Environmental Flows and Restoration of the Zambezi Delta, Mozambique

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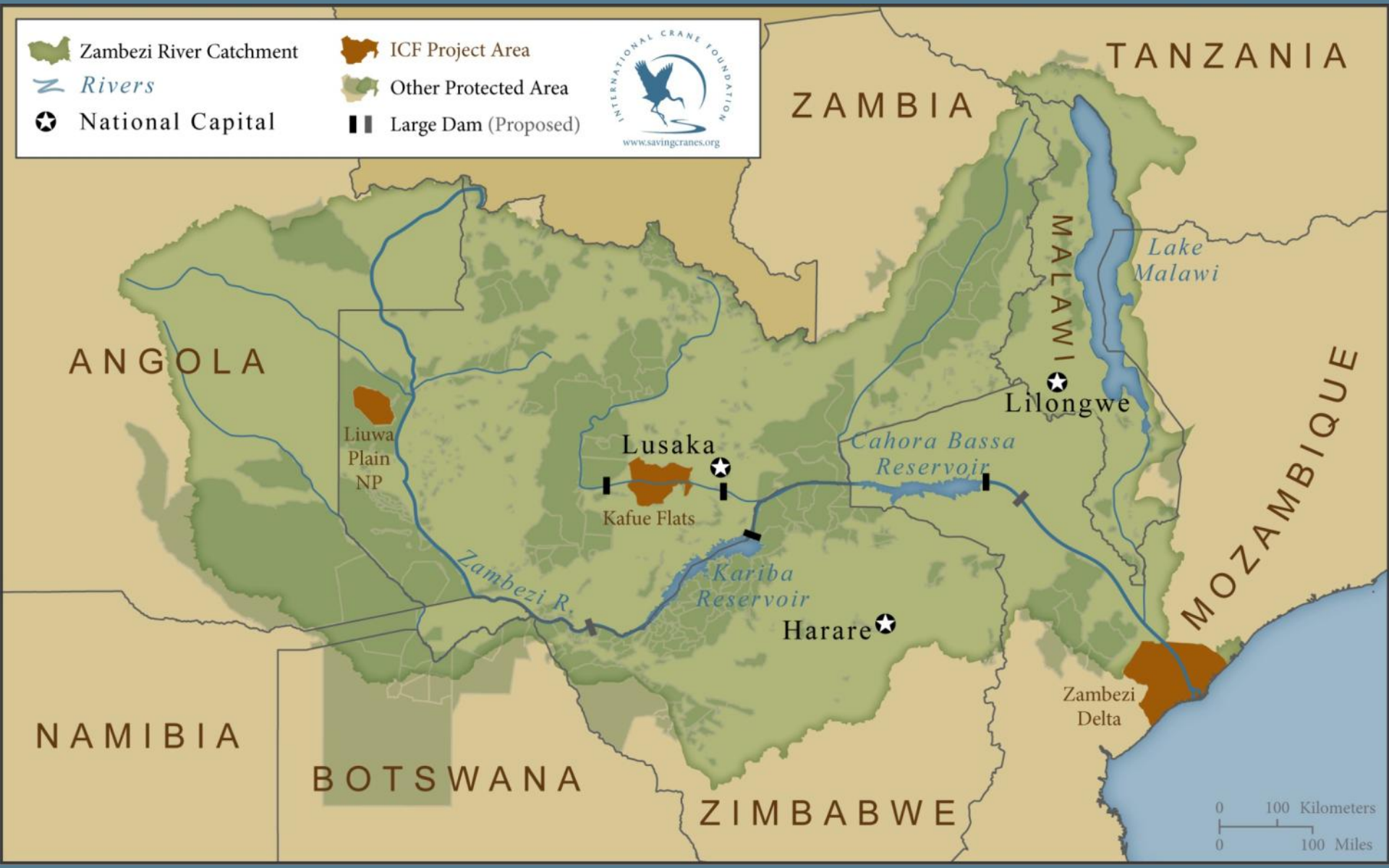
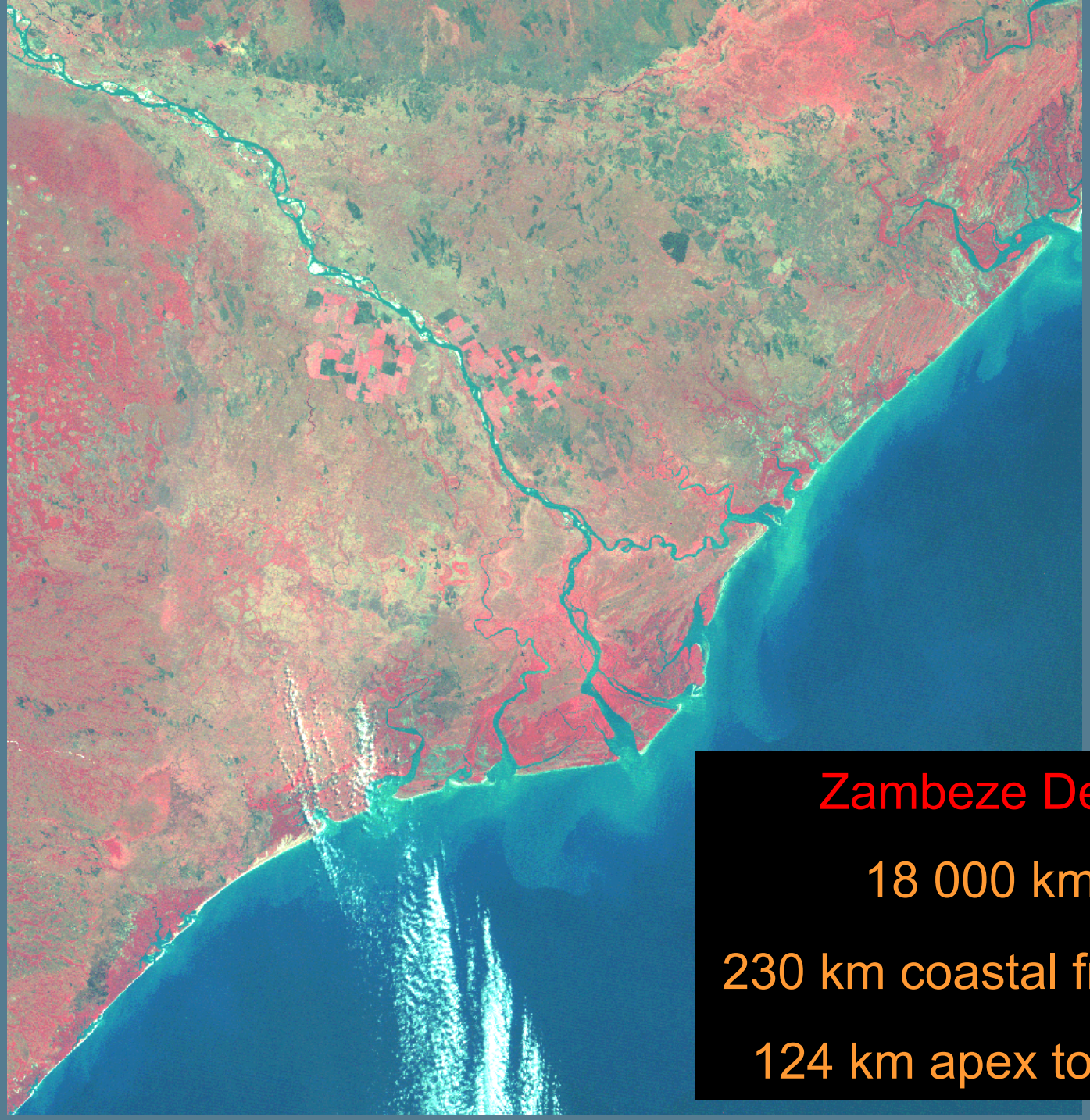
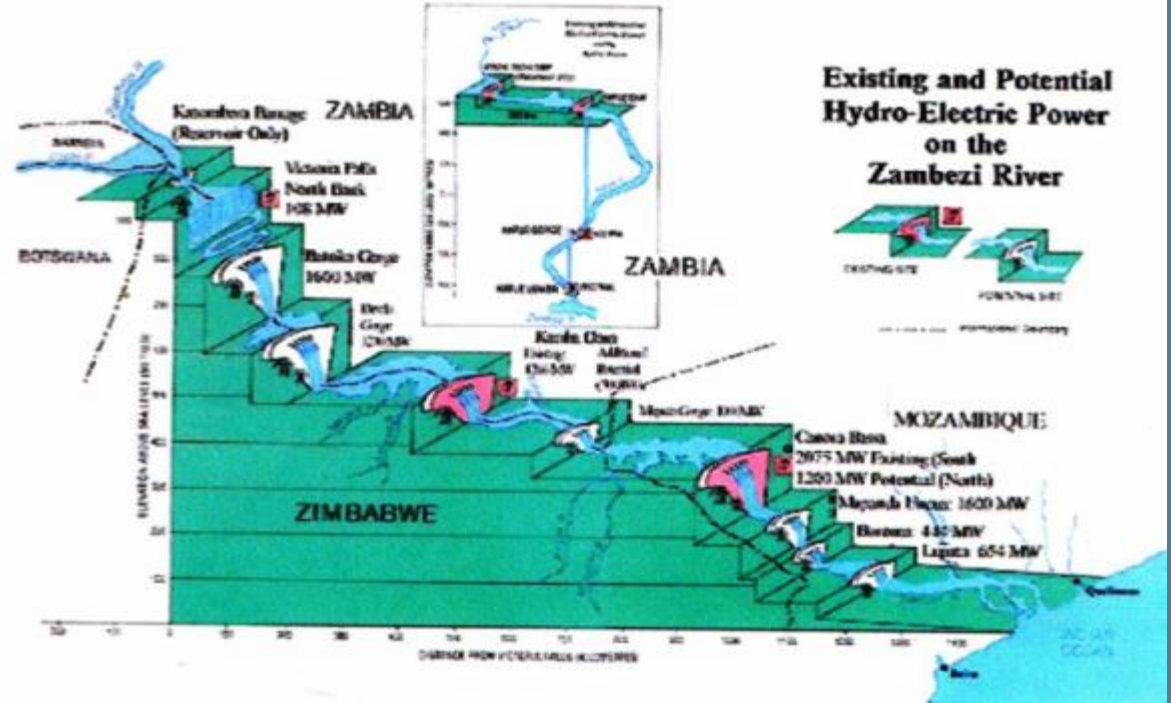
International Crane Foundation


