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Hydrological assessment of freshwater resource areas in the Zambezi River Basin

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INTRODUCTION

The Zambezi River Basin (ZRB), one of the largest African river systems flowing into the Indian Ocean, straddles across eight southern African countries (**Figure 1**).

There is an increasing demand for water because of population growth, rapid urbanisation and increased food production. It is critical that freshwater resource areas (FRAs) are protected considering their contribution to the main stem flows which support regional food security and hydropower production. This poster presents the preliminary results of the hydrological assessment of FRAs of the ZRB. It forms part of a scoping study with the objective to ensure that environmental flows are applied in the Zambezi River system.

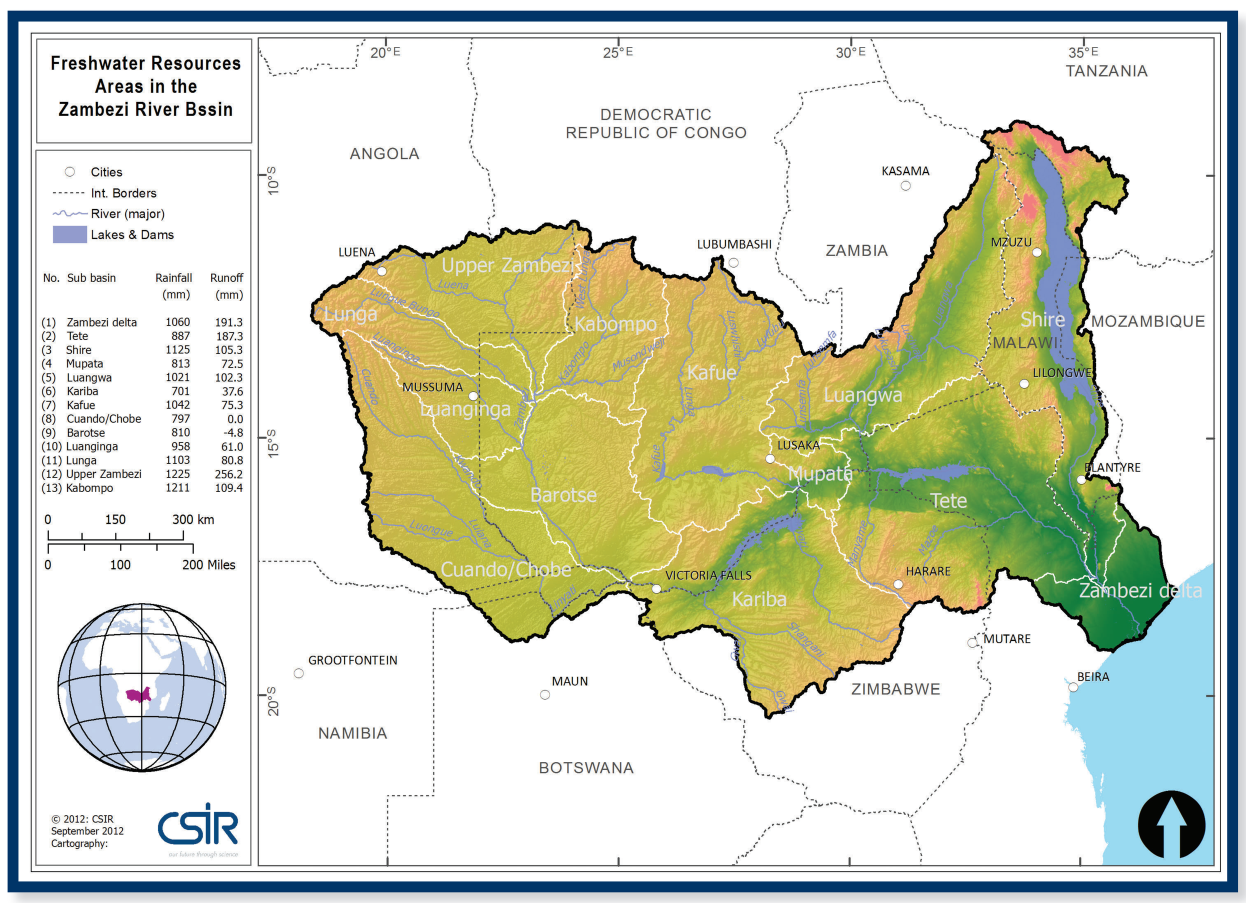

Figure 1: The Zambezi River Basin and its 13 sub basins

MATERIALS AND METHODS

The hydrological identification of key FRAs required a characterisation of the degree of regulation of the river system, followed by an assessment of high water yielding areas (water towers), groundwater recharge and base flow index. To understand the environmental patterns and processes that occur in the river basin around hydrology, the following datasets were either sourced or mapped:

