WATER RESEARCH COMMISSION

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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

Water and the environment

Non-perennial rivers

A completed Water Research Commission (WRC) study tested a methodology to determine the Reserve of non-perennial rivers

Background

The WRC funded three previous projects focusing on the environmental water requirements (EWRs) for non-perennial rivers. This latest project tested the Arid-Photo EWR method on the Mokolo River – a semi-permanent river, and developed a revised method, namely the Drift-Arid method.

Research into the development of a non-perennial EWR method started in 2005 using the Seekoei River (a non-perennial southern tributary of the Orange River) as a case study. Results from the study showed that the interaction between groundwater and surface water is of critical importance in non-perennial rivers, and probably also in perennial rivers, and that the methods used to determine the EWR should take this into consideration.

It was further found that the existing standard hydrological models are inadequate for describing and predicting the hydrology of the full spectrum of non-perennial rivers (episodic to semi-permanent). Licenses for the abstraction or release of water in these rivers would therefore have to be based on a specific understanding of the ecology of non-perennial rivers and a hydrological model that can address surface and groundwater interaction.

Due to the shortage of hydrological and ecological data on non-perennial rivers it is difficult to determine the reference/natural ecological conditions in the rivers being studied. It was therefore decided, by the team, that an approach beginning with present day (as most specialists have data for the present) was needed.

Overcoming the dearth of data

It was also evident from the study on the Seekoei River that monthly flow data were insufficient to capture the variability of flow in non-perennial rivers and that daily flow data should be used for hydrological modelling.

The social and economic aspects of the catchment were also deemed important and needed to be included in the method. Keeping the abovementioned aspects in mind the team involved in the Seekoei River case study examined current EWR methods used in South Africa, namely Ecoclassificiation, DRIFT, and HFSR and found that the DRIFT method included all of the aspects mentioned above and could possibly be used and modified where necessary.

A prototype EWR method for non-perennial rivers, called Arid-proto, was then developed using the Seekoei River as case study.

Mokolo River study objectives

The main objective of this WRC study was to test the Arid-proto method for non-perennial rivers on a variety of non-perennial rivers in South Africa.

The Arid-proto method was improved and adapted as the project progressed and a revised DRIFT-Arid method was developed using the Mokolo River as case study.

Drift-Arid method

The DRIFT method is based on capturing specialist knowledge of a specific catchment in a structured database that is then used to determine the ecological and socio-economic impacts of a future development scenario, or range of scenarios on the river or site.

The available discharge record of gauging weirs in the river is used to determine the degree of perenniality and if the river is a non-perennial river, the DRIFT-Arid method could be followed. Catchment data are collected and used to delineate homogenous units (Combined Response Units – CRUs) in terms of natural and management aspects. These CRUs are the prioritised and the most important CRUs are chosen which would represent the units that specialists regard as important in terms of their specific disciplines.

According to the level of EWR determination and the budget available, sites are then chosen in the most important CRUs. These sites represent the whole CRU and should have the characteristics which are dominant in the CRU.

Once sites are chosen, the team complete their specialist studies. The data collected by the specialists is used to determine the present ecological state (PES) for the site, which is used as the basis from which change in the specific discipline under different scenarios is determined.

Data collected in each discipline needs to have links to flow or water depth. Specialists also identify indicators which are variables that can be expected to respond to changes in flow or water levels. They should cover the main physical, chemical, biological and social aspects of the river ecosystem, including issues of interest of concern to stakeholders where possible.

For non-perennial rivers, it is suggested that the list of indicators should be short and, with trial and error, possibly generic for all such rivers. The indicators chosen as well as links between indicators (driving and responding indicators) are incorporated into a DRIFT-Arid DSS.

Planned future scenarios for the catchment or sites are identified using data from the stakeholders, the DWA and any other relevant reports. An integrated (surface and groundwater) hydrological model is used to simulate the hydrology for each scenario chosen and these data are used to determine the values (means and standard deviation) for the hydrological and hydraulic indicators chosen.

The values for each chosen scenario are entered into the DRIFT-Arid DSS. These data are automatically incorporated into the individual discipline datasheets and they are then sent to the specialists.

Each specialist now draws Response Curves for each indicator and links chosen for each site. Response curves describe how a responding indicator will respond to a driving indicator.

Each specialist data entry file is pre-populated, with a list of flow indicators, the particular indicators for the discipline, and other standard information such as site and scenario names. The summary statistics (values from the hydrological simulation) for the driving indicators are incorporated in the Response Curve as present day median value, range and standard deviation. Each Response Curve describes the relationship on the assumption that only those two indicators are changing, with the rest of the ecosystem remaining unchanged.

A seasonal time series for each indicator under each scenario is built up (in the DRIFT-Arid DSS) from the Response Curves and the time-series of input values for each discipline. Also produced in the DSS in each specialist file are various summaries, including an annual time series.

Specialists now have to calibrate their particular Response Curves input by using hydrology data from three fictitious scenarios that are also included in the DSS. The 'all' wet scenario includes values from the wettest years throughout the time series so that it appears as though the river has wet years throughout.

The 'all dry' scenario includes values from the driest years throughout the time series and the 'combined wet and dry' scenario includes values from the wettest years for half of the time series and for the driest years flow for the remaining half of the time series.

Once all the response curves have been calibrated and returned to the modeller, the DRIFT-Arid DSS is run and results indicating the impact of all scenarios chosen on each discipline as well as on the combined disciplines are produced. This is then presented to the stakeholders and the DWA so that they can decide which scenario is acceptable.

The output to the DWA on the specific management options for each scenario has not been finalised and needs to be researched in a future project with the input from prominent hydrologists, geohydrologists, DWA officials, hydrological modellers as well as staff involved in actual implementation of the Reserve.

