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WEAP as a participatory tool for shared vision planning in the River Njoro Watershed in Kenya

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Abstract

This paper presents a preliminary study of the Water Evaluation And Planning System (WEAP) as a decision support tool (DST) for local stakeholders and communities in addressing shared water issues in the River Njoro watershed. Located in the semi-arid Rift Valley of Kenya, the watershed includes important downstream habitat at Lake Nakuru, a large shallow saline lake designated a RAMSAR wetlands site of international importance, and a broad mix of water uses and users. A complex web of possible causes has been put forth by different groups for the growing water quality and quantity problems. Most attention has been focused on recent deforestation in the upper catchment. The magnitude, extent and duration of water shortage problems and their causes, however, have been poorly documented and poorly understood, hindering pursuit of more sustainable and effective options for water resource management and development. Lacking is a common understanding of the water system and a clear definition of the problems faced by different stakeholders, in part because no comprehensive quantitative assessment of the water supply and demand system has been undertaken. In this exploratory study, a model of the Njoro watershed using WEAP was created and a workshop held with a multi-disciplinary group of Kenyan researchers involved in local water and environmental issues. The workshop explored WEAP's potential as a participatory modeling tool to support Njoro watershed stakeholders to develop a shared vision of water management solutions. Modeling capabilities and features of WEAP are assessed and its usefulness as a DST considered for a developing country watershed such as the Njoro. Outcomes of the workshop included new information and increased common knowledge about the current water resources system, and new shared insights into the causes of water problems and potential solution strategies. These represent important stakeholder educative and attitudinal changes that support a shared vision of solutions and consensus on sustainable and cooperative water management.

Introduction

Kenya, a semi-arid developing country in East Africa, faces a growing and complex water management crisis. Roughly a third of its population have no access to safe water supplies and nearly 50% live below the absolute poverty line, while the national economy and environment are struggling with the negative effects of water pollution, deforestation, poor land management, and water shortages. Conflicts over scarce water sometimes erupt in violence and death, most recently in the Mara watershed (BBC 2005). A pressing need exists to develop environmentally sustainable and socially equitable approaches to water development and management that balance the needs of the environment, with economic growth, while addressing wide-spread poverty and lack of basic water and sanitation services.

Recent Kenyan government efforts towards decentralization in planning and greater recognition of the rights of local communities make it now feasible to bring communities and stakeholders concerned with and affected by water issues in a particular watershed or basin together in a dialogue with government water planners to address these issues. The success of stakeholder involvement in watershed management depends on many factors (Jenkins et al. 2004), but full inclusiveness in defining the problem(s), consistent knowledge, and shared perceptions are key factors in reaching agreement on facts and reducing conflicts.

Multi-objective modeling tools for decision support can help the dialogue process by bringing scientific and technical understanding of the water resource system together with local knowledge and interests of different stakeholder groups in a common forum, to jointly explore water issues and new solutions. Loucks (2002) argues that such shared vision modeling exercises require decision support tools (DSTs) that stakeholders, working with technical support, can populate with data to build a model that represents their joint understanding of the system. According to Loucks, model building DSTs would need to:

- Be understandable to stakeholders;
- Be compatible with available data;
- Work and provide the level and amount of information needed;
- Be verified or calibrated easily; and
- Give stakeholders interactive control over data input, editing, model operation, and output display to help them in making informed decisions.

A key requirement of such models is that assumptions or data put into the "modeling shell" are readily transparent and acceptable to all before using the model to develop shared vision solutions. Little documented work exists on decision-support modeling tools that best suit the knowledge, data, cultural, institutional, and problem contexts of watershed stakeholders in developing countries like Kenya. Through the kinds of experimentation, assessment, and documentation reported here, however, answers to these questions can be developed.

Taking up this imperative, the Sustainable Management of Watersheds Collaborative Research Support Program (SUMAWA), a joint Kenyan-US multi-institution research and development project funded by US AID's Global Livestock CRSP, is working in the River Njoro watershed at several scales. The project is based in the Njoro watershed at Egerton University (itself a stakeholder in water management issues) and consists of a multi-disciplinary team of scientists, engineers, and community development specialists. The WEAP system, developed by the Stockholm Environment Institute's Boston Center at the Tellus Institute, was selected as a promising DST for use in the stakeholder involvement process to address declining water quantity and quality concerns at the watershed scale. WEAP is an interactive modeling shell designed for integrated water resources evaluations. Here we report on the development and testing of a WEAP model of the Njoro water system. We then discuss some outcomes of the test workshop and explore future directions for WEAP model development and use as a DST in the Njoro watershed.