- Surface water hydrology: 1km mean annual and monthly precipitation (Hijmans et al., 2005); 50km mean annual and monthly runoff (Fekete et al., 2008); high water yielding areas; major dams (Lehner et al., 2011); river channel fragmentation and flow regulation by HydroSHED lines; baseflow index, river network (Lehner et al., 2008).
- Groundwater hydrology: modelled groundwater recharge; long-term average groundwater recharge (Döll and Fiedler, 2008).
- Physiographic characteristics: drainage classes (Jenness et al., 2007) and global land cover (Bontemps et al., 2010).

These were based on the principles of:

- Continuity: river segments are classified as 'impacted downstream reservoirs';
- Proportionality: river segments are classified as 'moderately impacted' after the conflux of an impacted river and a river draining a catchment area of similar size.

High water yielding areas were assessed using the NRCS curve number method, which combined the Wordlclim rainfall, the 2009 GlobCover land use and the soil drainage coverage.

The groundwater recharge and the baseflow index were generated using the Pitman rainfall-runoff monthly model. The model was run from January 1901 to December 2001. Where available, model results were compared with observed data sets to assess the model's ability to reproduce the hydrology of the subbasin under consideration.

RESULTS AND DISCUSSION

The flow characterisation undertaken as part of this study indicates that the upper reach of the ZRB is unregulated (**Figure 2**).

