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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

# Ecological reserve

## A recently completed WRC project saw the development of a prototype methodology for the determination of environmental water requirements (EWRs) for non-perennial systems.

### Establishing EWRs for non-perennial rivers: A legal obligation

The South African National Water Act of 1998 requires that the Environmental Reserve be determined for each significant water body before licenses for the use of the water may be issued. Methods of determining the Reserve are currently geared towards perennial systems and thus require verification for use on non-perennial rivers.

Non-perennial rivers are primarily distinguished from perennial rivers by their more variable (spatially and temporally) hydrological regime and by the periodic loss of connectivity of surface water within the system as flow ceases and surface water is confined to isolated pools that may themselves eventually dry up. In order to acquire the necessary field-based knowledge to provide the foundation for developing a prototype methodology to determine the Environmental Water Requirements (EWRs) for non-perennial rivers, comprehensive research was carried out on a selected non-perennial system. Initial phases of the study focused on gaining a better understanding of an ephemeral river ecosystem, while latter phases focused on the development and testing of the prototype methodology.

### Generating field-based knowledge of a non-perennial system

The availability of good quality hydrological data to allow for hydrological modelling proved to be an important requirement in selecting a suitable non-perennial system for study. The Seekoei River close to Bloemfontein, an ephemeral southern tributary of the Orange River, met this requirement. As a basis for selecting suitable study sites along the river, a comprehensive GIS/landscape-based approach that incorporates catchment information, hydrological data, data on river condition, as well as information sourced from stakeholders, also proved to be necessary.

This helps to ensure an adequate understanding of catchment processes and the catchment itself, which, in turn, guides the selection of suitable indicators for river sections, indicates what specific expertise would be need to be sourced, assists in the development of scenarios relevant to the catchment and in general, reduces costs and promotes the efficient use of time through improved and more informed project planning.

In the quest for improved knowledge of perennial systems, field data collected for the Seekoei River over a two-year period spanned the specialist disciplines of hydrology, geohydrology, hydraulics, catchment geomorphology, fluvial geomorphology, water quality, riparian vegetation, aquatic macroinvertebrates, freshwater fish, and socio-economics.

### The challenges of EWR determination for a non-perennial system

Six major challenges encountered in determining EWRs for non-perennial rivers are as follows:

#### Hydrological modelling

With the present condition of the river ecosystem described to the fullest extent possible, hydrological modelling allows the flow regimes linked to any potential water-related management intervention of interest to be simulated and the outcomes to be interpreted in terms of the physical, chemical and biological responses. The final hydrological output of

a flow assessment is a description of flows needed to attain and maintain a range of possible future ecosystem conditions that would be brought about by the different management interventions. The success of the process relies heavily on being able to model the movement of water through the catchment satisfactorily. In this respect, non-perennial systems pose several challenges to hydrological modellers that are unique and more severe than those faced with perennial rivers, resulting in simulated hydrological data generally being of lower accuracy.

### Understanding pools

Isolated pools appear at various points along a river system as surface flow ceases. These pools are important refugia for many of the riverine plants and animals. They may also be important support features in an otherwise arid landscape for a wide variety of wildlife species and also for local rural people and their livestock. Not only are the location, timing and persistence of pools poorly understood, but their chemistry can also be highly unpredictable.

### Intermittent connectivity

Connectivity between pools is one of the most important attributes of non-perennial rivers. Intermittent connectivity allows transport of sediments and nutrients along the system, mixing of gene pools, the movement of organisms to other refugia, and dilution of poor-quality pool water. Because of the poor coverage of flow gauging stations and uncertain nature of hydrological data for such systems, connectivity is not well recorded and cannot be simulated with great accuracy.

### Surface water and sub-surface water interactions

The nature of non-perennial rivers and their pools is largely determined by the interactions between surface and sub-surface waters. At various times and places, water may be either flowing underground into the river from catchment and bank storage, or flowing out of the river into such storage. Water may also be flowing along the river in underground channel aquifers, replenishing pools and filling wells in the riverbed dug by people.

