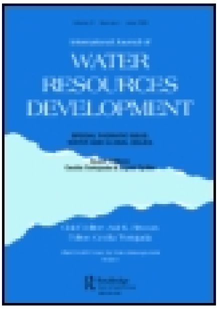

International Journal of Water Resources Development
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/cijw20

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Version of record first published: 21 Jul 2010.

Water Resources Development, Vol. 17, No. 3, 427–444, 2001

Red Routes on Blue Rivers: Strategic Water Management for the Ruaha River Basin, Tanzania

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ABSTRACT *Allocation of water in river basins not only requires the setting of targets of water supply to different users, but also the establishment of appropriate strategies to achieve those targets. As an example of this, 'red routes'—an idea taken from a plan used in the city of London to ensure free-flowing traffic on key arterial routes—is proposed for the Ruaha basin in Tanzania. The paper argues that allocation of water is best achieved by managing key rivers (red routes), rather than all rivers, and by concentrating on part of rather than the whole annual calendar. In this way, the principle of 'zoning' is employed to utilize comparative advantages found in some rivers and not in others. This strategic approach selects from the main theories of water management: command and control, technical, economic and community-based activities. It also uses, in part, a rural-livelihoods justification for re-allocation. This strategic approach fits the hydrological situation of both use and supply of water and has clear objectives in mind, proposing management activities necessary to deliver the objectives.*

Introduction

River basin management incorporates an integrated approach to water supply and demand within a river basin, often deemed to be a natural unit of water management:

> 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, and communities. (EC, 1998)

In developing countries, a key part of re-allocation of water is the ability to reduce the demand of water from irrigation. Such is the magnitude of irrigated water use, it is argued, that even small releases could provide significant benefits to other users. Yet solutions are not readily available. There are difficulties in applying economic and privatization forces to irrigation systems; of scaling up common property management mechanisms to the river basin scale; of applying 'command and control' approaches; and of applying out-of-fashion technical solutions. Individually these might not succeed, yet a flexible approach that mixes solutions taken from different theories of water management, 'zoned', focused and 'fitted' to the situation at the level of the river and irrigation system may provide the best means to redress water use patterns for large-scale surface

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DOI: 10.1080/07900620120065183

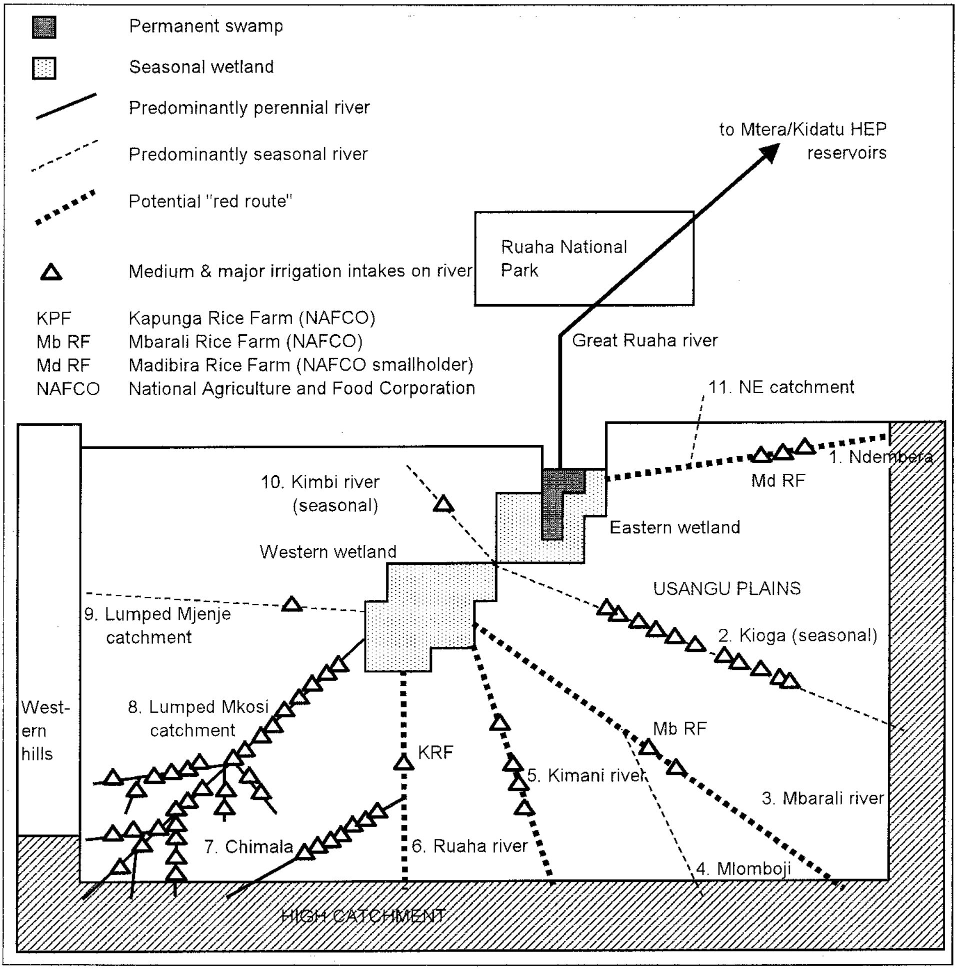

Figure 1. Red routes in the Usang catchment.

water systems. The 'red routes' notion in this paper details how such a 'strategic' approach at the river level might work.