Zambezi River Catchment
Rivers
National Capital
ICF Project Area
Other Protected Area
Large Dam (Proposed)
INTERNATIONAL CRANE FOUNDATION
www.savingcranes.org
TANZANIA
ZAMBIA
MALAWI
Lake Malawi
ANGOLA
MOZAMBIQUE
Lilongwe
Liuwa Plain NP
Lusaka
Kafue Flats
Cahora Bassa Reservoir
Zambezi R.
Kariba Reservoir
Harare
Zambezi Delta
NAMIBIA
BOTSWANA
ZIMBABWE
0 100 Kilometers
0 100 Miles


Zambeze Delta
18 000 km²
230 km coastal frontage
124 km apex to coast

Hydropower dams



Energy optimization

>5000 MW installed
>13 000 MW potential

Subordinate functions

flood control
water supply
reservoir development


“Worst” climate future among 11 African river basins:
26-40% reduction in runoff by 2050

Degradation of downstream flows, sediments, connectivity

Zambezi River Delta Environmental Flows Program

1. Economic valuation of restored delta biodiversity, ecosystem services, livelihoods relative to hydropower
2. Water availability for multi-objective operation
3. Trade-offs among water requirements for different users
4. Implementation and adaptive management

ZAMCOM

INTERNATIONAL CRANE FOUNDATION

HIDROELÉCTRICA DE CAHORA BASSA

ARA-Zambeze
Administração Regional de Águas do Zambeze

UNIVERSIDADE EDUARDO MONDLANE

WWF

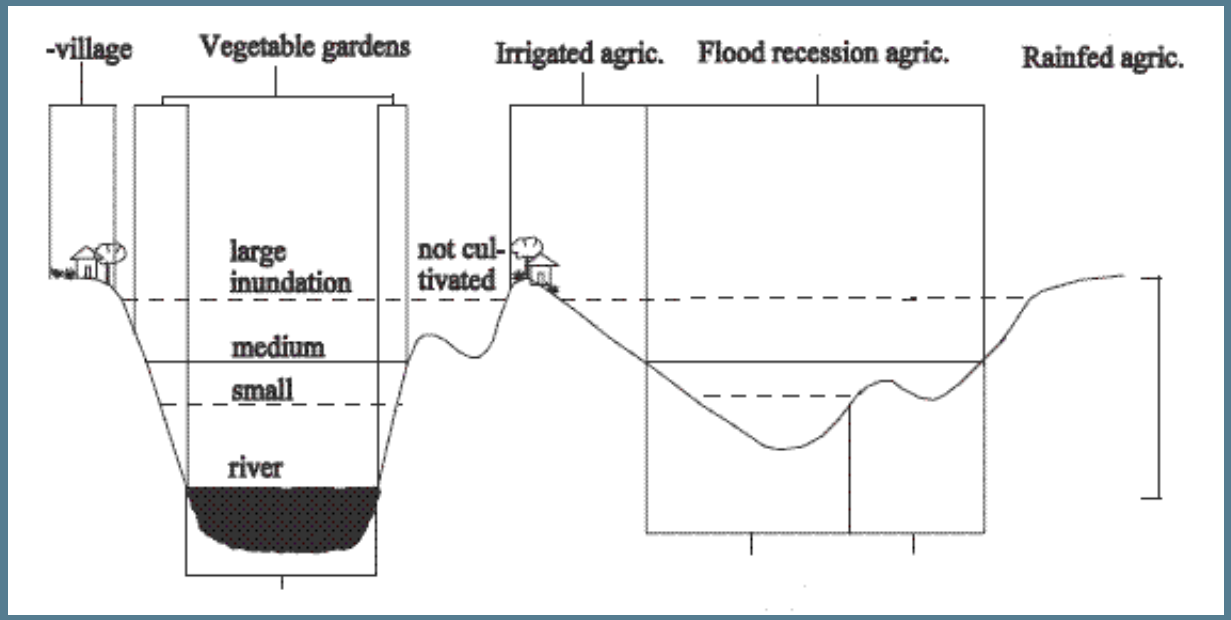
African buffalo

- Dry season body condition linked to declining soil moisture content
- Loss of carrying capacity related to wetland drying and increased fire
- Ecotourism and hunting revenue value of restored floodplains habitat at $millions/yr