River Njoro Watershed Overview

About 280 km^2 in size, the River Njoro watershed provides a microcosm of the complex water management problems facing Kenya and other countries in East Africa. It forms part of the Mau Forest Complex, an important water catchment area for the country. Starting in high elevation indigenous forests at about 3000 meters above sea level (msl), the river descends first through recently deforested areas being settlement by small-scale subsistence farmers. Livestock is grazed on open lands with streamflow and public springs providing the only water sources for this rural upper catchment area. The middle zone consists of older small and large farms mixed with a rapidly expanding urban population centered on Njoro Township and Egerton University campus. Developed groundwater supplies, surface water diversions, and wastewater discharges are increasingly common in this zone as small-scale commercial, industrial and agro-processing activities intensify. The lower third of the watershed is the most urbanized with expanding peri-urban areas, slum settlements, and extensive industrial and commercial activity in and around Nakuru Municipality, the fourth largest city in Kenya. The river then enters Lake Nakuru National Park (LNNP), a wildlife sanctuary and important international tourist destination, where it terminates in closed Lake Nakuru at about 1750 msl.

Water users range from nomadic pastoralists and dispersed rural farming and peri-urban communities who obtain their water directly at the river for domestic and livestock needs, to small and larger private and institutional users, small-scale irrigators, and public water and other agencies, including the Kenya Wildlife Service responsible for LNNP. Exploited water sources include local groundwater and local surface water, and imported ground and surface supplies from outside the watershed. Household rainwater collection is also common.

What is WEAP?

The Water Evaluation And Planning System (WEAP) is an object-oriented computer modeling package designed for simulation of water resources systems and trade-off analysis. WEAP stores information characterizing a water system in a transparent and easy-to-use database. Characterization includes water use patterns, equipment efficiency, losses, environmental flows, return flows, reuse rates, pollution loadings, and priorities for the demand side, and supply sources, hydrologic flow patterns, surface and groundwater storage, costs, and operation and allocation rules for the supply side. Rivers, canals, demand sites, water and wastewater treatment plants, conveyance and pumping facilities, local water sources, and surface and groundwater reservoirs comprising the water system are quickly drawn and linked in a graphical interface and can be organized to match real geographic locations with the help of imported GIS map layers.

WEAP simulates water system operations with a river-reservoir system optimizer and basic principles of water accounting on a user-defined time step, typically a month. Simulation allows the prediction and evaluation of “what if” scenarios and water policies such as water conservation programs, demand projections, hydrologic changes, new infrastructure and changes in allocations and operations.

Several notable aspects of WEAP make it particularly suited for shared vision exercises in the Njoro watershed. With no previous watershed-wide analysis or management undertaken, stakeholders new to the concepts and issues of integrated water management would benefit by moving through the following important planning stages as a group, namely: collecting information and developing knowledge; building a shared understanding of the water supply and demand system, the problems and their causes; exploring and expanding solution options; and developing and evaluating alternatives (Ubbels & Verhallen 2001). The following features illustrate ways that WEAP can be used to support these stages in a participatory setting with stakeholders.

Integrated supply and demand representation

WEAP allows a detailed representation of demands, including instream and other environmental requirements, partitioned by activity level, water use rate and temporal use patterns. Demand management options can be included with water reuse and conservation actions in “what if” scenarios. Demands can be projected into the future with growth rates or following mathematical expressions. Supplies can be represented with records of streamflow time series, or by water year types where hydrologic fluctuations are entered as variations from a normal water year defined by the user. The user can flexibly simulate one or a series of historical or hypothetical events, or approximate historical hydrologic patterns when data are limited. Perturbations to hydrology from land use or climate changes can be explored with the new rainfall-runoff module recently added to the package. Supply sources and infrastructure can be added, removed or changed, and operating and allocation rules modified to explore different supply scenarios. WEAP's intuitive windows interface and data structure mean these changes are relatively quick and simple to make as noted below. This rich set of features expands the option “space” and increases opportunities for seeking cooperative solutions.

Separate clear definition and easy access to data and assumptions

Both demand and supply data are accessed and manipulated in the same user-friendly database, with the help of wizards and instantaneous visual feedback. Key assumptions and parameters can be defined separately in the database and later linked to demand, supply and infrastructure calculations. This arrangement allows for rapid model reconfiguration and calibration to new parameters and immediate transparency. A notes section for each entry stores metadata information. A well organized and intuitive database structure and ‘windows’ interface allow quick and easy access to explore data assumptions and their implications in real time with a group of stakeholders, and “what if” changes straightforward to make. Stakeholders can visualize and discuss data inputs, and conduct iterative improvements to the system representation based on their choice of assumptions. In this way, uncertainty in system understanding can be addressed directly with stakeholders, and differing perceptions or points of view taken up as a group. Once stakeholders agree upon current stat of the water, solutions for its future development may be explored and reached quicker and with less conflict.

