Workshop on Mainstreaming of Environmental Flows (E-Flows) into Integrated Water Resources Management (IWRM)

Environmental Flows: Concepts and Methods

Venue: Holiday Inn, Cape Town, South Africa
Date: 25th November, 2019 (Monday)

By Dr. Winfred Mbungu

Sokoine University of Agriculture

Introduction and Overview

- ✓ Water resources are **prone to continuous changes** over time and space
- ✓ The **climate-human induced change** are responsible for different levels of modification of water resources to extents of **impairing existence of natural aquatic ecosystems**
- ✓ As human **populations continue to increase** further degradations to the water resources are envisaged
- ✓ As water is central to the socio-economic development, there are challenges related to water management
  - ➢ Water abstraction/diversion/storage
  - ➢ Barriers to movement
  - ➢ Point source and Diffuse pollution
  - ➢ Invasive species
  - ➢ Inter-basin transfers
  - ➢ Droughts and Floods/Climate Change

Water environment


Water quality/Pollution?


Water environment

Balancing needs

Development of Infrastructure is important as it ensures:

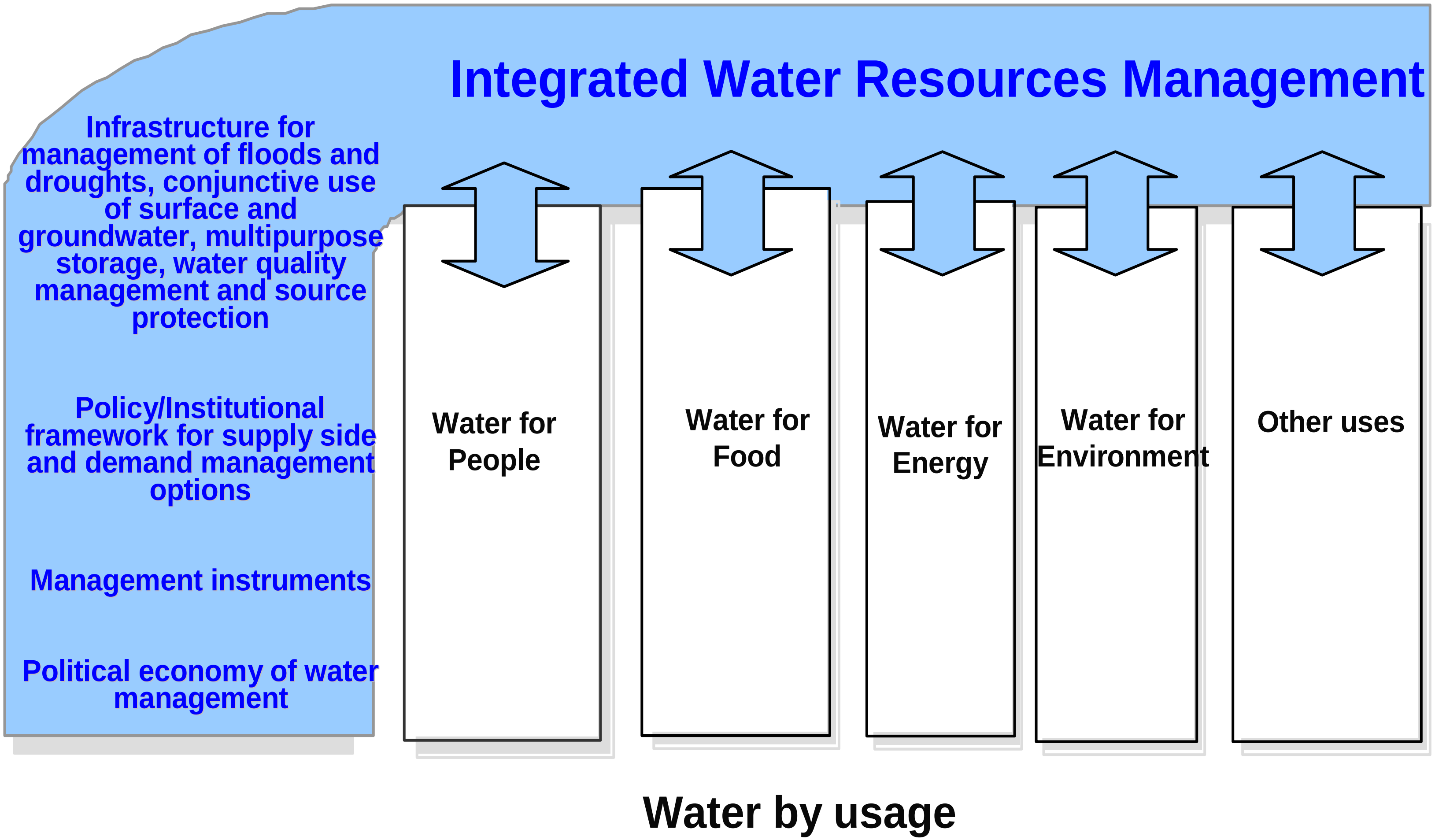
- Reliable, adequate, safe water supply
- Provision of water for development – competing uses as well