Strategies for Ruaha River basin management arose from interdisciplinary studies being conducted for the UK Department for International Development (DFID) by the team working on the project: "The Sustainable Management of Usangu Wetlands and their Catchments" (SMUWC) in Southern Tanzania. The project started in 1998, with a three-year time frame. Based in Mbarali District, it reports to the Rufiji Basin Water Office (RBWO) and to local districts. The project resulted from concerns over water, particularly when shortages caused electricity cuts in Dar Es Salaam during the 1990s. The case study is described in brief below and in articles by Kikula *et al.* (1996), Lankford & Franks (2000), Baur *et al.* (2000) and in reports by the consultancy team (SMUWC, 2000a–e). Hazelwood & Livingstone (1978) can be consulted for a historical perspective.

The Case Study

Difficulties with surface water management in Sub-Saharan Africa arise from characteristics found in rivers basins here; size, scale and distances involved, lack of groundwater, seasonality of rainfall and communications to name a few. Carter (1998) notes some of these in his analysis of river basin management in Nigeria. The Ruaha River basin reflects some of these characteristics. Found in the upper catchment of the Rufiji Basin in southern Tanzania, East Africa, the river has a catchment area of 22 000 km^2 consisting of a central plain surrounded by high mountains to the east and south, and lower hills to the west. Figure 1 shows a schematic of the catchment.

There is one rainy season from mid-November to April during which rice is grown. Annual rainfall averages 1500 mm in the upper catchment and 600 mm in the plains. The upper catchment is the source of the rivers that flow into the Usangu Wetlands, a permanent swamp of approximately 50–80 km^2, from which the Ruaha river discharges. There are eight small perennial rivers and five larger perennial rivers, namely, the Chimala, Ruaha, Kimani, Mbarali and Ndembera. There are a large number of seasonal streams.

The basin has seven inter-connected users of water, as Table 1 indicates. In the upper catchment, there is rain-fed and irrigated agriculture. It is thought that water use here is relatively minor.

On the foot slopes of the escarpment and plains, basin-irrigated rice is found. Approximately 40 000 hectares of rice are grown during a normal-to-wet year when statistically average weather conditions occur. In a dry year, the core-irrigated area is much less at 22 000 ha, utilizing mostly river flows, with little reliance on rainfall. The rice-growing season is now quite extended, and for the purposes of modelling water use is from the second dekad in October to the first dekad in August. There are approximately 120 irrigation intakes found on rivers in the Usangu area. These account for an estimated maximum abstraction of 45 cumecs (m^3/sec) when river flows are near their maximum. This is approximately 31% of the total volumetric inflow during a normal-to-wet year, and 47% during a dry year. More pertinently, during the dry season, the abstractive capacity of 45 cumecs exceeds the average incoming supply of 17 cumecs. (Dry-season irrigated cultivation overlaps in the cropping calendar but is minor in extent at 2500 ha.)

Third, on the escarpment and plains, villagers require domestic water. The net amount of water required is small, probably less than a cumec for the whole basin, but the gross flow used in supplying water to villages via surface canals accounts for three to five cumecs. In addition, on the plains, pastoralists require drinking water for their livestock. From the 320 000 livestock believed to be on the plains (SMUWC, 2000a), it is thought approximately 100 litres/sec is used by livestock, less than 1% of that required by the rice. Further downstream, the Usangu Wetland exists providing a variety of functions (see Hollis & Acreman, 1994). It is thought that the permanent wetland of 80 km^2 evaporates approximately 4 cumecs on an annualized basis—though this increases as the wetland expands to over 1000 km^2 during the wet season.

The river runs through the Ruaha National Park providing the main water source for animals. Environmental water requirements are difficult to estimate, but estimates suggest a minimum of 1.5–4.0 cumecs in order to meet seepage into the sand riverbed and flow for the length of the Park. Finally, TANESCO,

Table 1. Comparisons of water used and production values in the Ruaha River basin

Main user of river water	Net water required	Gross water used	Area, yield or other production function
(Water available for use from Usangu rivers upstream of Mtera/Kidatu is approximately 85 cumecs)			
Rain fed production	500 ETo mm over 670 km^2 area	*Not part of surface water system*	Total production unrecorded
Irrigated rice and crop production	15 cumecs	26 cumecs	40 000 ha rice, 100 000 tonnes pa, 75% of national production
Villages/domestic water requirement	0.5 cumec	1–3 cumecs	210 000 people and livelihoods supported.
Livestock	0.1 cumec	1–3 cumecs	320 000 head = sales produce 41% of total local district tax revenues
Environmental – Usangu wetlands	4–5 cumecs to maintain core area of 80 km^2	5–10 cumecs for increases in area to >80 km^2	Fish-based livelihoods (300 people, 700 tonnes catch/year). Environmental and biodiversity functions, estimated to be less than 1% of Tanzania total permanent wetlands area.
Environmental – Ruaha and other riverine stretches	1–3 cumecs	3–4 cumecs (seepage is estimated)	Numbers visited, Jobs involved Dollars income (figures unknown)
Mtera/Kidatu (proportion from Usangu)	33.6 cumecs	50 cumecs (including evaporation from dams)	51% of national production in 1997 284 MW capacity