Endangered Wattled Crane

- ~90% population reduction
- Reduction in main food source (*Eleocharis* rush tubers) and increased nest vulnerability to fire
- Substantial floodplain breeding grounds could recover with correctly timed annual floods of sufficient duration

Bento et al. 2007



Commercial and small-holder agriculture

- Mistimed floods damage riverbank cropping; increase drought vulnerability
- Reduced area for flood recession crops linked to >30% productivity decline
- Salinity intrusion most significant threat to sugar production
- Economic valuation of annual floods for agriculture suggests $millions/yr

Brito 2006

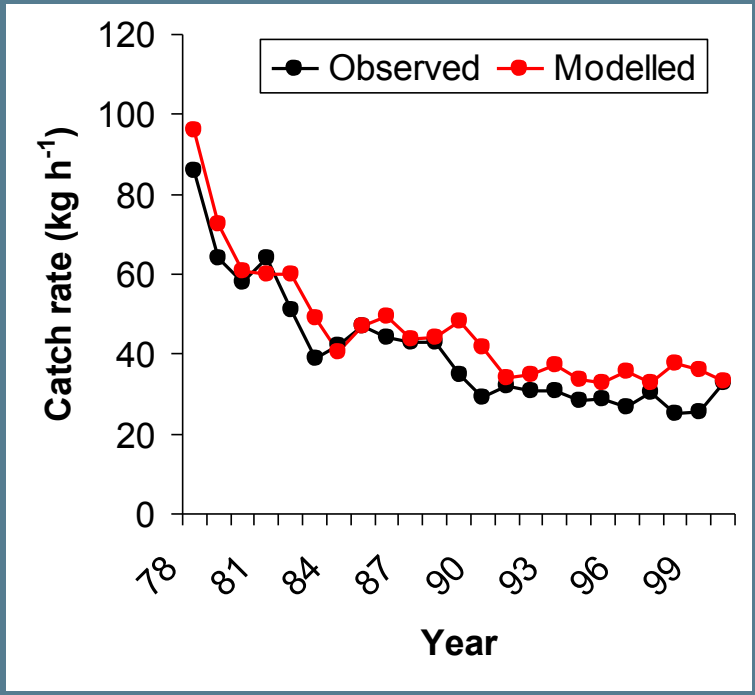
Freshwater fisheries

- Reduction in freshwater fisheries directly related to reduced flooded area and duration and mistimed flooding regime
- 30,000-50,000 tonnes per annum under restored flooding regime
- Highly responsive to large flooding events (2001, 2008)

Tweddle 2006

Wild-caught shrimp fisheries

- Life-cycle depends on wet season flood pulse and dry season low flows
- Strong correlation between Zambezi annual runoff pattern and fishery catch rate
- Lost economic value $10-30 million/yr could be recovered