BALANCE is needed → Protection for the environment

- Provision of ecosystem services
- Meeting international obligations

Integrated Water Resources Management

Integrated Water Resources Management



Source: World Bank(2015)

IWRM and Environment

- IWRM is being introduced in policy but not in practice
- Elements of IWRM are introduced opportunistically
- Recognition and provision of water for the environment is one of the least implemented aspects of IWRM practice

Environment Flows

- Environmental flows are the water that is left in a river ecosystem, or released into it, for the specific purpose of managing the condition of that ecosystem (King, 2008).

- Brisbane Declaration (2007):
  - "The **quantity, timing, and quality of water flows** required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems"

Environment Flows

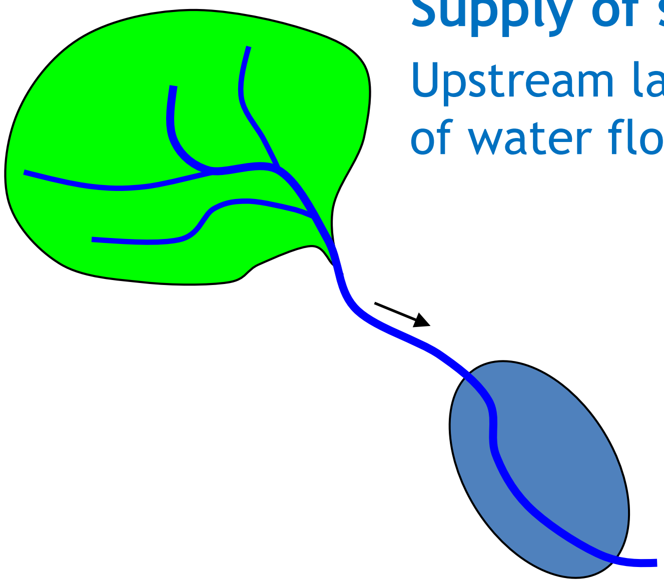
- **Environmental Flows are becoming the global standard** for determining the amount of water required to sustain aquatic ecosystems and satisfy basic human needs, accounting for both components of the reserve.

- Effective implementation of environmental flows should be ensured to meet the SDGs, especially SDG 6, **"Ensure availability and sustainable management of water and sanitation for all".**

- Consideration of environmental flows can help **reconcile the different demands** for water and **reduce the degradation and loss of wetlands**, protect and restore their ecological integrity and halt the loss of biodiversity they sustain.

Environment Flows

- Understanding E-Flows can help
- minimize or mitigate the impacts of new water resource developments
- rehabilitate systems impacted by past developments
- allow calculation of the costs of compensating people for such impacts.



Supply of services:

Upstream land uses affect the **Quantity**, **Quality**, and **Timing** of water flows

Demand for services:

Possible downstream beneficiaries:

- Domestic water use
- Irrigated agriculture
- Hydroelectric power
- Fisheries
- Recreation
- Downstream ecosystems