(NB, Flows are annualized averages; gross water used includes net water and losses to provide net water to certain points in irrigation/hydrological systems. Current Usangu flow at Mtera/Kidatu left over is 85 cumecs — 45 cumecs = 40 cumecs. This is annualized shortfall of 10 cumecs, assuming normal conditions apply. *Sources*: SMUWC Reports (2000a,b,c,e).

the national electricity generating company, owns and operates the Mtera/Kidatu hydroelectric power (HEP) generating reservoirs. In the past these supplied approximately 80% of the nation's electricity, though this has now decreased to 51%. Reservoir evaporation and releases to generate electricity require substantial volumes of water much of which is captured during the wet season.

Water Competition between Users

It was believed that rice was in direct competition with the replenishment of the reservoirs. Recent analysis suggests this is not the complete picture. For example, climatic fluctuation plays an important role; in normal-to-wet years, irrigation uses approximately 30% of available water, whereas in the 1-in-5 drier years, irrigation utilizes nearly 50% of all water. Moreover, since 1992/93, the previously perennial Great Ruaha River has dried up during the period September to December. Surveys of the rivers that feed the wetland reveal that flows reduce during the dry season, drying up completely during mid November through to December. This is a result of composite effects. The low flows are utilized by non-rice crops, domestic and livestock demand, watering of rice fields in error, and watering on purpose for duck hunting, fishing and, starting in September, to prepare fields for rice transplanting.

The Current Approach to Reallocation of Water in Usangu

There are currently two approaches to water control. A sectoral approach to improving irrigation is one; irrigators are encouraged to save water so that savings pass downstream. Efficiency is supposed to be gained from technical fixes (e.g. adjustable intakes) and management fixes (e.g. changes to water distribution). Such approaches are popular among donor agencies under the guise of smallholder improvement projects (e.g. DANIDA, 1998 and RBMSIIP quoted in the project Memorandum, DFID, 1998). However, it is not clear to what extent these past interventions have improved irrigation efficiency. In fact, due to expansion of rice and upgraded intakes, water demand has increased from approximately 10 cumecs in 1980 to 45 cumecs in 2000. Without additional safeguards, 'saved' water tends to be used by other irrigation systems in the Usangu area in further area expansion.

Command and control (Morris *et al.*, 1997) is the other main approach, providing formal non-tradable water rights to water users that then must be paid for. Water rights and fees are promoted widely in water resources literature (e.g. World Bank, 1993, pp. 44–53). These rights are flow rate based (e.g. 0.6 cumecs), and focus on wet season rice—though rights are halved for dry season period. The Rufiji Basin Water Office has records for 300 water intakes in the Usangu area, each of which will eventually, according to current policy, require a formal water right. (These intakes are on rivers and on drainage lines being tapped by irrigators peripheral to other irrigation systems.)

While water rights appear elegant (a simple flow rate) and may have worked in other countries, they may not be appropriate in Usangu. This is for a number of reasons. In some cases, the rights are simply water duties (command area multiplied by 2.0 l/sec/ha) without being reconciled with available water or downstream needs, in which case such water is not effectively available. In other cases, rights are not determined in a transparent way; they are not related to the command area or crop water requirement, but appear to be based on traditional rights, *de facto* rights, whatever is available during the peak flow period, or on unexplained reasons. In addition, because rivers change dramatically from wet to dry seasons, and from wet to dry years, the Usangu fixed rights approach only works for 'statistically mean' flows. In dry years, the right is greater than the available water, legitimizing the abstraction of water until the river is left dry. Conversely, for wet years, the right is less than the available water, and probably less than the actual abstracted amount because intake gates are surcharged with high flows.

Relating water use to right is problematic as water is unlikely to be ever metered and monitored and so farmers may take more than their right. Furthermore, with a fixed payment, farmers may not use the marginal rule—on the contrary—having paid for a right, they may be inclined to use more water than necessary.

RBWO staff and transport resources to monitor water use are restricted and are unlikely to increase, and access during the rainy season is difficult. Fees are rarely paid to RBWO and so do not augment the finances required to manage water. These constraints mean that, as evidenced by a recent survey (Gillingham, in SMUWC, 2000b), most farmers do not have, or are not aware of, their formal rights. The final response to 'failure to pay' involves locking of gates. Locks can be difficult to set for some gates and can be broken. Policing of a locked gate involves additional resources. Furthermore, such actions undermine engagement with the irrigation community. In effect, resources to implement the current vision of the RBWO are insufficient, and the strategy itself is questionable in terms of its intended outcomes. Howe (1996) also questions non-tradable permits under conditions of water scarcity.