Intuitive, common-knowledge representation of water in the system

The modeling simulation is based on common-knowledge concepts of water accounting that are readily understood and accepted by all manner of stakeholders through the simple analogy to financial accounting. This lays the foundation for understanding the effects of priority-based water allocations, water losses and return flows in the system.

Flexible results visualization and comparison

Multiple scenarios can be configured and run in a single batch. A particularly useful feature is the color highlighting of any inherited data or assumptions that have been changed from the ‘parent’ scenario. The results section allows simultaneous comparison of different scenarios with both standard and user configured charts of variations over time, space, and scale in the system. Results include river and channel flows, reservoir storage, demand coverage, costs and surface water quality, among others. Stakeholders can gain a clear view of the effects of different water policies, hydrology forecasts, population growth, and infrastructure operation, building a better understanding of the role and impact of their own and each others water activities and decisions on the system as a whole.

WEAP Application and Testing for the Njoro Watershed

WEAP was applied to the River Njoro watershed and used in a shared vision testing workshop with a group of Kenyan researchers and community development experts working in the watershed on water issues. Participants had backgrounds in agriculture, engineering, economics, fisheries, environmental and ecology fields, and many were part of the SUMAWA team.

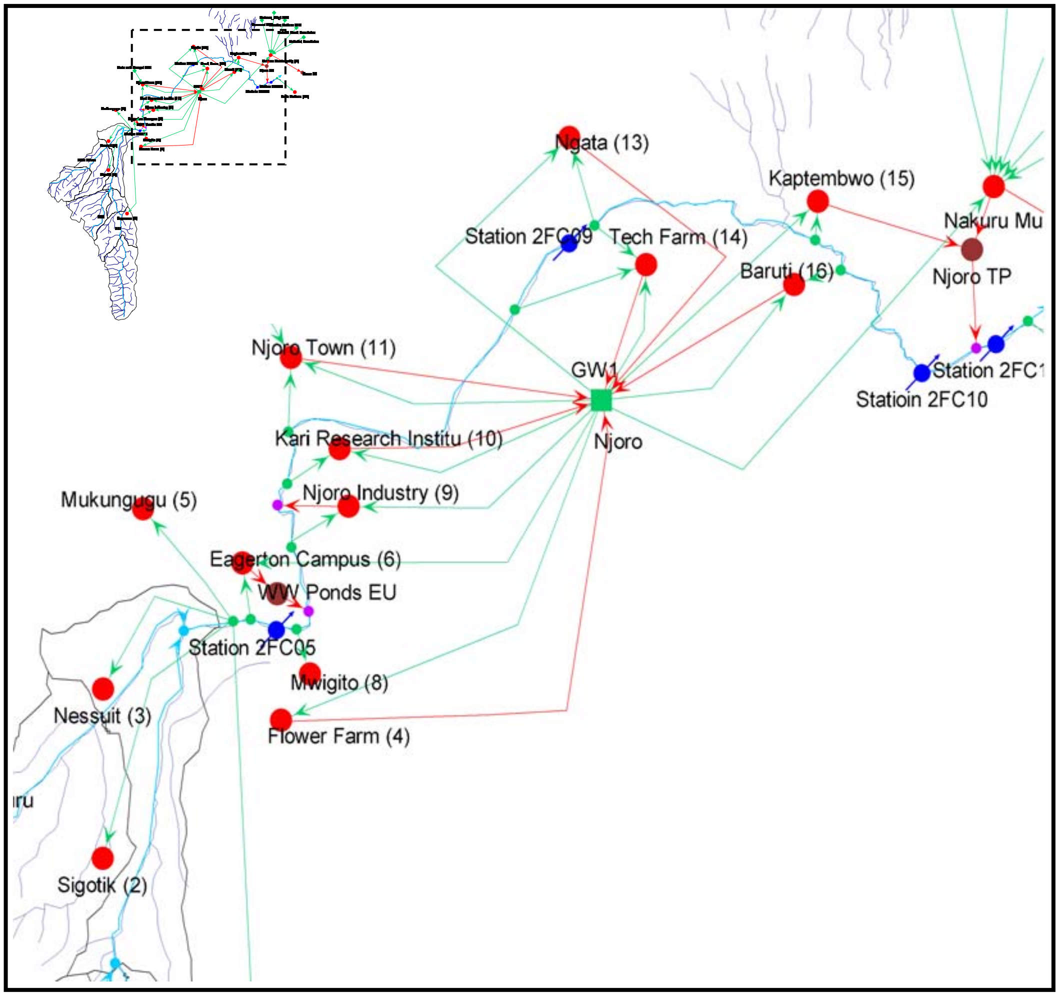


Fig. 1. Preliminary Configuration of Njoro Watershed Model in WEAP

(Dots of Red: demands; Brown: wastewater treatment plants; Green: withdrawals; Purple: return flows; Blue: gauging stations; Green squares: groundwater; Green diamonds: other supplies; Blue line; rivers)

A system network was built in WEAP using available information from maps, reports, facility managers, data sets, and field trips to provide a preliminary picture of current water supplies, infrastructure, demands, and system management (Fig. 1). Prototype scenarios were developed to organize preliminary information and illustrate analysis capabilities for the workshop. Scenarios included: 1) a ‘base case’ understanding of current (2003 level) demands, supplies, and operations under normal (historical average flow) and critical dry year river conditions; 2) a ‘new infrastructure’ scenario with Egerton University’s planned river diversion expansion added to the base case; and 3) a ‘population growth’ scenario of projected population out 10 years, with no other changes to the base case conditions.