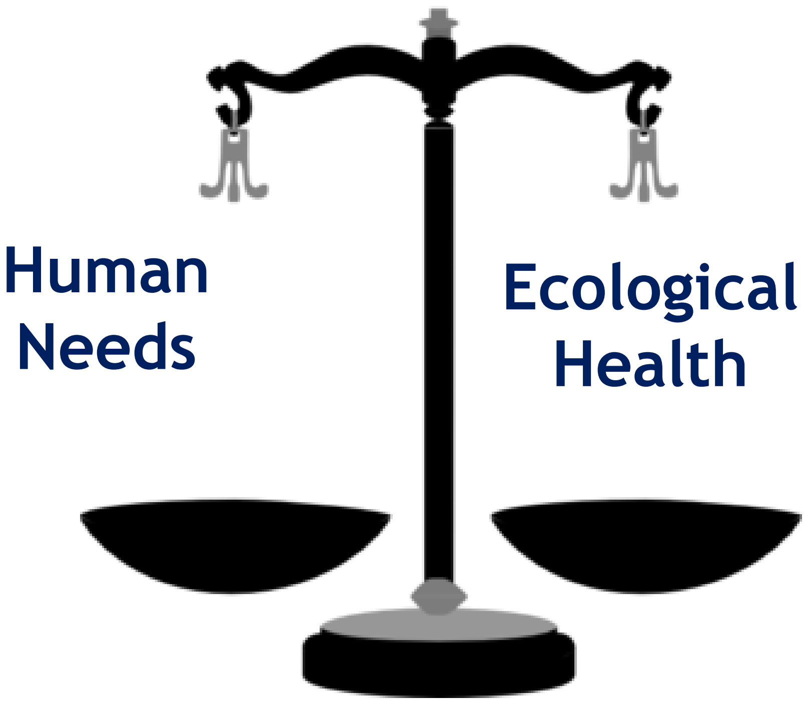
Source: World Bank 2003

Environmental Flows and Decision Making

- Deciding on e-flows is a social choice, not a technical decision – science and social input is essential
- Throws focus on ecosystem services – esp. for downstream communities
- E-flows provided through releases of e-reserves, and through restrictions on abstractions (or improved water use)

Environmental Flow

- Environmental flows should consider
  - minimum amount of flow
  - variation in flow regimes
    - low flows
    - seasonal highs
    - flood peaks
    - extraordinary events
- Environmental Flows Should be
  - legally defensible
  - scientifically defensible
  - administratively feasible



Environment Flow Methods

- According to Thame (2003), over 200 EWR methodologies exist which can be placed into four major groups:
  - Hydrologic-based methods
  - Hydraulic rating methods
  - Habitat simulation methods
  - Holistic methodologies

Hydrologic-based methods

- Based on analysis of observed or simulated historical streamflow data to obtain flows as indicators for ecological and biological functions of a water body

- They are the most widely used methods for EF due to available hydrological data

- The *biotic integrity of a water body is conserved based on the general assumption that more water left in the water body provides the best insurance for aquatic biota* and provision of sustaining low threshold reduces risk to the biota.

- Existing methods, Advantages and Disadvantages

Hydrologic-based Methods

<table>
<tr><th>Method</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Tennant</td><td>❖ easy to implement
❖ desktop method requiring no field work</td><td>❖ Highly dependent on degree of professional judgement
❖ Lack of biological validation</td></tr>
<tr><td>Tessman</td><td rowspan="2">❖ easy to implement
❖ desktop method requiring no field work
❖ Better fit to different geographical regions</td><td rowspan="2">❖ Highly dependent on degree of professional judgement
❖ Lack of biological validation</td></tr>
<tr><td>Texas</td></tr>
<tr><td>Tennant-British Columbia</td><td>❖ Slightly difficult to implement
❖ desktop method- no field work
❖ Better fit to different geographical regions</td><td>❖ Highly dependent on degree of professional judgement
❖ Lack of biological validation
❖ May not be applicable to geographical regions other than BC</td></tr>
<tr><td>FDC</td><td rowspan="2">❖ easy and quick to implement
❖ desktop method - no field work
❖ inexpensive
❖ Better fit to different geographical regions
❖ Appropriate for reconnaissance (level 1) water resources planning and management assessments
❖ Respond to natural pattern of variations</td><td rowspan="2">❖ Highly dependent on degree of professional judgement
❖ Lack of biological validation</td></tr>
<tr><td>IHA</td></tr>
</table>

Hydraulic-based methods

- Based on a relationship between hydraulic measure of a water body (wetted perimeter, depth, width) and water volume (e.g. discharge – rivers).
- Assume that the hydraulic measure is directly or indirectly related to **habitat quantity for a target species**, almost exclusively fish or in some instances the ecological function of the water body
- Seek to **establish a relationship between the water volume or flow rate and the amount of hydraulic parameter** and then use this relationship to identify an inflection point of the hydraulic measure-water volume relationship i.e. finding an indicator threshold below which a significant portion of a water body becomes exposed.

Hydraulic-based methods

Method	Advantages	Disadvantages
Wetted perimeter	❖ Rapid ❖ Requires minimum data collection of transects	❖ Highly subjective and error prone ○ Difficult to obtain consistent inflection/ break point ❖ Recommended thresholds cannot adequately protect habitat for aquatic ecosystem ○ No biological validation
Toe-width	❖ Rapid ❖ Requires minimum data collection of transects	❖ Highly subjective ❖ No biological validation
AEHRA	❖ Rapid ❖ Consider aquatic biology	❖ Slightly expensive compared to the other two methods due to cross section data requirements

Habitat Simulation Methods

- Aim to conserve specific and pre-selected target species for which the habitat requirements can be reasonably estimated or are believed to be known from previous studies elsewhere.
- It is based on the assumption that there exists a relationship between the hydrology level and optimum physical habitat conditions for the target species.
- The method aims at identifying optimum habitat condition and set a target hydrology level such that the amount of physical habitat for the target species does not decline beyond a subjectively determined conservation level.