A Seasonal Focus on Water Management

Before discussing water management further, it is necessary to understand the seasonal variation of supply and demand. Table 2 shows that three main periods exist. During the first 'highly stressed' period, November through to early-to-mid January, irrigators urgently need water to start rice nurseries and field preparation, yet rains and river flows have not picked up enough to meet and surpass this need. It is during this period that the rivers below intakes are frequently found to be dry. In the 'wet' period, from early-to-mid January to May, the rains arrive leading to substantially increased river flows. Apart from exceptionally dry years, the rains and river flows together provide enough water for both the irrigators and downstream users. The third 'managed balance' period is during the dry season, from June to the end of October. Here, *reasonable* gross crop and domestic water demand is thought to be less than 40% of total river supply, yet currently intakes are left open leading to much higher gross water use. This gross demand is used to distribute water to tail end and other localized points of water demand, to irrigate late-season planted rice, and to wet up land for the next rice season. Also water is abstracted and spread onto bare fields or into the bushveld either by neglect or because such water is used by fishermen and duck hunters to provide better conditions for their 'catch'.

Table 2. Seasonal variation of water demand and management

Period	Season	Dates	Hydrologic characteristic	Implications for flexible approach	Institutional focus
1	Late dry season/ early wet season	Nov to mid Jan	'Highly stressed' Demand $>>$ supply	Accept shortfalls in basin-wide allocation, but set targets for staged compensation flows	Local water users with external RBWO adjudication
2	Wet season	Mid Jan to end May	'Wet' Supply $>>$ demand	Allow for natural allocation of water	Local user monitoring with little RBWO involvement
3	Dry season	June to end Oct	'Managed balance' Supply $=$ demand (*Red Routes*)	Mixed strategic approach; irrigation interventions; technical demand and supply side solutions.	Local user monitoring with external RBWO monitoring

Strategies for Allocating Water

A review of options for allocating water was conducted by SMUWC (2000c). These are listed below under four main headings as they apply to the Usangu Plains. Some of these are utilized to construct the 'red routes' strategy, discussed later.

'Do nothing' strategies. During the 'wet' period (the second period in Table 2), it may be more efficient for the RBWO to 'do nothing' and rely on the natural allocation that occurs when water supply far exceeds demand. This happens during the mid-to-late rainy season, from approximately mid January to May. The RBWO has a diminished role as the process and scale of natural allocation of water is far greater than could be achieved by managing and monitoring intakes and water rights. However, if this becomes a 'do nothing' period, it may still be sensible to consider cautiously the construction and upgrading of additional intake structures which therefore would affect flows to the Mtera/Kidatu storage reservoirs.

During other times of the year, it may be necessary to accept severe shortfalls in re-allocation. This is another case of 'do nothing' except here demand greatly outstrips supply. This happens during the first period, mid October to mid January, when fields are wetted up for rice. The argument behind this 'do nothing' is that such is the intensity of water need that no external agency may meaningfully intervene to ensure compensation flows above a token gesture to ensure some environmental maintenance downstream. However, this would not preclude the agency from playing a role in mediating conflicts between users and ensuring these downstream compensation flows.

This second 'do-nothing' idea is predicated on the notion that for each downstream user there exists some buffering to low and zero flows. In other words, the Usangu Swamp, the National Park and TANESCO can go a certain period of time—specific to each user—without supply. This buffering capacity depends on the amount of storage and nature of demand of water by the user. The emphasis is on the time involved; for example a long and lengthening period of zero flow in the Ruaha is far more deleterious to wildlife than a short, but nonetheless highly visible period of zero flow.

Technical solutions. A number of supply side solutions have been proposed in the area (Riddle & Issae, 1993; SMUWC, 2000c). One solution is that storage or groundwater will solve shortages in water supply. However, these are problematic in Usangu due to a lack of suitable sites and the absence of a significant aquifer. However, an example of an appropriate supply-side solution is the establishment of boreholes and sand-dams for the Ruaha National Park.

A number of technical demand side solutions exist. These include: installing piped and borehole domestic water supplies to reduce canal conveyance of water; re-directing river flows to reduce losses in intermediate swamps; ceasing the upgrading of intakes; reducing the maximum capacity of selected intakes; altering canal layouts; and installing drains from irrigated areas back to rivers. While these represent technical solutions, they should be seen as negotiated solutions within a water user engagement process.

Community, institutional and legal solutions. Common property solutions are being closely examined by the project. SMUWC has proposed a river users association (termed a sub-catchment resource management programme (SRMP) (Devitt & Gillingham in SMUWC, 2000b). This idea encourages common property mechanisms within irrigation systems and also brings users from different irrigation systems together to reconcile water use within a sub-catchment of the larger Ruaha catchment. In this way, users might share water between intakes and agree to restrict the total irrigated command area. Although this is a scaling up of common property solutions to the catchment scale, success at these and still larger scales has yet to be observed. Alongside the river users association, refinements to water rights could be made. For example, the existing fixed intake right could be replaced by 'sub-catchment water rights' where one river water right is negotiated amongst the users.

