Sustainable Water Resources Management for agricultural and industrial water sectors – Participation of stakeholders in the Water Resources Management and Development – First Draft

By

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Abstract.

The National Water Policy 2002 (NAWAPO 2002), showed a paradigm shift from sector oriented and regional focused water resources development to integrated approach addressing participatory, multi-sectoral and multidisciplinary river basin management. Water uses that were considered in the policy include domestic use, livestock, agriculture, industry, mining, energy, fisheries, environment, wildlife and tourism, forestry and beekeeping and navigation.

The policy also recognizes that water is a scarce resource and integrates the linkage between land use and water use. Introduction of this new approach entails comprehensiveness in water resources planning and management, decentralization of decision making and devolution to the lowest practical level with facilitation of stakeholder participation, and economic aspect on the use of water while considering the value of water and other incentives for promoting the rational use of water.

The water resources management component of the policy is aimed at realizing the following; provision of the basis of the institutional framework and legislation on water resources management, adequate share of the water resources for the environment as well as among the social and productive sectors, stimulation of public awareness and stakeholder participation in water resources planning and management and financial sustainability and autonomy of Basin Water Boards (BWBs)

Establishment of Rivers and Lake Basin water Boards aimed at ensuring the sustainable water resources management for sustainable utilization of available water resources for social economic development. Wami/Ruvu Basin is one of the nine Basins established in the mainland
Tanzania.

Wami/Ruvu Basin is potential for irrigated agriculture and the government is investing in the area to improve existing irrigation schemes and possibly build new ones. Industrial sector is another economic instrument with an increased growth rate in the basin. Both agricultural and industrial sectors require the use of water from both surface and groundwater sources. Extraction of water by these sectors needs to be carefully monitored as there may be significant impact on water flows on surface water especially during the dry season and groundwater levels decline due to aquifer over pumping. Water sources pollution from both sectors is a common practice, which results from discharging untreated waste water in the environment. This pollution reduces access to safe water for different uses.

Since water resources management is a crosscutting issue, it is therefore important to involve stakeholders (Water Resources Managers, Water Supply, City and Irrigation scheme developers, and local Government authorities) in the development of an effective and sustainable Water Resources Management.
1. Introduction

*The Wami/Ruvu Basin Water Board (WRBWB)*

Wami/Ruvu Basin is one of the nine River and Lake Basins of Tanzania established under Water Act No. 42 of 1974 of Water Utilization (Control and Regulations) with its amendments No. 10 of 1981. The newly established Water Management Act Number 11 of 2009 repeals the fore mentioned Acts. The basin water office was established in July 2002, and it operates under the Wami/Ruvu Basin Water Board and the overall in charge is the Water Officer who is also the secretary of the Board.

*Location*

Wami/Ruvu Basin is located to the eastern part of Tanzania and includes two major rivers of Wami and Ruvu with an approximate area of 40,000 and 17,700 km² respectively. It has coastal rivers located from north to the southern part of Dar es Salaam City, which makes the total area of the whole basin to be 72,930 km².
Figure 1. Nine River and Lake Basins of Tanzania showing the location of Wami/Ruvu Basin

The basin is covered by low lying and mountainous regions (which some of them belong to the Eastern Arc Mountain Range).
Figure 2. Map showing the extent of the Eastern Arc Mountain Range

**Responsibilities of the Wami Ruvu Basin Water Board**

The overall intention of establishing Basin Water Boards is to have enhanced water resources management for socio-economic development and sustainable environment. The specific responsibilities of the Wami/Ruvu Basin Water Board is

- To issue water use permit
- To control and take legal measures against water source polluters
- To resolve water use conflicts
- To sensitize on the sustainable use of water resources
- To facilitate the formation of Water User Associations.
- To facilitate the formation of catchment/sub-catchment committees
- Operation and maintenance of water resource monitoring stations
2. Water sources in the Wami/Ruvu

2.1 Groundwater Aquifers in the basin

Aquifers in the basin are mainly categorized into three types namely; Quaternary aquifers (unconsolidated sedimentary layers), Tertiary aquifers (semi – consolidated layers) and Cretaceous Jurassic and Precambrian aquifers (water in fissure of consolidated sedimentary layers, granitic rocks and metamorphic rocks).