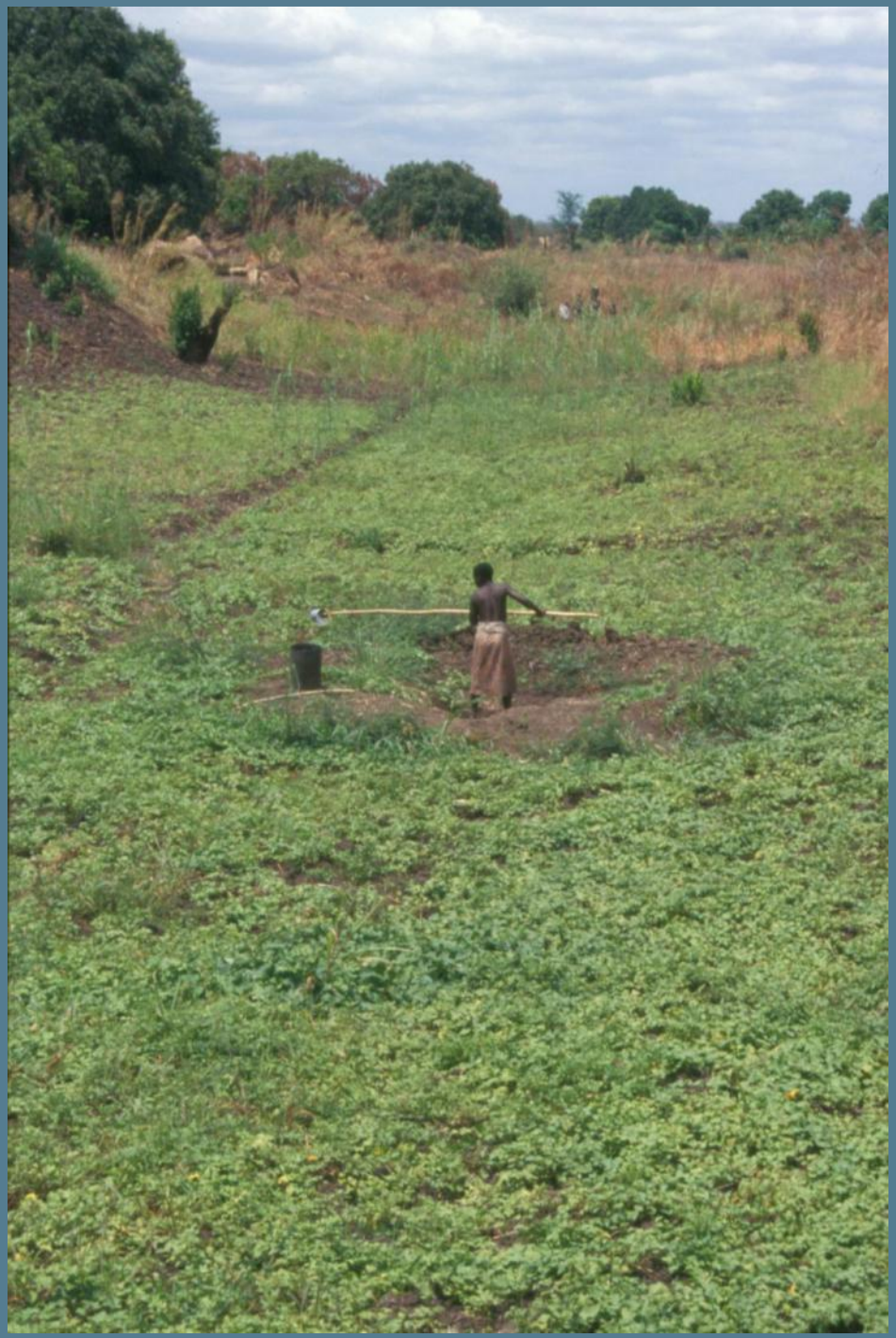


Gammeslrod 1992; Hoguane 2002

Floodplain grazing lands

- Reduced extent and quality of end-of-dry season grazing lands for cattle
- Restored floods flush disease-bearing ticks off of floodplain
- Lost economic value $millions could be recovered

da Silva 2006



Water supply

- >5 m water table decline on delta floodplain due to diminished recharge
- Increasing dependence on Zambezi River to meet domestic water requirements—crocodiles, waterborne disease
- Est. annual value $9 million during normal/flood; $14 million during drought years.

Guveya & Sukume (2008)

Cultural values

- Ceremonial, recreational, aesthetic, and spiritual values affected by changes in flow regime
- Improvements linked to restoration of more natural flow regime

Settlement and displacement

Adaptation to loss of flood pulse results in higher social and economic costs during very large (uncontrollable) floods

Loss of life, livelihoods, infrastructure; flood evacuation - $100 millions per major flood