In addition, proportional water rights are being tentatively discussed. Here, users negotiate with other stakeholders an abstraction based on a proportion of whatever the flow is in the river: for example, taking 10%, or taking 45% of the available flow regardless of the change in flow. By using appropriately designed intakes, the agreed proportion could be abstracted for a range of low-to-high flows. This initiative would need a redesign of intakes to ensure an acceptable transparency of division of flows. A repeated design down the river, termed 'castellated weirs' (see Figure 2) would enhance this transparency.

As Franks (SMUWC, 2000d) suggests, providing other sectors with water rights gives RBWO a wider non-rice perspective on claims for water. Examples are the passive water users such as livestock keepers, fishermen, the Usangu Game Reserve, the Ruaha National Park and TANESCO. At present, they require water but are not provided with water rights.

It may be possible to consider water right payments in kind. This idea suggests that cross-seasonal water payments be made in water rather than money on the basis that water has differing values at different times of the year for different users. The idea goes alongside the three-season analysis discussed above. Water users would 'pay in water' by not taking water during the main part of the dry season (June to November) in order to be given greater access to water during late dry season and the early part of the rainy season when water is more critically needed. In a sense, users would not pay money for rights, but accept greater discipline when water is restricted. This acknowledges that paying in cash for water is unpopular among farmers.

Economic solutions. The theory is that markets enable users to bid or pay each other for water so that its price reflects its value, resulting in water use controlled by cost–benefit decisions. Centralized and decentralized water markets are unlikely to play a major role in the near future, but are not discounted altogether. A centralized system is least likely to function because of variable nature of water supply; the large distances involved in communication; high transaction losses due to evaporation in the Usangu swamps; a lack of flow monitoring; and weak financial structures to support bidding for water. However, decentralized payments might function where tail-enders within the river system pay upstream users to release water. For example, the fishermen in the Usangu swamp could be paid by the Ruaha National Park to keep swamp channels open to maintain the through-flow of water.