A 3-day workshop and training was prepared to introduce the concepts of water planning and water planning models, present WEAP features and capabilities, foster discussion about the watershed water system, its problems, data reliability and availability, and explore WEAP's potential as a DST for watershed stakeholders, in a participatory learning and dialogue format. The workshop was organized in five sessions:

- Session 1 – How can water models help decision-makers improve water management
- Session 2 – Types of water models
- Session 3 – Concepts in water management and planning with stakeholders
- Session 4 – WEAP characteristics, purpose, and capabilities illustrated with the Njoro application
- Session 5 – WEAP hands-on exercises with data input and results analysis

Watershed water problems cited by participants included water rationing and shortages, a host of water quality-related problems, deforestation, and others. Past periods of low flow in the river are associated by many participants and stakeholders with recent intense exploitation of the upper catchment by farm settlement and grazing following extensive logging of long-standing forests after 1989.

In session 4 the audience participated in discussions about data availability, model data use and requirements, and preliminary results. They were put in pairs with laptop access to WEAP and a model of the Njoro River watershed. The preliminary Njoro model characterization was presented and results for the 3 prototype scenarios discussed.

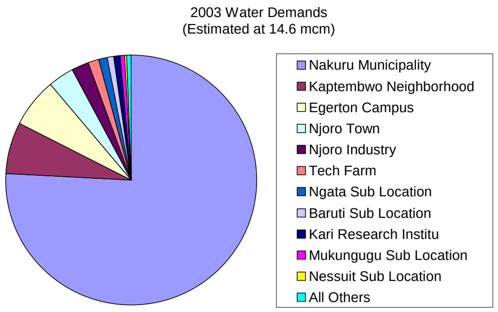
Results and Discussion

An overview of the Njoro system based on the preliminary WEAP model developed for the workshop is presented, followed by some of the participant reactions and workshop outcomes using WEAP as a DST. The model system and results represent a partial and preliminary assessment of available information. More work is needed to refine system configuration and parameter specificity, and incorporate local information and knowledge through the SUMAWA stakeholder engagement process. The results shown here are therefore preliminary and were developed using assumptions regarding water resource allocation and use that will be improved through on-going SUMAWA research activities.

Preliminary Njoro WEAP Model Overview

The study area was estimated with a 2003 population of 333,164. Livestock, mainly cattle, sheep and goats, was estimated at 25,700. An initial set of 15 demand areas were identified, and categories of domestic, livestock, commercial, industrial, institutional, and irrigation water use activities and rates developed. Total 2003 water demands were estimated at 14.6 million cubic meters (mcm) per year (Fig. 2) equivalent to about 120 liters per capita-day (lpcd). Supplies required to meet this demand, however, were much higher at 26.1 mcm/year (or 215 lpcd), given conveyance and distribution leakage losses ranging from 3% up to 50%, the latter for Nakuru Municipality (SAPS 2002).