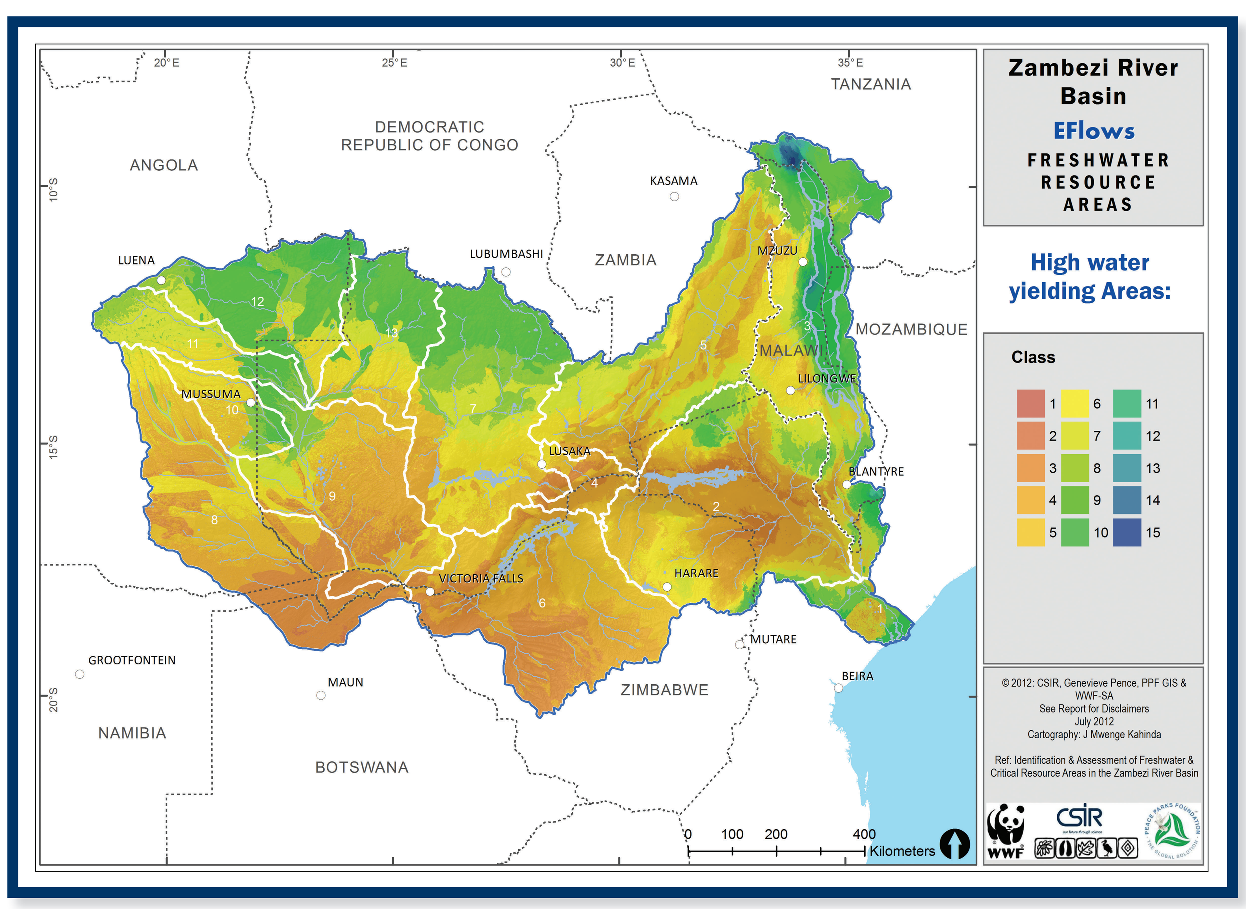

Figure 3: High water yielding areas of the ZRB. High water yielding areas were classified as 15, and low water yielding areas as 1

High water yielding areas of the ZRB (**Figure 3**) are primarily located in the Lufilian Arc covering eastern Angola, southern Democratic Republic of Congo and northwestern Zambia. These results are in line with the Global Composite Runoff Fields (Fekete et al., 2002).