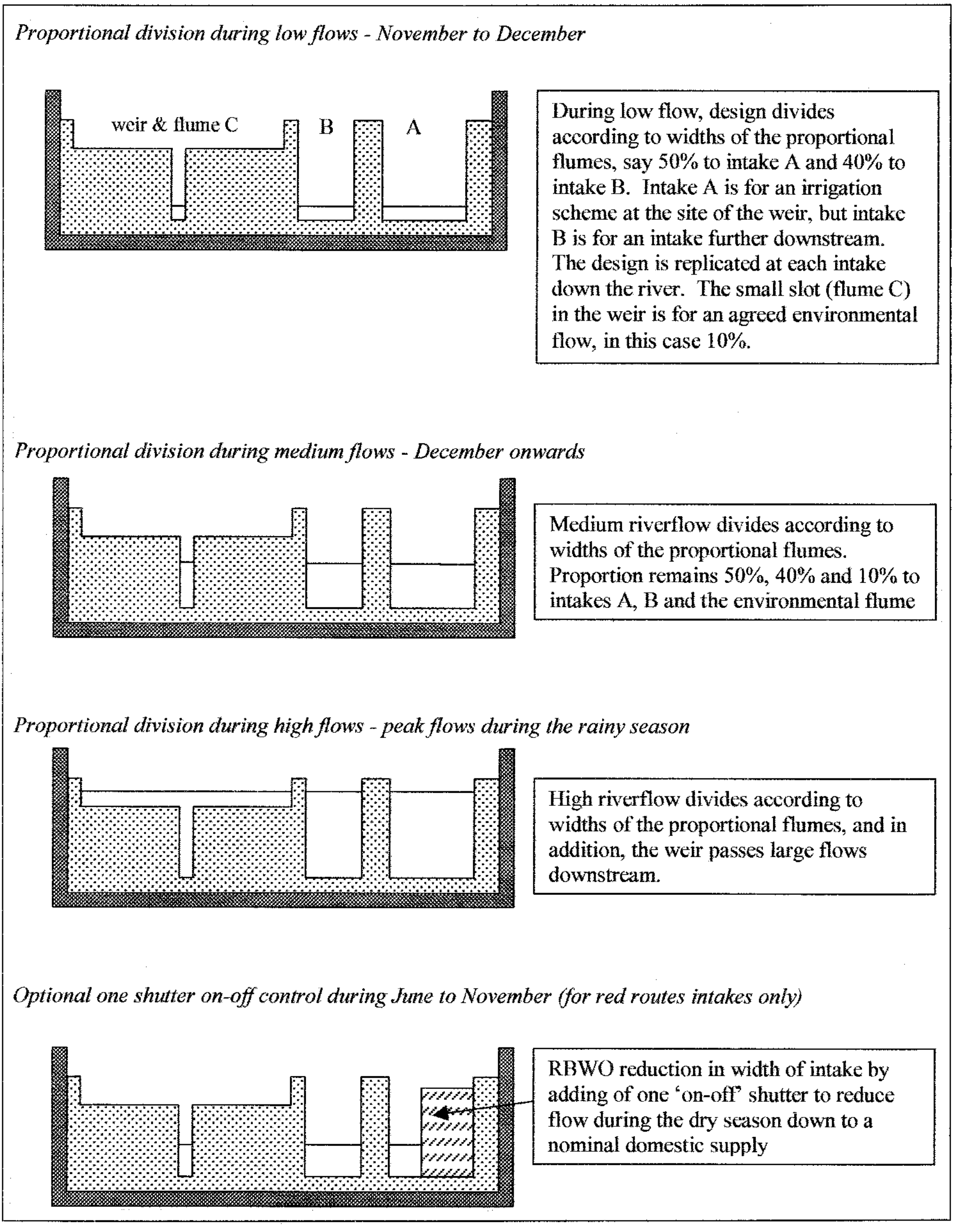

Figure 2. Technical support of water division between intakes—castellated weirs.

Red Routes: An Introduction

The term 'red routes' is an expression taken from traffic control in London where measures are used to keep key selected roads flowing freely (TDFL, 1993, 2000). This effectively zones some roads and allows traffic staff to concentrate their effort accordingly. In the Usangu, the objective of red routeing is to maintain a minimum flow into the swamp during the dry season from key upstream rivers. The red routes idea is essentially a dry season command-and-control 'zoning' concept applied to some Usangu rivers in an attempt to use

RBWO time more efficiently during the 'managed balance' part of the year to ensure compensation flows within key rivers at key times. It signals to stakeholders that some rivers feeding the swamp are markedly different from each other in terms of supply and demand of water resources. The principle of zoning in natural resource, water and wetland management is well founded (Ramsar Convention Bureau, 2000; Ministry of Environment, Water Resources and Legal Amazon, 2000), acknowledging that certain localities have different natural endowment or use characteristics, and need to be managed accordingly.

Selection Criteria for Red Routes

Since the emphasis is on cost-efficient management during the dry season, certain rivers are unsuitable. Seasonal rivers are not chosen, as their regimes are dynamic and unpredictable. They have no flow during the dry season and are highly responsive to the wet season rainfall events. Irrigation is opportunistic and intakes are traditional in design, often changing in location; are abandoned and added to; and flow rates through them fluctuate considerably.

Perennial rivers with many intakes and a history of substantial dry season irrigation are not selected. The high numbers of intakes makes these rivers difficult to monitor. In a sense, these rivers are unlikely to supply the swamp during the dry season in the future. For example, the Chimala, which has much dry-season irrigation and discharges into an intermediate swamp is excluded. The eight perennial streams of the Mkoji catchment are not ideal; they feed 70 intakes supplying extensive dry season irrigation.

Red routes are perennial rivers with few intakes, where natural losses can be minimized, and where dry season irrigation is poorly developed and can be further controlled by informal or formal legislation. Four candidates arise: Kimani, Ruaha, Ndembera and Mbarali (see Table 3). These four rivers account for approximately 22 cumecs of abstraction, which is 49% of the intake capacity found in the Usangu area. They supply approximately 50% of rice area (during a normal to wet year), but only 25% of total Usangu dry season cropping. Importantly, they only have 15 intakes on them, which constitute 13% of the total in Usangu. With this proportionally small amount of dry season cropping, there is no reason why river supplies should not be enough to meet the small net demands arising within the irrigation systems on these rivers, yet provide significant dry season flows downstream. In essence, the strategy reduces the need to manage 120 intakes for 52 weeks of the year, down to 15 intakes for 22 weeks of the year.

Managing Red Routes

While the ultimate objective might be to ensure a minimum flow in the Great Ruaha below the Swamp, a more pragmatic basis for the success of the initiative might be a duration target of zero flow. This recognizes the pressure on water resources upstream of the swamp, particularly in November. Such a target might be, for example, 'zero flow in the Great Ruaha for no more than two weeks'. This requires a staged but diminishing series of flows in the Red Route rivers, e.g.:

Table 3. Possible red route rivers

River	Reason for considering red route status	Number of intakes	Flexible strategies
Kimani	A relatively deep, channelling river. It has only one improved intake, but here operators allow downstream flows and generally close down their abstraction from mid June onwards. Below, a proportion of low flows pass to the Ihefu past unimproved intakes.	5 (1 main one and four small intakes)	Water right to whole sub-catchment, proportional rights, and intakes. Reviews of water rights. Extension advice to reduce water demand.
Ruaha	Currently a spreading river, which discharges into the Ifushiro swamp. Water demand in Kapunga could be subject to new controls if irrigation management transfer was introduced, by permanently reducing the command area from 3000 ha to 2000 ha, and having the remaining area rain fed. The Ruaha could be returned to a channelling river if the old course was re-opened, although this requires construction of a diversion.	2 (1 main one, and one minor one)	Irrigation management transfer on Kapunga Scheme, irrigation extension advice, renegotiated lower water right. Technical solutions on Ruaha river to reduce losses to swamps. Improvement of domestic supply via boreholes.
Mbarali	The Mbarali river has one main intake for the Mbarali scheme and two other lesser intakes; Mulla and Igomelo. Mbarali scheme is the oldest state farm; there is comparatively little development of dry season irrigation but there is abstraction for domestic use and wetting of fields. It should be possible to maintain both adequate domestic supply and compensation flows in the Mbarali river.	1 main one, plus two medium sized others	Irrigation management transfer, proportional water right, renegotiated lower water right. Improvement of domestic supply via boreholes. Extension advice to reduce water demand

Table 3. *Continued*

River	Reason for considering red route status	No. of intakes	Flexible strategies
Ndembera	Until recently, the only remaining perennial river. The new Madibira rice scheme should be encouraged not to abstract high flows during the dry season for non-rice crops and domestic needs. The Madibira intake is the largest and most significant intake. (In theory, the Madibira intake is shut from May to November—it is important that this remains the case).	1 main one, and assorted others.	Irrigation extension advice.