A preliminary inventory and estimate of exploited water supplies in the system identified eight water sources (Fig. 3). Groundwater, an important local resource, is not shown in Fig. 3 because lack of information made it difficult to assess. Historically, flow in the River Njoro has averaged 17 mcm/year (Chemelil 1995; station 2FC05 1941-90 record), but varies greatly with climate (notably El Nino), runoff processes, baseflow conditions, and stream-aquifer interactions. We chose 1984 (2.9 mcm flow), the most recent but not the most severe low flow year, to understand the potential role of natural low flow conditions on reduced water quantity and quality since watershed residents today have lived through this event.



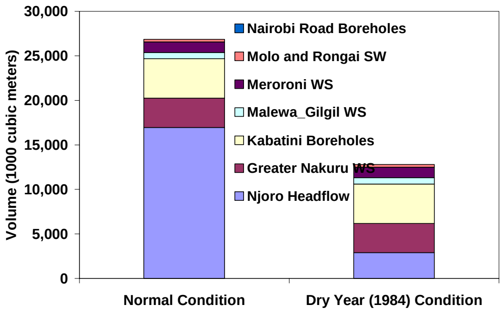
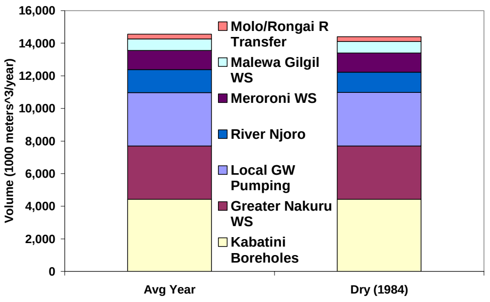


Fig. 2. 2003 Estimated Demands **Fig. 3. Natural & Developed Water Sources**

Precipitation is the critical driver and varies from 1200 mm/year in the headwaters to 800 mm/year in the valley floor, distributed tri-modally with peaks in April (largest), August (second), and November (smallest) (Chemelil 1995). The hot dry season runs January to March. As the river approaches its terminus in the valley floor, it has historically become influent and is thought to loose much of its flow in the porous fissured zones of the Rift Valley floor before reaching Lake Nakuru (McCall 1967). Streamflow losses to the aquifer in the lower watershed are an important modeling aspect which has been neglected in this preliminary effort.



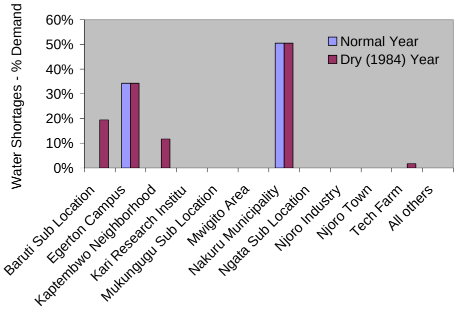


Fig. 4. Total Water Deliveries **Fig 5. Estimated Water Shortages**

Extraction from all eight sources was estimated at 14.6 mcm/year in normal years, dropping slightly to 14.4 mcm under the dry year river condition (Fig. 4). Deliveries in normal years are well below the required 26.1 mcm/year to meet demands. Egerton University and Nakuru Municipality currently ration water and operate with permanent shortages of about 35% and 50% respectively (Fig. 5). Only under the dry year condition do other river users in the lower watershed experience shortages in the model (Fig. 5). The greatest impacts occur to Baruti, the lowest river withdrawal point. Shortage estimates are conservative, as stream losses to groundwater, minimum flow requirements, minimum diversion depths, and water quality thresholds have all been ignored.

Preliminary Njoro WEAP modeling insights

The WEAP Njoro model characterization, visualization of system information, and results presented at the workshop provoked spontaneous discussions, debates, and many new insights. Some highlights of these discussions are presented next.

1. Water Supplies & Demands:

Model representation of the River Njoro watershed explicitly included imported water from neighboring watersheds and local groundwater supplies. These sources contribute 68% and 22%, respectively, to overall supplies (Fig. 4) and their inclusion in the model raised new awareness among participants about the need for cooperation and coordination with neighboring basins and other users. Excluding imported sources from the analysis and focusing on water supplied from within the watershed (4.7 mcm/yr) shows that local groundwater pumping provides about 70% and river withdrawals about 30% of estimated deliveries to users (Fig. 6).