Endemic and Endangered species


People

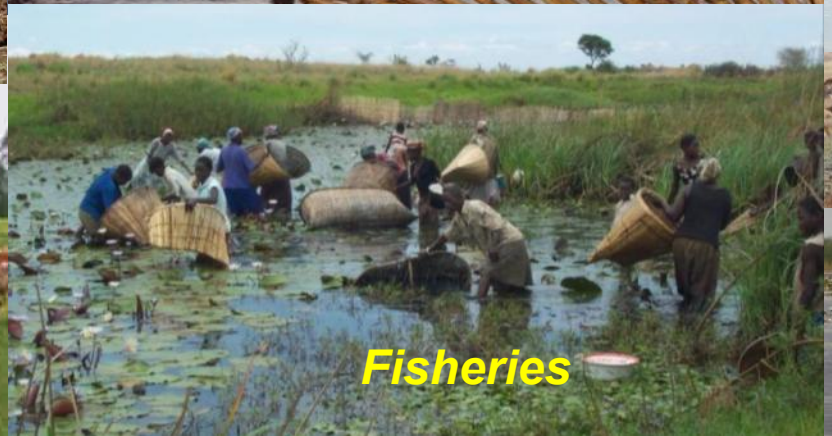

Tourism


Fertile soils


Culture


Materials


Grazing lands


Fisheries


Flora and fauna

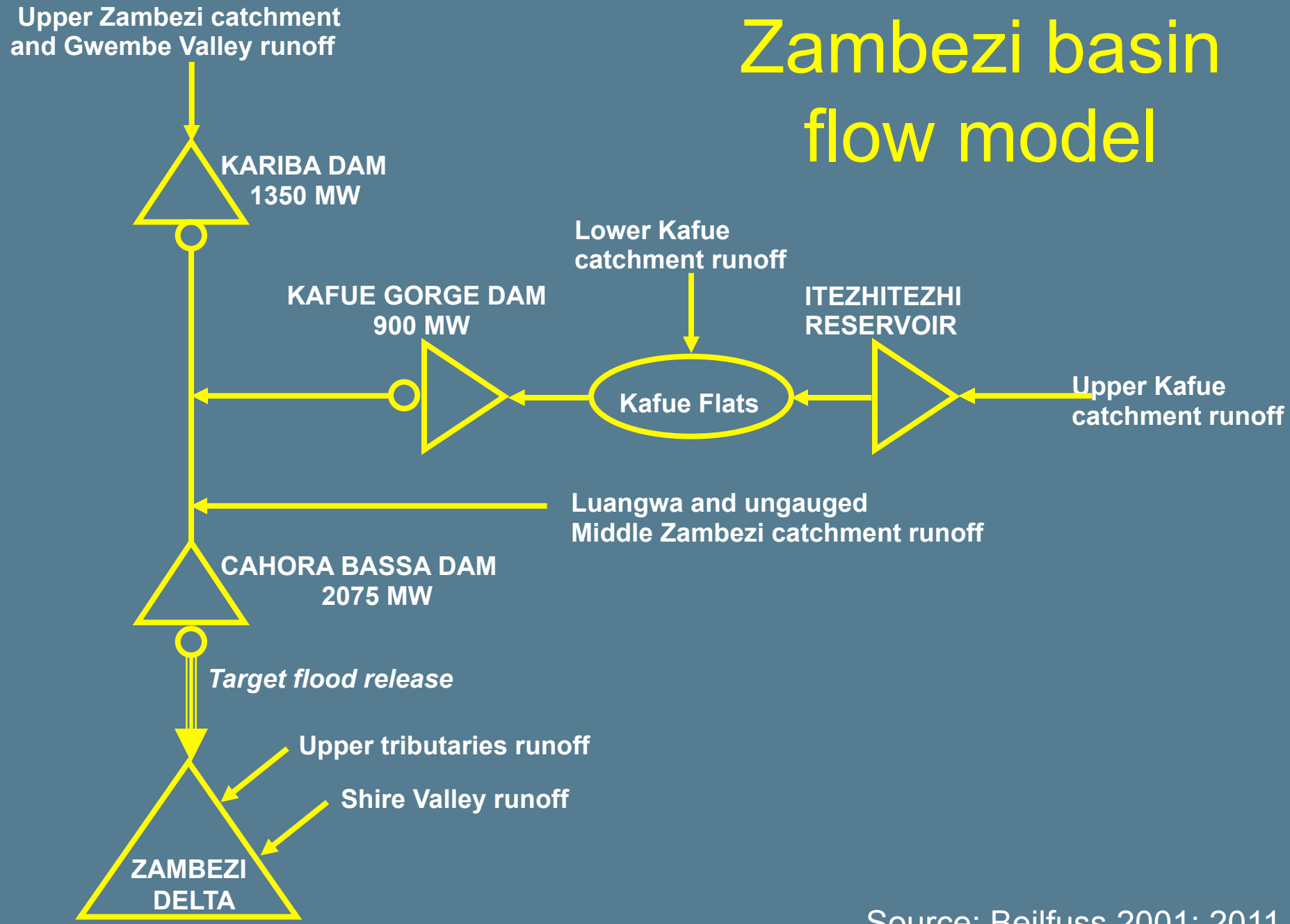
Modeling water availability for multipurpose management and delta restoration

1. Likelihood that different e-flow scenarios can be achieved, constrained by water availability and hydropower contracts

2. Assess the affect of each e-flow scenario on firm power generation and total annual energy production

3. Sensitivity of 100-year flow series to increased water abstractions and reduced runoff scenarios (climate change)

Zambezi basin flow model



Source: Beilfuss 2001; 2011

E-flow Scenario	Target outflow reliability (%)	Baseline outflow reliability (%)	Firm power reliability (%)	Energy production (GWh/yr)	Energy as % of baseline
Baseline	--	--	98.4	14393	100.0
1	95.6	85.7	97.3	14333	99.6
2	94.5	58.2	96.7	14273	99.2
3	**97.8**	**7.7**	**97.3**	**14407**	**100.0**
9	94.5	3.3	95.8	14064	97.7
10	91.2	3.3	92.5	13637	94.7
11	72.5	4.4	89.7	13112	91.1
12	78.0	1.1	83.9	12963	90.1
13	89.0	5.5	93.3	13801	95.9
14	78.0	0.0	90.9	13067	90.8
15	90.1	2.2	92.2	13612	94.6
16	83.5	1.1	90.0	12993	90.3
17	24.2	0.0	87.0	12575	87.4
18	25.3	0.0	68.0	12018	83.5

Scenario 3 = 4500 m^3s^{-1} flood pulse for 2 weeks in February – achieved with >97% firm power and with no reduction in annual energy production. Target outflows in ~98% of all years, <8% of years under current management

Is water available for delta within constraints for hydropower production?

- YES—Modeling indicates a range of eflow scenarios are possible
- Improved flow conditions realized through water reallocation with minimal reduction in hydropower
- E-flows could help ameliorate climate change flow reductions if power production commitments realigned

Modeling trade-offs among water users

What are the trade-offs in water requirements (magnitude, duration, timing) among the different users?