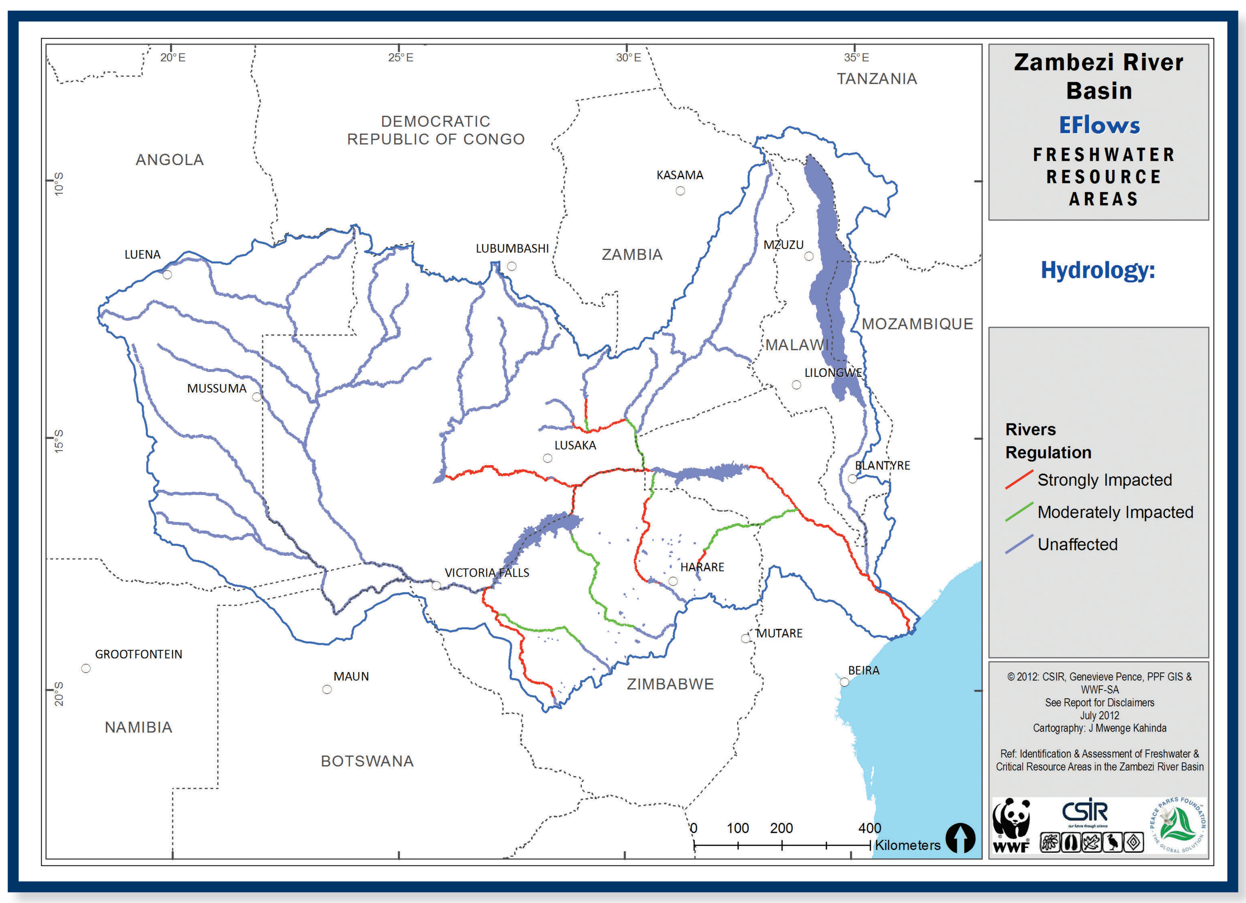

Figure 2: River channel fragmentation and flow regulation of the Zambezi River Basin. Unaffected rivers – shown in blue – are those without dams in the main channel of the river

High values of recharge were modelled for the Upper Zambezi, Kabompo, Lungue Bungo and Kafue subbasins which are subbasins that receive higher annual rainfall. Luanginga, Cuando, Kariba and Zambezi Delta have low recharge values. Recharge results are comparable to findings by a global study (Döll & Fiedler, 2008) (**Figure 4**).

For the basin as a whole, baseflow contribution to flow is generally low. This is consistent with results from South African studies (Xu and Beekman, 2003). Arid subbasins such as the Cuando and Kariba have very low baseflows. The geology of the basin can also be used to explain the low contribution of baseflow. Precambrian and basement complex rocks predominantly underlie the basin.