a). Quaternary aquifers

- Dar es salaam and Coast Region, the thickness varies from 1 – 100 m and more (Kent et al, 1971)
- Mgeta plain, situated southeast sides of Uluguru Mountain in Morogoro Rural. The well drilled in Gomero village (western part of the plain); BH (No. MG 361/2011) is 113 m with yield of 550l/min and draw down of 4.03 m. This suggests the groundwater potential of quaternary aquifer to be very high.
- Mgeta plain, widely distributed along the Wami and Kinyasungwe Rivers with its tributeries. Average yield is 240 l/min (DGIS – 1980)

b). Tertiary Aquifers

Tertiary aquifer is distributed from the hills of Mkuranga district in the east to the Chalinze ward of Bagamoyo district. The sediment consists of interbedded sandy clay and clay sands with minor lenses of pure sand or clay (Temple, 1970). In the western part of Tertiary aquifer, which is situated in the west side of the Ruvu River, no lithologically defined aquifers were found, although discontinuous sandy zones were encountered (CIDA, 1979). In this area, it was suggested that the groundwater is recharged from the Ruvu River.

In the areas from east side of the Ruvu River to the west side of the Mzinga River, it was suggested that this area is the recharge zone (CIDA, 1979). In the areas from the east side of
Mzinga River to areas eastward, Neogene deposits are typical and consists of interbedded sandy clays and clayey sands sometimes cemented in irregular bodies to form weak sandstone. Neogene sediments in this area are separated by depressions. The Kimbiji aquifer, which is now being assessed by DAWASA is a deeper part of the eastern part of Neogene aquifer.

c). Mesozoic to Paleozoic Aquifers

Jurassic Formation

DGIS (1980) reported that three formations distributed in Jurassic formation that are Jurassic Sandstone, Jurassic Limestone and Station Bed. The geology and groundwater information of these three formations are as follows.

The Jurassic Sandstone, which is distributed in Ngerengere, is predominantly medium-coarse, poorly sorted, firmly cemented, feldspathic sandstone. The sandstone layer contains water-bearing zones. The groundwater mainly flows along faults and fractured zones. The fault zone offers fair possibilities for successful boreholes with moderate to low yields between 24 and 300 liter/min and acceptable salinity.

The Jurassic Limestone, which is distributed in Kidugalo area, is groundwater-bearing and offer fair possibilities for boreholes. The yields of exiting boreholes are between 72 and 144 liter/min. The electric conductivities in the limestone are between 120 and 190 mS/m.

The Station Bed consisting with siltstone, fine sandstone, massive medium to coarse grained sandstone and argillaceous limestone overlies the Jurassic limestone formation. According to the drilling result of four boreholes reported by DGIS (1980), it is reported that there is no possibility of development of groundwater due to high salinity of water, and primary permeability is very low.

Karoo Formation

The Karoo formation is distributed in eastern foothills of the Uluguru Mountains, and consists of
very coarse sandstone, green shale, fine sandstones and siltstone. The rocks are firmly cemented and thus have a very low porosity and permeability. The rocks are well bedded and groundwater flows principally along bedding planes and fractures. According to DGIS (1980), the Karoo formation in southwest is water-bearing and most probably offer fair prospects for boreholes with low to moderate yield between 150 and 306 liter/min and specific capacities between 6 and 102 liter/min/m.

**d). Precambrian Aquifers**

**Granite**
Granite and migmatite are distributed in western side of the basin, where Dodoma Urban, Bahi and Chamwino districts are located. In this area, the graben and horst formed by the faults with the direction of NNE-SSW are distributed. The groundwater is mainly distributed in the weathered and fractured part. The Chenene Hill located in the northern edge of the Granite, is the recharge area of the groundwater in Makutupora basin (Shindo, 1994). The median of yield is 305 liter/min and the value of electric conductivity is 1,360 µS/cm. The most of high yield wells are located in Makutupora basin, which is the main water source for the capital city, Dodoma.

**Metamorphic Rocks**
Metamorphic rocks are extensively distributed in Wami/Ruvu Basin. The meta-igneous and sedimentary rocks are distributed from Kilosa district to southern part of Kondoa district in Dodoma region. In the northwestern part, the graben and horst are formed by NNE-SSE direction fault. The groundwater mainly exists along the fault. The median of the yield in the area of metamorphic rocks is 150 liter/min.

The composite metamorphic crust domain and granulite, gneiss and migmatite are distributed in the north part of Morogoro region, southern part of Tanga region and north of Coast region. The fault is not well developed compared to the meta-igneous and sedimentary rocks described above. The median yield in this formation is 62.8 liter/min, which is less than half of that of meta-igneous and sedimentary rock. The high value of electric conductivity is observed in Morogoro Urban.