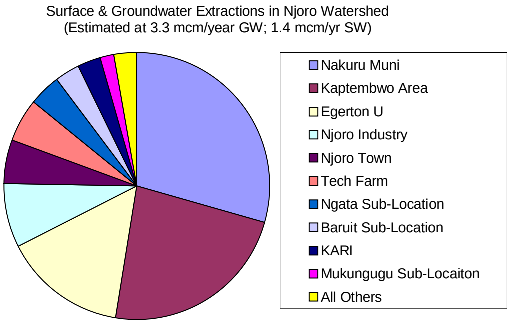


Fig. 6. Local Surface & GW Extractions

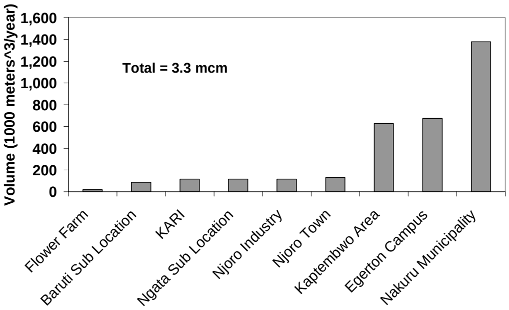


Fig. 7. Local Groundwater Pumping

Groundwater is hydrologically linked to the River Njoro and plays an important role in maintaining Lake Nakuru water levels (McCall 1967). The modeling results showed several important aspects of water management related to groundwater of which participants had little knowledge. Nakuru Municipality relies on local groundwater for about 13% of its current supply, and is the biggest single groundwater user in the basin (Fig 7). Of the 3.3 mcm/year of estimated pumping, nearly half is thought to be pumped by Nakuru Municipality, followed by Egerton University (21%) and Kaptembwo Area (19%). Most River Njoro users with developed water systems rely mainly on local groundwater, one of the most dependent of which is Egerton University (Fig. 7) which has recently experienced wells drying up. The new awareness of groundwater's role in the watershed highlighted to participants the importance of cooperation between River Njoro surface water diverters, watershed groundwater pumpers, and Nakuru Municipality water users, if the Lake is to be maintained as an environmental sanctuary and water shortages addressed. Further hydrogeology investigation will be necessary to identify the linkages between River Njoro streamflow conditions, local groundwater recharge, and pumping across the watershed.

River Njoro withdrawals contribute about 8-10% of the supply mix (1.2 to 1.4 mcm) depending on the year (Fig.4). River extractions by user are shown in Fig. 8. This volume was surprisingly small to participants, at only about 8% of runoff in normal years. However, without storage to modify natural flows, withdrawals account for a much more significance fraction of available runoff in the dry season (February and March), about 50% of normal flow (Fig 9). In a dry year like 1984, withdrawals would divert 40% of the naturally available runoff and completely dry up lower sections of the river from October through March (Fig. 9). Visual displays in WEAP of dry year river conditions, prior to deforestation and settlement, and the effects of withdrawals on streamflow in Fig. 9, stimulated a broader debate about the causes of dry river conditions, and lead to new appreciation for the substantial natural variability in River Njoro runoff, both seasonally and inter-annually.

Water quality, although not modeled explicitly at this stage, is strongly influenced by low flow regimes in the River Njoro. Simulation of dry year conditions pointed out critical locations, such as in the Baruti area (Fig. 9), and just upstream of Njoro Town, which become severely impacted by water diversions and wastewater return flow conditions. Although most of these locations are well known, the model identified the relationship between temporal and spatial water use patterns and these water shortage and quality issues.