### Extrapolation

Under high levels of physical, chemical and biological unpredictability, extrapolation of ecosystem attributes over long stretches of river is of uncertain value, mostly because much of the basic data will be from isolated pools that behave differently from one another. The inability to extrapolate data means that, at present, generalisations cannot be made with confidence unless they are of very coarse resolution, and so understanding of the rivers remains at the level of individual study sites.

### Establishing reference condition

Setting a reference condition is one of the early stages in the established method of Ecological Reserve determination. Because setting the reference condition has proved to be extremely difficult in the case of non-perennial rivers, a more suitable approach uses the present condition (which scientists can study and understand) as a baseline and then describes how this could change for various flow scenarios. Any knowledge of the historic reference condition which might exist would, nevertheless, be useful for gaining an insight into the extent and causes of changes to date, and therefore the trajectory of likely change into the future.

## The prototype methodology

The prototype methodology developed for the determination of EWRs for non-perennial rivers addresses the above challenges. It follows a comprehensive approach, comprising 11 phases and 28 distinct activities. Once this methodology has been fully verified and finalised, it is envisaged that a suitable process for performing more rapid assessments will be extractable from it.

In this prototype methodology, Phases 1 and 2 deal with initiating and setting up the study. Phases 3 and 4, in turn, focus on accumulating catchment information in order to identify the important catchment processes, components and issues that require further consideration. Phases 5 to 7 aim to choose realistic and applicable future scenarios for the catchment and to gather, document and process the data needed to analyse and evaluate these scenarios. Phase 8 captures the acquired knowledge in the form of response curves and a database. Phases 9 and 10 consider and predict the impacts that the chosen scenarios might have on selected biophysical and socio-economic indicators. Phase 11 advises the relevant decision-making body of the outcome of the study, and provides feedback to the community of stakeholders.

The methodology provides as its output a description of the expected status of key biophysical and socio-economic indicators under a range of possible future flow management options. Seventeen indicators, grouped as follows, represent the non-perennial nature of the Seekoei River:

- **Driving indicators:** Connectivity of surface water; Floods for channel maintenance; Sediment delivery.
- **Responding indicators:**
  *Physical-chemical:* Pools; Channel aquifer; Riparian aquifer; Water quality (electrical conductivity).
  *Biological:* Riparian vegetation cover; Aquatic/marginal vegetation; Number of important invertebrate taxa; Abundance of invertebrate pest taxa; Status of indigenous fish community; Abundance of exotic fish; Terrestrial wildlife; Contribution to parent river and a
  *Socio-economic:* Quantitative indicator, Qualitative indicator.

While some of the method's features are similar to those used in other South African methods of EWR determination, it has some unique features, e.g., the comprehensive GIS/landscape-based approach to identifying integrated units of analysis on which site-selection is based and the fact that change is described from present conditions owing to difficulties in setting reference conditions for non-perennial systems. Key features further include:

- the important emphasis placed on creating an understanding of the nature of the river and its catchment;
- the use of information on the catchment as a whole and not just river channel information in river delineation;
- the provision of an unbiased means of capturing the knowledge, experience and wisdom of specialists by means of response curves; and
- recognition of the particularly important role that stakeholders could play in determining EWRs for non-perennial rivers.

## The way forward

Although the prototype methodology has been successfully applied to the Seekoei River, a number of steps require further consideration and development. Examples of these are:

- issues of scale pertaining to the use of hydrological models with regard to the delineation of the catchment into combined response units;
- model development for the provision of data on sediment delivery;
- assessment of the suitability of multi-criteria decision-making approaches; and
- formalisation of the set of drivers for each responding indicator and establishment of a protocol for obtaining the integrated impact of these drivers on each responding indicator.

The prototype methodology needs to be further tested on a range of non-perennial systems in order to assess its universal applicability and to modify it wherever necessary. At the same time, monitoring of the Seekoei River should continue in order to establish the longer-term variability of this particular non-perennial system.

**Further reading:**
To obtain the report, *Developing a Method for determining the Environmental Water Requirements for Non-perennial Systems* **(Report No: TT 459/10)** contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; E-mail: orders@wrc.org.za; or Visit: www.wrc.org.za