**Marble**
Marble is distributed in the eastern side of Uluguru Mountain, and is groundwater bearing formation. The groundwater in a karst area mainly moves along solution openings and zones of fracture and fault (DGIS, 1980). The value of electric conductivity of water of spring varies from 450 to 550 µS/cm.

Figure 3. Geological map of Wami/Ruvu Basin showing different aquifer formations

2.2 Surface water resources.

*River network and profile in Wami/Ruvu Basin*
The most upstream of the Wami River is the Kinyasungwe River, and then its name changes to Mkondoa and Mkata River. In the downstream of the Mkondoa sub-catchment, it becomes the Wami river that flows up to the estuary. Major tributaries of the Wami River are the Diwale, Mjonga and Lukigura Rivers.

The Ruvu River originates from Mt. Kimhandu in the southwestern part of the Uluguru Mountain. The Mgeta River originates from western part of the Uluguru Mountain and it joins to the Ruvu River after the Ruvu river gets out of mountainous area, then the Ruvu river flows to the estuary, and along the way it is joined by many tributaries such as the Ngerengere, Msua and Mbiki Rivers.

The Coastal Rivers catchment consists of small rivers such as the Mpiji, Msimbazi, Kizinga, Mzinga and Mbezi Rivers. Most of these rivers in the catchment are seasonal at present.

![Figure 4. Wami/Ruvu Basin river networks](image)

### 2.3 Water Resources use in the Wami/Ruvu Basin

*Domestic:*
The current domestic water demand for Wami/Ruvu Basin is estimated by using the projected population based on the 2002 census. Population in Wami/Ruvu as per 2011 was estimated at approximately 7.04 million; in which 4.11 million are urban population [58%] and 2.95 million are rural [32%].

Unit water consumption rate is set at 25 l/capital/day for rural population and at 45 l/capital/day for urban population. Urban Water and Sanitation Authorities [UWASA] are providing paid water and unit water consumption rate is set through estimating median amount of actual household period of the year [June 2010 to May 2011]. Domestic water demand as for 2011 was estimated at approximately 188.5 million m³/year.

<table>
<thead>
<tr>
<th>Sn.</th>
<th>Category</th>
<th>Unit rate [l/day/capital]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Rural</td>
<td>25</td>
</tr>
<tr>
<td>2.</td>
<td>Urban</td>
<td>45</td>
</tr>
<tr>
<td>3.</td>
<td>UWASA</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Morogoro 114</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dar es Salaam 206</td>
</tr>
</tbody>
</table>

Table 2. Unit water consumption rate by area:

### 2.4 Water use in Agricultural and Industrial sectors

**Agriculture:**

In order to project for water demand for agriculture, the average annual area planted with each crop [1995 – 2005] was calculated. Assuming the planted areas to be expanded according to the population growth in Wami/Ruvu Basin and the amount of water required for growth of each crop is known. Based on the projection of the area planted and amount of water required for growth of each crop, agricultural water demand in Wami/Ruvu Basin as of 2011 was estimated at approximately 4.59 billion m³/year.

<table>
<thead>
<tr>
<th>Agricultural water Use</th>
<th>Number of Water Use Permit</th>
<th>Amount of water l/sec</th>
<th>Amount of water m³/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>River Catchment</td>
<td>Source type</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Groundwater</td>
<td></td>
<td></td>
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<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Surface water</td>
<td>9</td>
<td>12.68</td>
</tr>
<tr>
<td>Ruvu</td>
<td>Groundwater</td>
<td>7</td>
<td>10.02</td>
</tr>
<tr>
<td></td>
<td>Surface water</td>
<td>41</td>
<td>59,434.12</td>
</tr>
<tr>
<td>Wami</td>
<td>Groundwater</td>
<td>24</td>
<td>1,479.65</td>
</tr>
<tr>
<td></td>
<td>Surface water</td>
<td>101</td>
<td>34,501.37</td>
</tr>
</tbody>
</table>

Table 2. Groundwater and surface water use according to water use permit issued as per 2009

Figure 5. Water use permits from groundwater and surface water for Agricultural water use in three catchments

*Industry:*

The amount of water required for industrial sector in the Wami/Ruvu Basin in 2010 was calculated based on the amount of production for each products estimated by BSB 2011,
applying unit rate of water required for each production developed by DFID [2003]. Therefore, water demand for industrial sector as of 2010 was assumed at 17.68 million m³/year.