- A minimum total flow of 9000 l/sec during April through to 1st June
- A minimum total flow of 4000 l/sec during June through to the end of October
- A minimum total flow of 500 l/sec from early November through to mid January, when intakes are opened up to allow irrigation, yet rainfall has not arrived.

Further research is needed on the size of the flows needed to keep the Usangu swamp flowing. The size and staging of such flows, while not being sufficient to maintain a continuous flow below the Swamp, might be critical in keeping the swamp 'topped up', ready to spill once flows increase in December/January.

It is likely that each river needs to be tackled separately taking into account the nature and pattern of water use. The four red routes would be subject to greater attention by water officers during June through to November. It is believed that the intake gates could be partially closed with farmers' agreement, from 1 June through to 1 November. It is important to recall that dry season cropping is almost non-existent and that net water demand is for domestic needs and nursery preparation. This change would have to be carefully managed requiring new dry season water rights and appropriate fees to be drawn up. Boreholes in affected villages might have to be installed to meet domestic needs.

The main issue is to improve water management during June and July when some water is used for late season irrigation of rice. This will not be easy, and requires new planting schedules and changes to the physical means of distributing water. These ideas are based on existing signs of water control that exist in Usangu including cessation of irrigation before harvesting, the site of nurseries, and construction of canals and in-plot mini-furrows that are used to channel flow through fields at the end of the season.

Irrigation management transfer (IMT) could be applied on the two NAFCO schemes situated on the red routes (see Figure 1). The premise is that this will raise farmer density and increase 'within-system' competition for water. Apart from saving water via increased irrigation efficiency, IMT might raise yields from the current average 2 t/ha to smallholder yields of 3.5 t/ha, and provide livelihoods for more families.

Should this option be considered in the future, it is worth noting that peripheral farmers relying on NAFCO drainage water should be given priority to move 'upstream'. Secondly, such a transition provides an opportunity to decrease the overall command area supplied by the intake, and so throttle down the maximum abstractable flow from the river.

For the remainder of the year, from 1 November to 1 June (this includes the 'do nothing' periods), the intake gates would be opened, so that abstraction is controlled by adjustments or design of intakes. For the most part, irrigators would be able to abstract what they need.

Sub-catchment and proportional water rights could be provided to newly established River User Associations. The proportion of water allowed downstream for the Swamp would have to be carefully set to allow for the necessary compensation flows during the dry season. Proportional intakes (see Figure 2) could be an efficient and transparent way of managing water between intakes (for example, see Bellekens, 1994). Each intake would consist of a replicated design of weirs plus flumes, with each flume providing water to an irrigation intake on the river plus an additional flume for downstream environmental flows. Proportional intakes have important design considerations in order to work. These are:

- The widths of the flumes needs to be matched to the dynamic supply available in the river; target total and individual abstraction rates; and the proportion allowed for downstream environmental supply at low flows (in this example, it is set at 10%).
- For higher flows, the by-pass weir sill height should be related to the flume base levels so that release of water over the weir occurs at the desired flow rate.
- The total weir width should be set in accordance with expected flood-return flows.
- The levels of the floors, and the shapes of the proportional flumes should be uniform to assist in the transparency of division.
- Additional on-off shutters could be installed to control flows during June to November on those intakes where minimum flows need to be throttled down further to meet real needs within the command area.

Implications for Theoretical Approaches to Water Management

The notion of red routes in the Usangu Plains raises a number of issues. Firstly, that command and control, perhaps currently out of favour in comparison to market and community-based solutions, has a part to play in Usangu, albeit implemented in a flexible and situation-sensitive way. Secondly, the efficacy of market and community solutions towards water allocation is being explored. Thirdly, the flexible seasonal strategy implies priority water rights for rice irrigation (or rather of the intakes leading to rice systems) during the wet season, whereas domestic and environmental demands take precedent during the dry season. Howe (1996) summarizes the benefits of priority water rights.

However, it should be stated that resolution of national priorities of rice production, electricity generation and protection of the environment have yet to be undertaken by all stakeholders at the Ministerial, Regional and Local levels. This process is underway at the moment through a number of mechanisms involving newly convened stakeholder institutions and processes (SMUWC, 2000d). Whatever the outcome of these deliberations, it is likely that the flexible management strategies described in this paper will be part of the process.

