenge is to marry these agreements with formal water laws and with users further downstream who might not be represented. As explained in the next section, the paper by Lankford and Mwaruvanda (2005) gives one way in which this might occur.

Economic instruments
Related to the previous two sections, formal economic instruments influence water allocation by costing the demand for water. In Ruaha this has been problematic (van Koppen et al., 2004). The fixed fees have not acted to dampen demand or associate a value with water use, as was intended. Yet on the other hand, some farmers in Usangu have discussed and implemented their own land based tax to help restrict over-development of land. This contrast between the failure of formal economic instruments and the introduction of informal charges designed by users informs an adaptive approach that water users are not against water charges but that the *means* by which they are introduced and then supported or related to service provision or scaled up is important.

Building on current legislation of water permits, Lankford and Mwaruvanda (2005) propose making the permit apply to the volumetric cap that curtails the use of bulk water during the wet season, allowing local users to negotiate shares of scarce water during the dry season either as proportions of the river flow or as time scheduling. This mechanism relates economic instruments, formal and informal water rights, infrastructure to the phase of water as argued in adaptive framework in Table 1.

Recurrent water management
The framework, given in the previous section, needs to be implemented. This section describes two issues that feed into the day-to-day management of that framework; cross-compliance and engaging with detailed knowledge of water. (We omit other factors that support daily management such as logistics, finance, personnel, administration, training and resources. These are adequately covered elsewhere in the literature).

Cross-compliance mechanisms
Cross compliance defines mutual agreements for progressing an agreed schedule of initiatives between two or more partners. Cross compliance involves wrapping all parties in such agreements. In a sense this is about managing motivation and leveraging further action out of all parties involved. Another term for this is 'transactional-transformational'; certain financial or physical transactions (for example building an intake) are connected to transformations, principally of an institutional-strengthening nature, of those receiving that

benefit (for example, having water users join a catchment committee). Thus for example water users 'comply' with some responsibilities in response to or parallel to work being completed by Government of NGO offices.

In the new Water Resources Strategy (MOWLD, 2004), the role of the Government is worth examining. In the draft document, the Government believes that it should no longer be a service provider (Section 3.1.3, page 14). However, under a cross-compliance framework this is not advisable; it has to be a service provider because users are paying fees for water, and a 'service return' for that fee is an important pre-requisite for on-going fee collection. Service provision can include the following: conflict resolution; co-ordinating infrastructural changes to improve water management at the catchment level; sourcing and disbursing funds to improve water source security (e.g. dams and boreholes); partnering with local user groups; and resolving water rights issues. Thus, the basin office creates a partnership with a given sub-catchment WUA to move through various stages of their water development.

Cross-compliance applies to both the river basin and sub-catchment scale, but also, importantly to irrigation systems. Irrigation has special significance because, although government and donor institutions should be cautious about the need to roll out irrigation, there is a case for their involvement and facilitation of improved water management. However, rather than this occurring because engineers dictate that irrigation efficiency is 'low' (with little dialogue developed with users), it is better framed as a response to requests by farmers who genuinely identify and verbalise water distribution problems. Such an approach has important dimensions of being problem-focussed, service-orientated, responsive and demand led. Various activities are envisaged; partnership engineering, facilitation sessions, game and role-playing, farmer training, problem ranking and participatory institutional analysis. It is likely that such an approach will develop new skills amongst engineers whose training tend to focus on conventional methodologies. The responsibility for instigating such capacity reform probably lies with the international irrigation community, although it is not clear that within this institutional group there is general agreement on the objectives and modalities of agricultural water management.

Working with detail

Expediting solutions relies on the cumulative outcome of detailed water management at the field level and a willingness to engage with and foster knowledge of this. This is an important point because detailed knowledge underpinned by field validation allows higher-level policies to be appropriately drafted and gives space for local users to explore their own methods for improving the productivity of water. The RBMSIIP programme revealed a lack of engagement with detail, believing that irrigation systems deplete water via seepage within the hierarchical canal system. This is understandable given that most irrigation engineers are trained to conceive of irrigation efficiency being a product of canal-level efficiencies multiplied together. Yet, losses in Usangu irrigation, which is not hierarchical in nature, do not arise during the supply of water to the crop but because of evaporation before and after the window of evapotranspiration during crop growth.