Habitat Simulation Methods

Method	Advantages	Disadvantages

Habitat Quality Index	- Office work and therefore rapid
	- It has the capacity to perform well if suitably calibrated
		- Never tested outside Wyoming, USA
		- It is not likely suitable in its present form in many SSA countries
		  ○ unavailable regression models
		  ○ expensive habitat data collection for model predictions

IFIM/ PHABSIM	- Office work and therefore rapid - Produces an incremental relationship of habitat vs. flow - Useful for rapid assessment of EWA where hydraulic data is available	- Time consuming and expensive for Tanzania due to expensive hydraulic and habitat data collection and analysis - Highly species specific

Holistic Methods

- They are a **group of methods or rather frameworks**, which are **based on the need to maintain some resemblance to the natural hydrological regime** in order to sustain healthy aquatic and riparian ecosystems.
- Holistic methods aim to **merge human and ecosystem water requirements** into a seamless assessment framework.
- integrate social, cultural and economic values within ecosystem protection goals
- are sometimes referred to as **expert panel approaches,** where environmental water standards are developed in a workshop setting where water body-specific data is considered by a **multi-disciplinary team** consisting of specialists, water management authorities and other water users for agreeing on the recommendations.

Holistic Methods

- Holistic methods can be categorized into two main approaches, bottom-up or top-down strategy to describe environmental water regime
- The **bottom-up procedures are based on the assumption of possibility of prescribing the critical components of hydrologic regime** that needs to remain in the water body.
- In contrast, **top-down methods assume that the entire natural hydrologic regime is ecologically important** but some hydrology components can be modified or removed without ecological risk.

Existing Holistic Methods

- Building Blocks Methodology (BBM)
- Downstream Response to Imposed Flow Transformation (DRIFT)
- Ecological Limits of Hydrological Alteration (ELOHA)
- Habitat Flow Stressor Response (HFSR)
- Benchmarking Frameworks,
- Savannah process,
- Expert panel assessment method
- Flow restoration methods

Existing Holistic Methods

- All holistic approaches share some common properties regarding maintenance of ecological sustainability:
  - some components of the natural hydrologic regime cannot be scaled down and shall be entirely retained
  - some other components of this natural regime can be scaled down
  - some other components of this natural regime can be omitted altogether
  - the variability of the regulated regime should mimic that of the natural hydrologic regime

Overview of types of EF Methods

Type	Approach	Required data	Required time	Estimation of funds required*	Specialist expertise required	Advantages and constraints
Hydrology-based	Look-up table (e.g. Tennant)	Existing or modeled flow data	1 day	< $ 5 000	Some hydrological knowledge, and ecological insight**	- Low confidence. - General results. - Low costs. - Quick.
	Hydrology based (e.g. IHA)	Existing or modeled flow data	1 day - 1 mon	< $ 10 000	Some hydrological knowledge Ecological insight**	- Low confidence. - General results. - Low costs - Quick.
	Extrapolation (e.g. Hughes Desktop)	Based on correlation with existing detailed studies	1 day	$200 000 to develop < $ 10 000 to apply	- Hydrologist - Modeller - Ecological insight	- Only possible for regions in which numerous assessments have been done using more comprehensive methods, to provide the dataset for extrapolation. - Low confidence - Low costs. - Quick.

Type	Approach	Required data	Required time	Estimation of funds required*	Specialist expertise required	Advantages and constraints
Hydraulic rating	**Hydraulic rating**	**Surveyed cross-sections**	**≤ 3 months**	**< $ 50 000**	**- Hydraulics engineer - Hydrologist - Ecological insight**	**- No/Few ecological inputs. - Low/Medium confidence.**
Habitat simulation	Habitat simulation (e.g. IFIM)	- Hydraulic habitat requirements of target species. - Multiple rated hydraulic cross-sections.	3 mon - 1 yr	$ 250 000 - $ 3 mil.	Hydraulics engineer Biologist Hydrologist Modeller	**High confidence for target species, but lacks ecosystem focus.**
Holistic	Site based Comprehensive (e.g. BBM, DRIFT)	Existing and sampled biophysical and social data. Hydraulic cross-sections. Socio-economic needs	1 - 3 yrs	$ 150 000 - $ 3 mil.	- Hydrologist - Hydraulics engineer - Freshwater biologists - Geomorphologist - Water quality specialist - Socio-economist	**- Ecosystem based. - High confidence. - Socio- economic factors included. - High costs of resources.**

Source: SWMRG