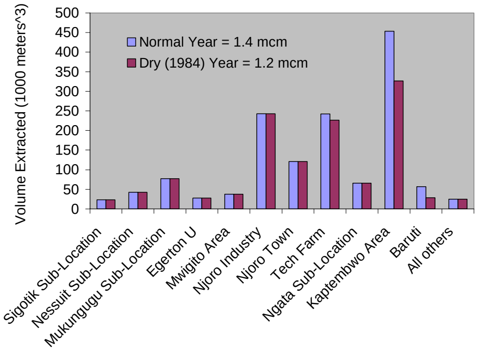


Fig. 8. Estimated River Extractions

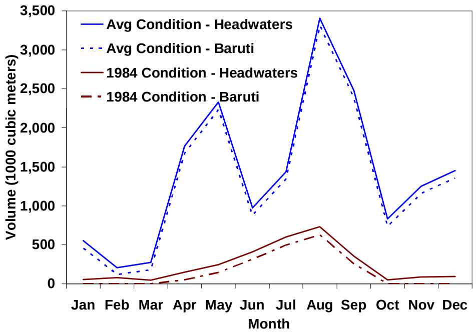


Fig. 9. Flow Conditions – 2003 Demands

Some participants expected withdrawals by livestock and poor households in the upper catchment (Sigotik, Misepei, and Nessuit Sub-Locations in the model) to cause substantial negative effects on the river's regime, in contrast to their actual very small share of overall watershed demands and river withdrawals (Fig. 3 and 8). This prompted an exploration and discussion of water use rates and activities for different areas and users in the watershed and raised awareness of the very low water consumption rates of households without adequate access to developed water supplies relative to those households with better access. Similarly, participants had thought livestock watering at Egerton University was a major fraction of its water demand and were surprised to see the WEAP display of Egerton's water activity levels showing it at about 4% of demand. The importance of Nakuru Municipality as a key water player in the watershed was brought home with WEAP's visual displays of system demands (Fig. 3) and breakdown of local surface and groundwater extractions (Fig.6).

2. Water Shortages and their causes:

Recent years have resulted in water shortage and water quality deterioration in the watershed, and have been related to upper watershed settlement and deforestation started after 1989. While reduction of upper watershed vegetation is prone to reduce natural water storage in the basin and baseflow contributions in dry seasons and years, hydrologic records prior to deforestation indicate that Njoro River streamflow is naturally highly variable, with low flow regimes occurring seasonally and very low flow years periodically in the historical record. The three most severe flow drought years in the River Njoro 1941-90 record (Chemelil 1995) were 1 mcm (6% of normal), 2 mcm (12% of normal), and 2.9 mcm (17%), respectively, in 1953, 1965 and 1984. Highest flows were recorded in 1964 at 55.6 and 1956 at 54 mcm (>300% of average).

Fig. 3 illustrates the relative importance of the different supply sources and their variability by year type. Fig. 3 provides a message to stakeholders that users who rely heavily on a highly variable supply source (River Njoro flow) are vulnerable in very dry years. This awareness provided new insight on proposed solutions for water shortage, such as Egerton University's surface diversion capacity expansion. Confronted with natural streamflow variability, both seasonally and annually, such solutions were questioned during the workshop, and infrastructure to provide multi-period carry over storage was raised.

While perceptions that recent changes in river flow are the critical cause of water shortages in the watershed have tended to dominate discussions of water problems, the WEAP Njoro model characterization and results showed that other causes are also important reasons, including inadequate infrastructure, high water distribution system loss rates, inoperable facilities (esp. groundwater wells), and reduced imports. None the less, those communities and households that depend directly on localized river flow for their main source of water are the most vulnerable set of users.

3. Planning issues:

"What if" scenarios were included to illustrate water supply conditions under population growth and Egerton University's river diversion expansion. The study area population was projected to reach 426,194 in 2013, assuming continuation of 1989-99 annual growth rates. Livestock was expected to grow to 28,400. The possibility of separate assumptions in WEAP allows one to define livestock growth based on population growth or using independent assumptions. Both diversion expansion and population growth worsened water shortages for middle and lower watershed river users in dry years, both in duration (up to 7 months) and severity (up to 75%), with some experiencing shortages for the first time. These findings emphasize how planning and coordination between upper and lower catchment users is critical to minimize water shortage impacts in dry years.

Egerton University is projecting a campus population of about 22,000 by 2013, up 60% from 2002. It already faces significant water shortage problems (Fig. 5), despite 96% reliance on groundwater. Their water extractions currently account for about 1/6 of all local extractions in the watershed (Fig. 6) and the University's water management decisions are expected to impact other users. Detailed demand characterization capabilities in WEAP allowed Egerton's demand to be broken down by use category (i.e., domestic, buildings, livestock, and irrigation) and further divided into sub-categories, for example, domestic was divided into dormitory, apartments, and single family units. These subunits of demand can be characterized down to the most detailed water use activity or fixture level in WEAP, each with its own water use rate and pattern. Separate representations allow quick assessment of the contribution of different water use activities to campus water consumption and investigation of demand management alternatives. During the workshop, the water efficiency of fixtures such as toilets was discussed. The use of efficient low flow toilets in new construction could represent important water savings for Egerton University. Discussion of demand management options broadened the range of strategies available for managing current and future shortages.

Watershed residents in the rural upper catchment and in many other communities along the length of the river have no access to developed water supplies, getting their water from the river and other distant public sources. Most consume as little as 15 lpcd and live in poor hygiene conditions, facing high child mortality rates and other diseases, and significant personal costs to transport water. Improvement of these communities' living standards will necessarily involve new infrastructure to increase water access which will raise demand in the watershed. For example, 60% of the estimated 16,075 habitants of Ngata Sub-location are thought to collect water directly from the River Njoro or from other public sources located outside their homes, with a demand of 15 lpcd. Improving water supplies to yard taps would typically increase consumption to an estimated 91.5 lpcd, resulting in an additional 270 tcm/yr of demand for Ngata Sub-Location alone. Analyses like this demonstrated that solutions for improved public health and sanitation will pose other challenges in the future and that the model can be useful in pinpointing priority locations to address these problems.