What are the "minimum" flood requirements?

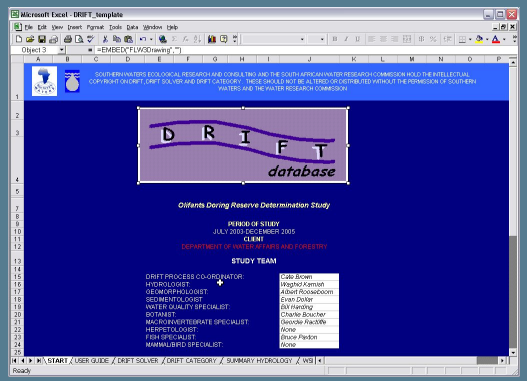
Are the "minimum" flood requirements realistic with respect to the hydropower generation?

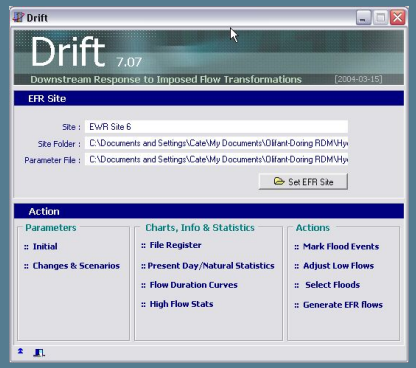


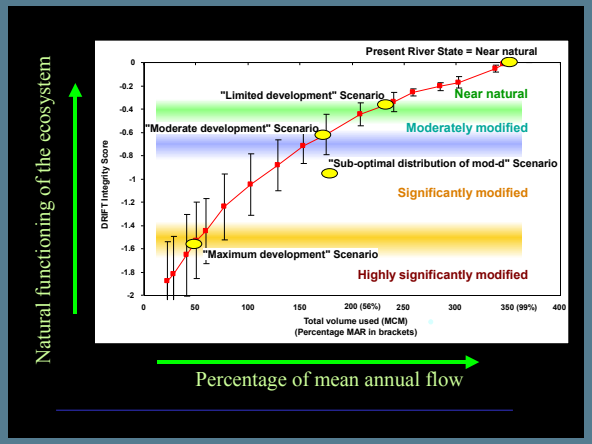

DRIFT

Downstream Response to Imposed Flow Transformations

A holistic, scenario-based environmental flows methodology applied to a range of river basins worldwide







King et al. 2004

Different water users/concern in the delta

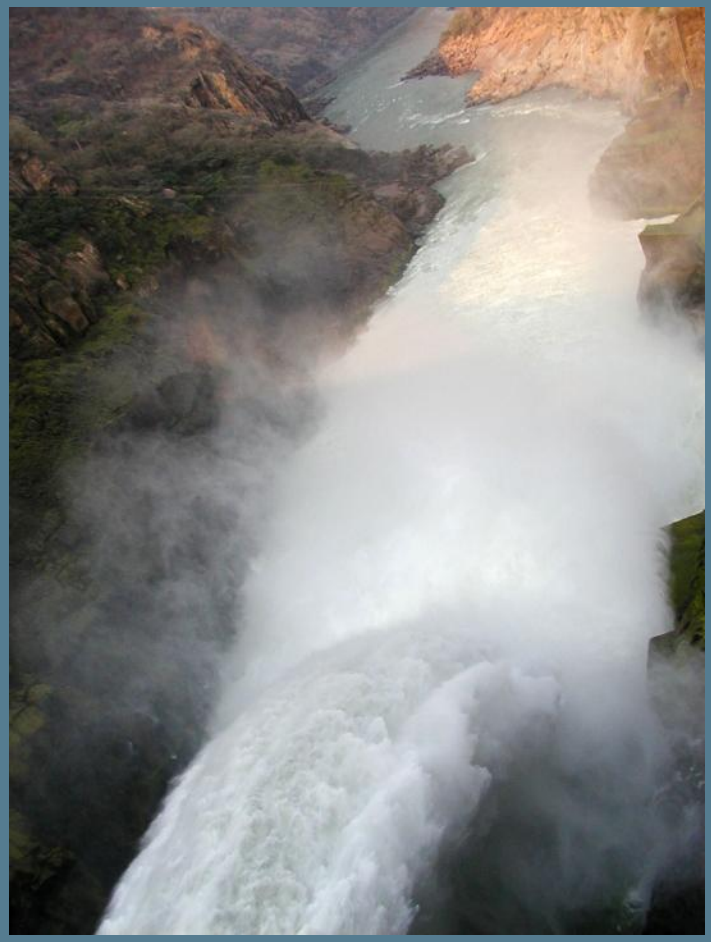
- Small scale agriculture (subsistence and cash crop)
- Irrigated commercial agriculture
- Estuarine ecology and coastal fisheries (esp. prawns)
- Freshwater fisheries
- Livestock
- Large mammals
- Waterbirds/wetland biodiversity
- Wetland vegetation and invasive species
- Natural resource utilisation (socio-economic and cultural)
- Water quality
- Domestic water supply
- In-river navigation
- Public health
- Settlement patterns