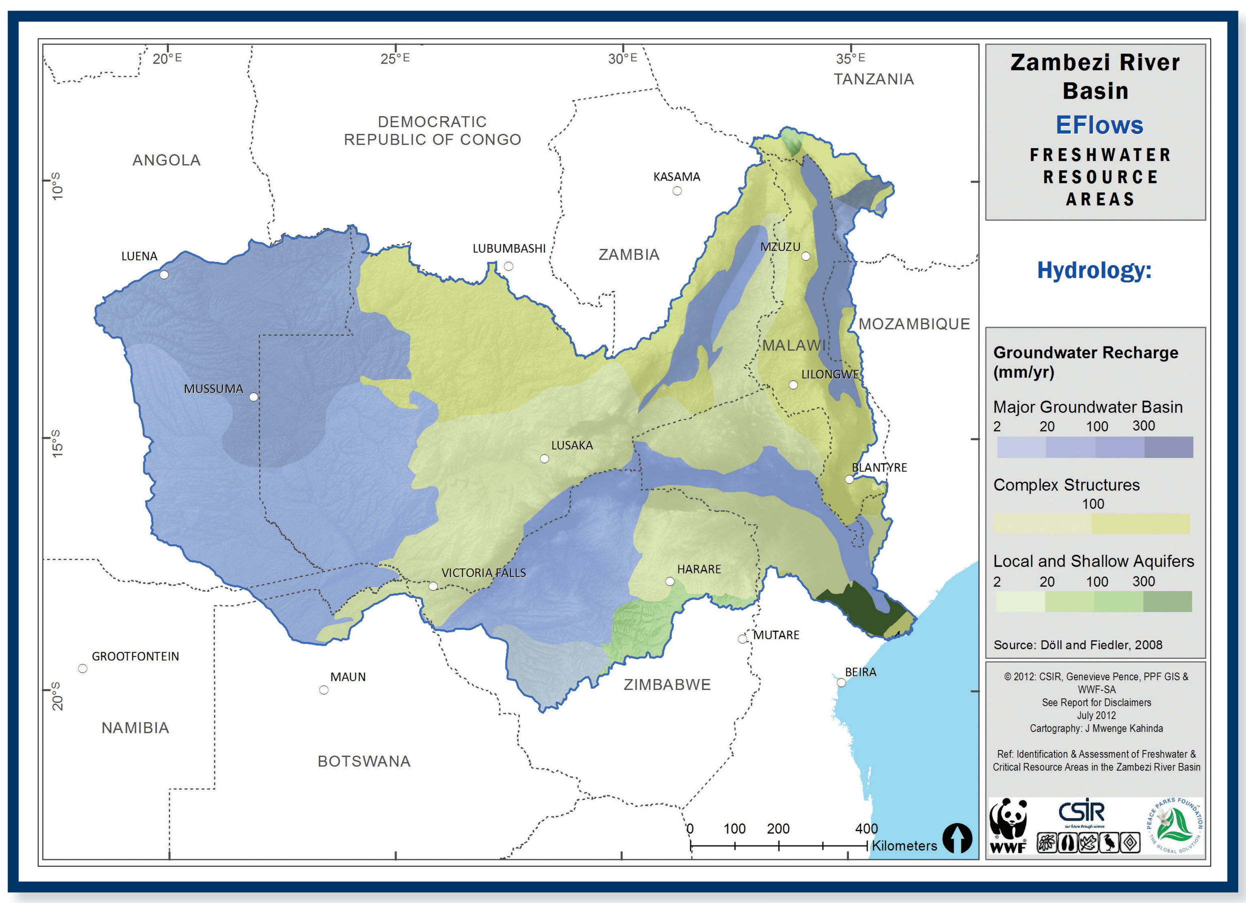

Figure 4: Long-term average groundwater recharge map of the ZRB (Döll & Fiedler, 2008)

CONCLUSION

The appropriate way to characterise catchments in terms of degree of flow regulation will be to use the degree of regulation index, which represents the proportion of a river's annual flow that can be withheld by a reservoir or cluster of reservoirs. This requires quantitative knowledge of the flows of most rivers of the basin.

Uncertainties, though not quantified, in the high water yielding layer could be caused by the accuracy of the rainfall estimate and the assignment of Curve Numbers for each 1 – km pixel.

The results should be used to estimate runoff yield within the pixel as opposed to aggregating the results to estimate watershed yield at the outlet. Watershed-wide aggregation of runoff from the individual pixels without runoff routing between pixels and connecting channels in large watersheds overestimates the watershed yield.

This exercise provided a good representation of the low flow component of the ZRB which would enable reasonable estimates of groundwater recharge and baseflow contribution to the total. The results show that both groundwater recharge and baseflow contribution to channel runoff are low. It is important to consider the contributions of baseflow as this has a huge impact on the flow regime of the river and the sustenance of the ecology of the basin. It also provides an idea of the source of water that flows in the basin and thus informs the development and formulation of river basin management strategies.

ACKNOWLEDGEMENTS

Funded by the Royal Netherlands Embassy, Maputo, through WWF-SA. Special thanks to the Institute of Water Research (Rhodes University) for providing the initial set up of the Pitman model.

Hydrological modelling of the Zambezi River Basin will inform the development and formulation of appropriate management strategies to ensure and maintain environmental flow requirements.

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