Working with detail is achieved by devolving responsibility for water management to farmers. Farmers are concerned about waste that they themselves define and observe each day. For example, the river basin game (Lankford et al., 2004a) generates considerable discussion of what constitutes waste and what to do about it. These discussions build on an agreement that productivity of rice need not be reduced. In addition, some farmers separate to the IWRM solutions forwarded by the Government, have explored economic solutions to demand management – they agreed to a land-based byelaw that encourages people to manage a few acres of land that can then be supplied with water rather than optimistically clearing land that remains dry (SMUWC, 2000). The comparison between the Government fixed charges for water rights and the marginal rules promoted by farmers speaks loudly about the ability of different 'players' to craft solutions based on intimate knowledge of how to dampen water demand in the face of shortages of supply. Benefits are gained from having experienced water professionals provide inputs here, but this is subtlety and crucially different from a Government call to provide training to farmers on water management as this is unlikely to reach the level of detail required by experienced irrigators that changes from place to place and over time.

Water resources assessment and monitoring
Water resource assessment (WRA) and monitoring allows us to observe the efficacy of water management and is a critical part of the framework, enabling adjustment of the goals and devices. However, ways need to be found of sustainably and transparently obtaining flows on supply and demand, and of incorporating local users in the recording of those flows engendered by a much greater utility and benefit from having them as a part of their local sub-catchment deliberations and allocations. WRA needs to be part of social learning and be included in the water management engine.

Revisit water goals and vision
The final part of the framework for interpretive water management involves revisiting the water goals and vision in order to pragmatically adjust it or add details that incorporate other principles of allocation.

Part 4. The water management engine – social learning

The previous sections describe three stages of acquiring knowledge, establishing visions and creating water strategies. We posit that the water management engine is at the heart of these, and is virtuously synonymous with social learning within a water-competitive environment. We argue that a healthy water management engine is based on selecting appropriate activities and programmes to mediate conflict, while on the other hand; a dysfunctional engine is constructed from inappropriate or infrequently held activities. Thus at the centre of adaptive water management is the development of capacity and skills of iterative social and technical learning by all water stakeholders. Blocking this development is any sense of arrival and accomplishment of a finalised water resources strategy. The very antithesis to social learning, therefore, is an over-reliance on short-term consultancies to develop water strategy documents because they create difficulties in creating long-term partnerships and adaptive strategies. How to develop relevant skills in social learning of all stakeholders is a question with few easy answers because various challenges exist in moving from consultation of stakeholders to representation of their opinions (Wester et al., 2003).

A review of RIPARWIN's experience in Ruaha and of the literature seems to point to some key elements of social learning in water: the cautious use of experts but a wider discussion of their findings; the use of stakeholder deliberative inclusionary processes (e.g. workshops based around the river basin game); support to the Basin Office via a river basin decision-aid that gives options for managing water and water rights while allowing the operator to see the outcomes of what-if scenarios without being overly didactic. One might be more explicit; providing 'social learning' to local groups using 'rural advocacy teams' and educational and intermediary (conflict resolution) tools as a means to determine perspectives on water sharing and management using farmers own experimentation and observation. The river basin game has potential here, eliciting many suggestions for saving water while producing rice. With respect to new or adjustments to devices to adjust allocation (e.g. infrastructure), these can be openly part of a locally negotiated road-map to sub-catchment water security.

Conclusions
Although the term 'integrated' in IWRM denotes a pragmatic and problem-focussed flavour, IWRM becomes scientifically 'ideological' in two ways at the operational level if not adapted to the circumstances. Firstly, idealogy is maintained if 'integrated' becomes the guiding

principle to establish an all-encompassing holistic approach, occluding a more expeditious and sometimes even mono-disciplinary 'objectives-guided' approach. Secondly, 'component ideology' occurs by applying a strand of IWRM theory without first determining its fit. In Tanzania, an example of misfit is the application of formal water rights designed to act as an economic tool (van Koppen et al., 2004).

In reality, the ideology of full IWRM is rarely accomplished. Instead, a reflection of it, in partial or focussed IWRM is. If integrated water management resources consists of 'a long list' of ideals for river basin professionals to implement, then *de facto* river basin management, which applies a narrow range of activities, is far from this. In this paper, we have argued that trying to achieve ideal IWRM while hampered by logistical constraints, institutional gaps and resource misunderstandings results in an 'improvised' IWRM that might use up precious resources without effecting desirable outcomes. If *de facto* river basin management is the commonplace model, which we argue it is, then the study of the process of distilling IWRM into water resource activities is important because this process defines the outcomes. On the other hand, utilising ideal IWRM as a template but attempting to expedite effective strategies in IWRM is more efficient, and requires, we argue, an interpretive, adaptive process. Trying to represent IWRM chases the ideal, while the interpreting IWRM targets success. Following this, the paper provides a possible theoretical framework to guide the interpretive process of creating meaningful adaptive water management programmes.

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