This analysis suggests that a strategic, problem-centred approach to water management rather than the reliance on an application of one theoretical approach over another may improve the likelihood of successful re-allocation of water. The literature on water resources management reveals a comprehensive framework of ideas but which often read as a checklist of options at the river basin, regional and national level. The challenge is to use a flexible approach at the level of the 'river, tributary and irrigation system' to create relevant meaningful strategies applicable to the stakeholders at these lower levels, an objective that Duda & El-Ashry (2000) also argue for. To achieve this, a process of analysing the situation at hand, selecting a mix of solutions from the comprehensive range of options and then elaborating effective lower level strategies is required.

Thus, the advantage of this approach over other approaches is that, while some time and effort is required to analyse the hydrological and user environment to draw up this strategy, it is believed that once in place, real opportunities to ensure downstream compensation flows will emerge. The advantage for River Basin Officers is less monitoring of rights and intakes; red routes envisages only 15 intakes being managed for approximately five months.

Although 'red routes' attempts to fit policy with situation, its disadvantages may lie in its 'blind spots'. While it levers outcomes on rivers where outcomes are likely to be successful, it is selectively blind to those rivers where water is fully committed and are therefore 'closed' (terminology used by IWMI; Keller *et al.*, 1996). In such rivers, much greater emphasis might be needed on one particular approach (e.g. command and control or community management). Secondly, as hinted above, an associated 'cost' of the approach is the time required developing the strategy. (In this case, it required a large multi-disciplinary team on site for about two years to determine the dynamics of current water use.) Thirdly, the intended potential outcome of the red routes approach may be undermined during implementation when agreements may be reneged by upstream users. Fourthly, over a longer period, increasing population and irrigated areas may alter the circumstances in which this strategy was originally drawn up. There will be a need for periodic reviews to manage and respond to this long-term change accordingly.

The applicability of this kind of zoning approach to other river basins depends on the hydrology and configuration of supply and demand characteristics of tributary rivers supplying arterial rivers in those basins. For example, in Tanzania, this approach could be applied in the Kilombero River System, and possibly the Pangani River Basin, which has a range of closed, closing and open sub-catchments. Further afield, this strategic approach might find application in other Sub-Saharan rivers with similar tributary typologies and contrasting wet and dry season hydrology. For example, the Kafue sub-basin of the Zambezi (Burke *et al.*, 1994) would appear to be a candidate. Ephemeral and seasonal rivers arising in areas with a wholly arid climate would not suit this kind of 'red route' approach. Likewise rivers in areas with tropical rainfall regimes, or those rivers tapped by significant numbers of smaller users, would not be appropriate for this focused approach.

Conclusions

The 'red routes' idea is a means by which water is released from upstream irrigation abstractors during the dry season—the period when water competition between downstream-upstream sectors is most visible. 'Red routes' describes a flexible, situational, prioritized, targeted, zoned and timed water policy, which may be more appropriate for the Usangu Plains, enabling differing strategy options to be used for each tributary supplying the Ruaha. This strategic approach analyses the situation, cherry-picks from the main theoretical approaches to water management and applies selected strategies to the meso-scale levels of the hydrological system.

The approach marks a shift from a blanket 'fixed rights' approach to one that is prioritized and might have proportionally based water rights. It efficiently concentrates on key rivers rather than all rivers, and only addresses dry season water use. This approach acknowledges the characteristics of the dynamic hydrology of the Usangu Plains, doing nothing (or doing less) when there is an excess or substantial shortfall of water supply over demand. The idea also is predicated upon the argument that buffering exists for each water user, and that staged discharges relate well to buffering capacities.

The strategy acknowledges an increasing livelihoods-reliance on rice as a cash crop, recommending that 'irrigation management transfer' occur on the government rice farms. However, it also accounts for livelihood patterns during the dry season when most Usangu farmers turn to non-farming activities. Reducing wasteful non-crop watering of harvested fields balances core upstream needs against core environmental needs downstream.

This policy, now being discussed among stakeholders and the researching team, could fit and build upon local community management concerns and energies for water distribution. This water policy heralds a more flexible approach, able to evolve to meet new user initiatives, to respond to changes in water supply and demand, and to incorporate economic instruments in the future. The approach might consider efficient technical solutions when and where possible, and appreciates that these should be locally owned and understood.

Finally, the analysis envisages that source of the 'problems'—large abstractions of water from the state farms, play a crucial role in providing the 'solutions' to the drying up of the river by providing the necessary dry season compensation flows.

Acknowledgements

SMUWC is funded by the Department for International Development, UK (DfID). The Client is the Ministry of Water, Tanzania. The companies managing the project are HTS Development Ltd, UK in collaboration with Water Management Consultants (UK) and Local Perspectives (Tanzania). Thanks are given to these organizations for permission to present this material. The contribution to the discussion of water resources in the area by other members of the SMUWC team is strongly acknowledged: particularly Tom Franks, Polly Gillingham, Geoffrey King, Nick Mandeville, Lawrence Mbuya, Paul Devitt, Alistair Graham, Jeremy Berkoff, Stan Western, Peter Baur and Tom Boyd.

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