A possible solution is to set up a real-time hydrological model such as MIKE SHE and then to implement the Ecological Reserve on a day to day basis but this would need highly specialised modellers to run.

Key features in the DRIFT-Arid method

The key features of the DRIFT-Arid method are:

- A structured GIS-based approach to determine the homogenous units (CRUs) in the catchment based on catchment characteristics. The input of all specialists is included.
- Site selection process is streamlined and sites are chosen that represent the most important units in the catchment. Here all specialists input are also included and not only input from then hydrologist and biologist. Sites represent the habitat, biotopes and socio-economic characteristics of the homogenous unit.
- New flow (and hydraulic) indicators are included in the DRIFT-Arid DSS which are relevant for non-perennial systems and the indicators can be switched off (not included) if they are not relevant for a specific site.
- Weighted (as opposed to un-weighted) lag periods have been created, such that more recent results have a greater influence than those further in the past (now also incorporated in DRIFT) and
- Links within disciplines have been included (already in DRIFT and pilot tested in the Mokolo River).
- An integrated surface and groundwater hydrological model is used to simulate the hydrology for each chosen scenario.

Evaluation of the DRIFT-Arid methodology

Overall the team was satisfied with the output from the DRIFT-Arid model and the resilience of the model where a different indicator for different types of rivers or sites could be used, i.e. the method does not restrict the specialists to use a specific type of biotype (stones in current) or indicator (sensitivity of riffle dwelling taxa) but provides the opportunity to choose relevant indicators.

The use of the present day situation as a baseline is also suited to the data-scarce non-perennial rivers as most specialists have knowledge of the present day situation but do not always have knowledge of the reference condition of the site or river.

The structured process of selecting sites worked well, and using GIS to determine the CRUs provided a process which was each to follow, although an experienced GIS specialist needs to be included in the team.

The main difficulty in the suggested DRIFT-Arid method is the integrated surface and groundwater hydrological modelling. Several problems were identified in applying the MIKE SHE model to the Mokolo River catchment, namely:

- It is a model that requires a large dataset and data for non-perennial rivers are few. The results from the MIKE SHE model, however, could be used in a non-perennial river, and it has the advantage of being a real-time model which can be improved as data are collected. An approach that would be possible is to first develop a simple, non-data intensive integrated model (MIKE SHE LIGHT) using easily obtainable data and then to increase complexity if and where needed.
- It was difficult to calibrate the model to periods of no-flow, likely due to a combination of irrigation issues (lack of accurate data), topographic resolution/accuracy and also because the model cannot distinguish between surface and subsurface flow so cannot accurately pinpoint times of cessation of surface flow. DHI therefore had to post process the data obtained from the MIKE SHE model to produce the zero flows observed in the gauging weir data.
- The calibrated model largely reproduced the long-term, regional-scale flow behaviour observed in the Mokolo catchment. Particularly in the groundwater, the lack of observations and field data meant that the simulated groundwater response was only generally correct.
- The model generally reproduced the expected direction of changes in flow associated with the scenarios chosen. However, the absolute magnitude as well as the relative magnitudes of change were less certain given uncertainties in model inputs and the difficulties with non-perennial conditions.

The DRIFT-Arid DSS could provide the comparison between the chosen scenarios and the team was generally satisfied with the output.

Conclusions

The WRC-funded research on EWR have contributed tremendously to the knowledge of the ecological functioning of non-perennial rivers, and the testing of a method to determine the EWR for non-perennial rivers.

The DRIFT-Arid method developed in these projects is based on DRIFT which was developed by Southern Waters for use in perennial rivers. The DRIFT-Arid method was used with success in the semi-permanent Mokolo River but is not recommended for use on all non-perennial rivers until it has been tested on an episodic river to verify its applicability for use. It is possible that only thresholds for pools in non-perennial rivers should be determined instead of using a traditional EWR method as applied in perennial rivers.

Hydrology is one of the main drivers of the DRIFT-Arid method and the importance of groundwater in non-perennial rivers was emphasised in two previous WRC projects. A first attempt at using an integrated surface and groundwater hydrology model (MIKE SHE) was included in the current project.

An important output of the MIKE SHE modelling of the Mokolo River catchment was the identification of data gaps and the implications of this for reliable modelling. It also highlighted the type of data that should be prioritised in the data collection process. The sensitivity of the integrated model to vegetation (especially riparian vegetation characteristics), subsurface and soil data emphasises the need for more studies in these disciplines.

The calibrated MIKE SHE model largely reproduced the long-term, regional-scale flow behaviour observed in the Mokolo catchment. Particularly in the groundwater, the lack of observations and field data meant that the simulated groundwater response was only generally correct.

The network of dikes and faults probably compartmentalises the regional groundwater flow system, which could not be simulated in the current model. This may partly explain the difficulty in simulating non-perennial flows, since groundwater baseflow is likely a very local process.

The calibrate model had difficulty simulating some peak flow responses. This can also be attributed to the lack of sub-daily precipitation data and the lack of information associated with instream weirs and farm dams.

In data-scarce rivers it would probably be easier to model the hydrology than in a data-rich system where data are inaccurate, but calibration is difficult if not impossible if gauging data are not available. In systems with sparse data, the modeller could use climate data as a surrogate for gauge data.

A recurring theme in all projects where hydrology is modelled is the lack of accurate data. This needs to be addressed and in South Africa where functioning gauging weirs are scarce alternative methods need to be developed to collect data on flow.

Further reading:
To order the report*, Testing a methodology for environmental water requirements in non-perennial rivers: The Mokolo River Case Study* (**Report No. TT 579/13**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.