**Increased water demand:**

During the drought period of 1996/1997, there was a tremendous decrease of water from the surface water, where the largest population of Dar es Salaam and Bagamoyo depend for domestic and other uses. Since then there was a shift from surface water to groundwater. Figure 6 indicates a rapid increase of groundwater development from 1997 in Dar es Salaam Region.

![Figure 6. Groundwater development trend from 1959 to 2007.](image)

Due to unreliable water supply from surface source, most of population shifted to groundwater source especially industrial uses. A rampant increase of well drillings was carried out by both private and institutions without following proper and administrative guidelines. Unskilled people in the field of groundwater exploration engaged themselves in the groundwater exploitation without being monitored. The drilling was also done without knowing in detail the potential of groundwater resource. Figure 4 shows the increased water use in the industrial sector from groundwater source in Coastal, Ruvu and Wami River catchments.
### Table 3. Groundwater and surface water industrial use permits from three catchments

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Source type</th>
<th>Number of Water Use Permit</th>
<th>Amount of water l/sec</th>
<th>Amount of water m³/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal Rivers</td>
<td>Groundwater</td>
<td>76</td>
<td>134.00</td>
<td>11,577.60</td>
</tr>
<tr>
<td></td>
<td>Surface water</td>
<td>6</td>
<td>38.78</td>
<td>3,350.50</td>
</tr>
<tr>
<td>Ruvu River</td>
<td>Groundwater</td>
<td>12</td>
<td>10.00</td>
<td>864.00</td>
</tr>
<tr>
<td></td>
<td>Surface water</td>
<td>27</td>
<td>10.40</td>
<td>898.56</td>
</tr>
<tr>
<td>Wami River</td>
<td>Groundwater</td>
<td>9</td>
<td>24.53</td>
<td>2,119.39</td>
</tr>
<tr>
<td></td>
<td>Surface water</td>
<td>16</td>
<td>49,897.67</td>
<td>4,311,158.63</td>
</tr>
</tbody>
</table>

3. Current and future Water use and development potentials in different sub catchments.
The Wami/Ruvu Basin has seven hydrological sub catchments namely Kinyasungwe, Mkondoa, Wami, Upper Ruvu, Ngerengere, Lower Ruvu and Coastal Rivers sub catchments.

Figure 8. Seven sub catchments in the Wami/Ruvu Basin

The hydrology and hydrogeology of all seven sub catchment differ depending on their geographical location and the geological set up.

Figure 9. Annual rainfall distribution in the Wami/Ruvu Basin

<table>
<thead>
<tr>
<th>Sub-catchments</th>
<th>Annual Rainfall Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>800 – 900 mm</td>
</tr>
<tr>
<td>Uluguru Mt</td>
<td>&gt; 2000 mm</td>
</tr>
<tr>
<td>Dodoma</td>
<td>500 mm</td>
</tr>
</tbody>
</table>
Water demand for different uses is increasing due to an increased population as well as increased social economic activities in the Basin. The trend of demand increase differs from one water use to another and from one sub catchment to another. Some of the sub catchments show that the development potential of the water resources will not be affected by the increased demand into 25 years from 2015 to 2035 in both normal and dry periods. These sub catchments are Mkondoa, Wami, Upper Ruvu and Lower Ruvu. Other sub catchments show that the increased water demand for different uses will be affected especially during prolonged dry period starting from 2025 to 3025. These are Kinyasungwe, Ngerengere and Coastal Rivers sub catchments.

During the assessment made by the consultant preparing IWRM and D plan for Wami/Ruvu Basin, calculation of current water use, future demand (2015 to 2035) for Industries, irrigation, mining, livestock, energy, fisheries, domestic, commercial and institution was done and development potential with respect to groundwater and surface water estimated. The percentage of irrigational water use is generally higher than other current water uses and future demand, but the growth rate for industrial water demand in the future is higher compared to water demand for other uses. Below are figures showing comparison between general current water use, future demand and the water resources development potentials in the Basin.
Figure 11. Water use, Demand and development potential in the whole Wami/Ruvu Basin
Figure 12. Water use, Demand and development potential in the Kinyasungwe sub catchment
Figure 13. Water use, Demand and development potential in the Ngerengere sub catchment
Figure 14. Water use, Demand and development potential in the Coastal rivers sub catchment
4. Impacts of change on land use on water resources

The Basin Hydrological cycle

Water circulates on earth from the oceans to the atmosphere to land and back to the oceans in what is called the hydrologic cycle. Water evaporates from the oceans, lakes, and rivers into the atmosphere. This water vapor is transported with the atmospheric circulation and eventually falls as rain or snow onto the land, lakes, rivers and oceans. Of the water falling on land, a portion quickly evaporates, some flows into streams or lakes as overland flow, and another proportion infiltrates into the subsurface. Of the water entering the soil, some is transpired back into the atmosphere by plants. The remaining water follows a subsurface pathway back to surface.