Flow changes considered for the Zambezi Delta

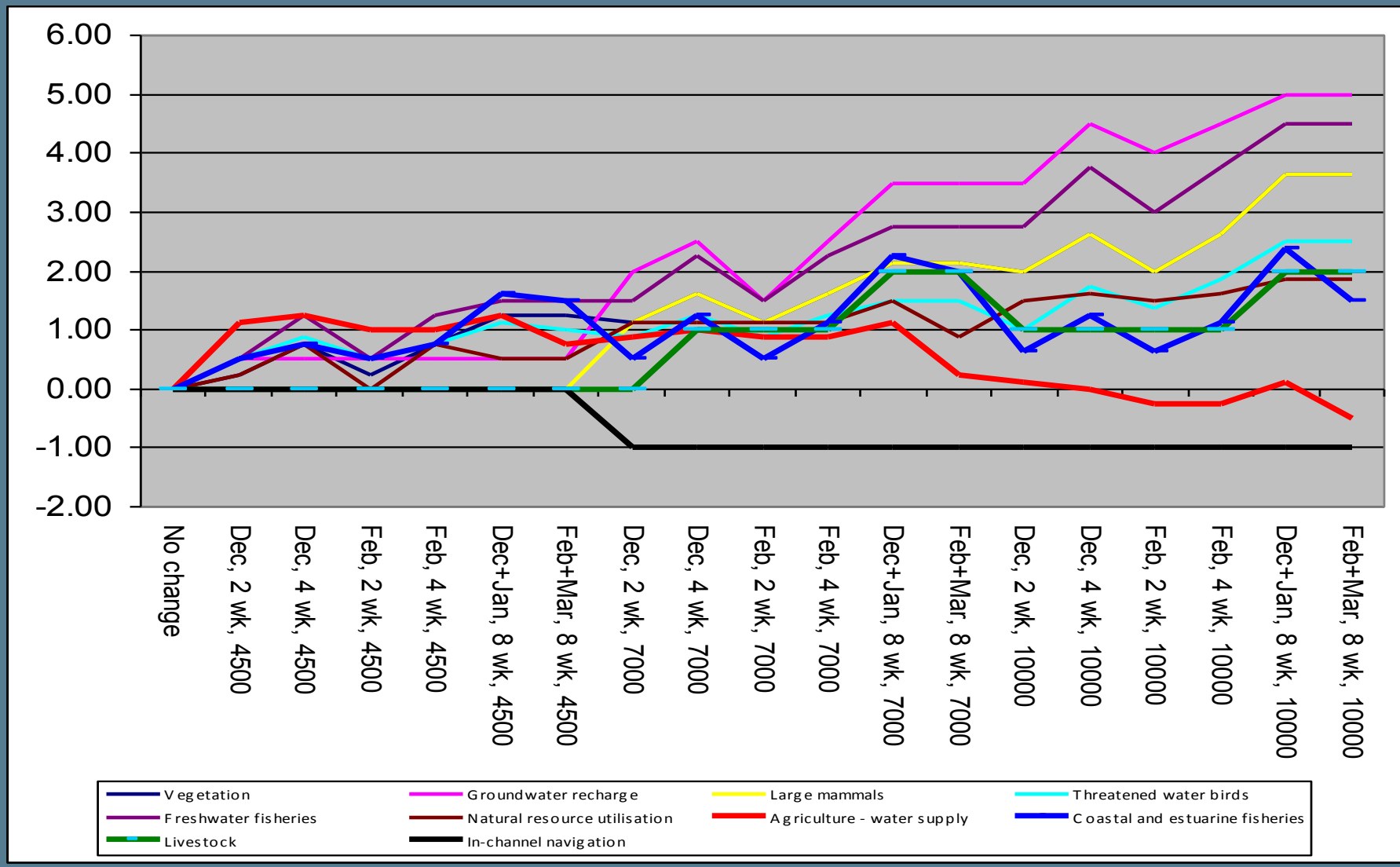
The three flow categories were:

- Dry season lowflows (PD + 5)
- The ‘annual’ flood (PD + 18)
- 1:5 year return flood (PD + 1)

The flow changes encompass a mixture of:
Changes in magnitude.
Changes in duration.
Changes in timing.



Trade-offs among users?
Annual floods



Beilfuss and Brown 2009

Are there significant trade-offs among Zambezi Delta water users and concerns?

- NO—range of water users show consistent need for improved flows, especially annual floods
- Strong consensus among experts/representatives
- Scenarios indicate a range of benefits with minimal hydropower reduction

Beilfuss and Brown 2006, 2010

Moving forward in the Zambezi Delta

- Engaging with water authorities and operators to implement water management scenarios and operational guidelines
- Restoring floodplain connectivity
- Helping communities adapt to water scenarios
- Learning from experimental releases - monitoring results for adaptive management