Although not yet modeled, groundwater and surface water interactions are a critical component of the watershed's hydrology. Groundwater is the most reliable supply source in the watershed, both in terms of quality and quantity. River Njoro flow contributes to local groundwater storage with seepage through fissured media in the valley floor (McCall 1967).

Changes in river flow regime could affect groundwater recharge in the lower watershed, with potential reduction of groundwater availability in dry years. In the opposite direction, high demand for groundwater in Nakuru Municipality, coupled with population growth, may lower the groundwater table, causing increased losses of river flow to the aquifer, potentially reducing surface water availability. Increased groundwater extraction could affect the level of Lake Nakuru and its salinity, which also depends on groundwater.

WEAP as a participatory DST

The Njoro WEAP application test model and demonstration of its capabilities stimulated an unexpected and active discussion about aspects of the water system of which participants had little prior exposure or differing perceptions from one another or from those characterized by the model input and output. At times these discussions led to new insights about water problems and their causes. Discussions allowed local data used in the prototype model to be questioned, and the importance of making the best use of scarce data was pointed out by participants. Proposed solutions to water shortages, such as Egerton University's expanded diversion were debated as the model highlighted the effects of the natural variability of River Njoro streamflow, for which there is no dedicated storage infrastructure. The conjunctive operation of surface and groundwater supplies could be a promising direction for more reliable and flexible management. The WEAP model and workshop experience, while preliminary, shows potential to achieve experiences reported elsewhere with successful stakeholder model building exercises which have gone on to reach a consensus on how the system should be developed and managed (Loucks 2002).

Areas for further assessment and model development

Characterizations of environmental demands, stream-aquifer interactions, and other surface water losses are important areas that remain to be developed in the model, in addition to improvements in the current representation of demands, supplies and operations. While the critical depth in Lake Nakuru for ecosystem needs has been established, a water budget model is needed to translate the requirement into a minimum river outflow to the Lake to integrate this critical environmental demand into analysis of system performance. A better scientific representation of groundwater resources also needs to be developed, including estimates of natural deep percolation recharge, streamflow gains/losses in the middle and lower sections of the river, and sub-surface flows to/from the study area.

Conclusion

Water resources planning is of critical importance and a significant challenge for many communities throughout the world. The importance of adequate planning and infrastructure are magnified in poverty-stricken areas. This challenge involves not only technical aspects of scientific disciplines, but also management challenges where people with different objectives must understand their water problems and build trust in order to solve them. In a participatory workshop, the decision support modeling tool WEAP provided a forum for participants to improve understanding of the River Njoro water management system and discuss the impacts of various water-related activities on the system and on other stakeholders. Through a participatory model building process, unwritten locally specific information about parts of the water system held by isolated groups of stakeholders is quickly shared. Workshop discussions illustrated the importance and impact of visualization as participants explored the preliminary Njoro watershed system model network and assumptions together. Using WEAP's transparent model database, diffuse information about the water system held by different stakeholders is collected and integrated, and divergences on assumptions and data exposed, requiring stakeholders to communicate to fill in the gaps and search for agreement in order to continue. Through exposure to the Njoro model and

WEAP features and capabilities, participants also gained direct and practical knowledge of water planning concepts such as infrastructure operation and demand management, and their potential roles in addressing water shortage problems in the watershed.

Key insights raised during the workshop included the need to collaborate with other users to ensure reliability and sustainability of water supplies; to improve infrastructure to increase water supply reliability; to make best possible use of available data and to evaluate proposed solutions from an individual stakeholder and system-wide perspective. Most important, the exercise highlighted the value of quantitative analysis in order to build up understanding of causal relationships and linkages in the watershed, and to effectively support management and operations decisions. WEAP was able to provide such analysis with an accounting analogy that is both easy to understand and to interpret, and with the help of effective visual tools and readily available results charts.

WEAP's features were shown to be well adapted to the local decision-making context and supportive of a participatory dialogue and learning process. With clear evidence of WEAP's potential as a DST for the Njoro watershed, plans are underway at SUMAWA to form a watershed-wide stakeholder representatives group to further develop and use the WEAP model to support cooperative management solutions by stakeholders in the watershed.

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