Many activities influence hydrological regimes by their impact on soil moisture and sub surface water storage and movement. The abstraction and return of water for domestic, agricultural and industrial use and the use of surface reservoirs also directly affects flow within rivers. Water quality changes also have a significant impact on water resources availability. Sedimentation in reservoirs due to erosion and subsequent transport of sediments is also a widely acknowledged water resources management problem. Changes in land use may lead to very important changes in the hydrological behavior of a particular basin. The relative importance of all these attribute of a basin must be considered in any concept of regionally integrated water resources management.

4.1 Why should stakeholders participate in water resource management?

Key factors of water management

Water resources stakeholders are those who have an important interest in a specified resource. This may be because they use that resource, or because they practice activities that could cause pollution, or because they are concerned with resource and environmental management (Table 3). Since surface water should be managed conjunctively with groundwater, and municipal or industrial wastewater may pose a threat to groundwater or surface water quality, stakeholders should also (where appropriate) include municipal and industrial representatives.
Stakeholder participation in water resource management is essential for the following reasons:

- Management decisions taken unilaterally by the regulatory agency without social consensus are often impossible to implement.
- It enables essential management activities (such as monitoring, inspection and fee collection) to be carried out more effectively and economically through cooperative efforts and shared burdens.
- It facilitates the integration and coordination of decisions relating to water resources, land use and waste management.

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>WATER-USE CLASSES</th>
<th>POLLUTING PROCESSES</th>
<th>OTHER CATEGORIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>Domestic supply</td>
<td>Household waste disposal</td>
<td>drilling contractors</td>
</tr>
<tr>
<td></td>
<td>livestock rearing</td>
<td>farmyard drainage</td>
<td>educational establishments</td>
</tr>
<tr>
<td></td>
<td>subsistence agriculture</td>
<td>intensive cropping</td>
<td>professional associations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>wastewater irrigation</td>
<td>journalists</td>
</tr>
<tr>
<td>Urban</td>
<td>Commercial irrigation</td>
<td>Urban wastewater disposal/reuse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>water utilities</td>
<td>municipal landfills</td>
<td></td>
</tr>
<tr>
<td></td>
<td>private supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry &amp; Mining</td>
<td>Self-supplied companies</td>
<td>Drainage/wastewater discharge</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>solid waste disposal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>chemical/oil storage facilities</td>
<td></td>
</tr>
<tr>
<td>Tourism</td>
<td>Hotels and campsites</td>
<td>Wastewater discharge</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>solid waste disposal</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>River/wetland ecosystems</td>
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<tr>
<td></td>
<td>coastal lagoons</td>
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</tbody>
</table>

Table 3: Potential range of interests and activities of water resources stakeholders

Water resources management decisions taken with the participation of stakeholders should help to bring:
- Social benefits, because they tend to promote equity among users
- Economic benefits, because they tend to optimize pumping and reduce energy costs
- Technical benefits, because they usually lead to better estimates of water abstraction.

5. **Conclusion and recommendations**

Availability of water for different sources seems to decrease while the demand is increasing due to increased population and social economic developments. The cause of decreased water availability may be resulted from unsustainable land use which causes water sources degradation and pollution. This reduces the available water for different uses.

It is therefore recommended to take responsibilities in safeguarding the available water resources for the current and future generation. This requires the support from different stakeholders especially for those with high investments. Interventions are much required from big water users, who receive and benefit from available water resources. The following are few recommendations

a) Big water users participating in payment for environmental services. Upstream water users to benefit from downstream water users

b) Build storage facilities like dams so as to harvest rainfall during rainy season and use the water during dry season

c) Collective decision making to ensure proper water source development, which will not alter the availability of water resources eg. Establish and implement good land use plan

d) Enforce the available legislations and related regulations which favors sustainable use of water

e) Ensure sustainable water resources developments for different uses
f) Ensure efficient water use in agriculture and industrial sectors

g) Prepare and implement Integrated Water Resources Management and Development Plans to be prepared by all nine Basins
References.

