October 2013
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 resource management

Delineating river network quinary catchments for South Africa

A WRC-funded study aimed to create a smaller-scale hydrological unit boundary for improved integrated water resource management.

Background

Nested hierarchical catchments or hydrological unit boundaries are being used as planning units in planning, management and implementation decision-making in water resources. In South Africa, these catchments, which are endorsed by the Department of Water Affairs (DWA), range from primary through to secondary and tertiary, with the smallest operational unit being the quaternary catchment. Until very recently, the latter was the finest spatial level of data resolution.

Substantial datasets and information are linked to these scaled catchments. Manual catchment delineation which was subjective, error-prone, costly and time-consuming preceded automated catchment extraction or mapping within geographic information systems (GIS).

Nested hierarchical catchments are employed in a wide range of applications. However, these studies have often highlighted the need for sub-quaternary scale information, i.e. catchment delineation at a scale smaller than the quaternary level. This stems from the fact that quaternary catchments are fairly large topographical units within which the physiography can be highly heterogeneous. Because runoff to rainfall responses are non-linear, any quaternary catchment interpolation to finer resolutions would yield hydrologically incorrect results.

Sub-delineation of catchments

At present, sub-delineation of catchments is taking place piecemeal, both locally and internationally. This is problematic because consistent and standardised methods and protocols are lacking, and conflicting boundary extractions hinder data sharing and comparison of assessment and monitoring information. The usage and implementation of final products are also challenging because of a lack of government (and other) authority agreement or endorsement.

This project was initiated to produce a fifth level quinary catchment GIS layer with linked hydrology for which the pre-cursors were altitudinal and river network quinary catchments. These catchments originated from three WRC-funded projects.

A nationally accepted quinary catchment layer is an important first step in operational decision-making and general coordination. In addition, reliable hydrological data at the appropriated scale (in this case the quinary catchments) is essential for hydrological modelling and integrated water resource management.

Methodology

The boundaries of quaternary catchments were refined in an aligned WRC project. The river network quinary catchments delineated in this project are defined as nested hydrological catchments around the river reach of the 1:500 000 DWA river network and major dams.

The following rules guided the delineation of the river network quinaries:

- Quinaries were nested with the DWA quaternary catchments
- Every quinary contains a 1:500 000 river segment, defined as the stretch of river from the source to a tributary, or from a tributary to another tributary
- Quinary catchments which did not contribute to the runoff for the estuary mouth were merged into a catchment which drains to the coast

- Quinary catchments were delineated for entire primary catchments even if they extended beyond the borders of South Africa, and then clipped to the border of South Africa based on the DWA quaternary catchments
- Quinary catchments were delineated so that catchments can be modelled upstream of major dams.

The quaternary catchments were built as walls into the digital elevation models (DEMs) used to delineate the quaternary catchments in ArcHYDRO. The DEMs were exported as geotiffs into GRASS 6.4.2 and r.watershed was used to delineate various scale catchments. An exterior basin threshold of 5 000 cells was used to create a river network quinary catchment GIS layer with an average area of 30 km^2. A larger exterior basin threshold was, however, used for topographically flat catchments. The river network quinary catchments were cleaned up in ArcGIS so that a quinary catchment was delineated along the 1:500 000 river reach code, particularly along the coastal primary catchments of South Africa.

The report also discusses the methodology used in creating altitudinal quinaries and the methodology used to assign daily hydrological data to those. The methodology used to transpose the daily hydrological data to the river network quinaries is given for the following hydrological information: daily rainfall values; daily minimum and maximum temperatures; daily values of solar radiation; daily vapour pressure deficit; daily reference potential evapotranspiration; hydrological soils attributes and hydrological baseline land cover attributes.

Results

One of the major constraints in generating a river quinary GIS layer is the rule that the catchments need to be generated around the 1:500 000 river reach. The 1:500 000 river network GIS layer is not spatially consistent in terms of detail and scale of mapping.

It was originally generated for cartographic purposes and, as a result, there are complications using it to generate river network catchments around the river reach. Despite the 1:500 000 rivers being burned into the DEM, the catchments derived always required significant manual GIS cleaning. In some cases, where the pour points obtained from DWA were manually moved, the generated catchments from the geographic resources analysis support system aligned very poorly with the borders of the updated quaternary catchments.

Three primary catchments were selected for the purpose of reporting on the river network quinary catchments. Summary statistics are given for these catchments and compared to characteristics of the NFEPA sub-quaternary catchments, which represents a precursor GIS layer of river network quinary catchments for South Africa, generated for the National Freshwater Ecosystem Priority Area (NFEPA) project. For the three primary catchments, the number of river network quinaries compares favourably with the number of NFEPA sub-quarternary catchments.

For operational modelling of many elements of Integrated Water Resource Management, hydrological simulations need to be undertaken at daily time steps. Diurnality encapsulates, albeit not perfectly, many hydrologically related processes (e.g. evaporation, transpiration and many discrete rainfall and related stormflow events). Furthermore, many operational decisions are made according to daily conditions (e.g. irrigation, tillage, reservoir operations).

There are, however, two other major reasons for promoting daily time step modelling/ the first is the availability of data, with South Africa having approximately 1 800 stations with over 40 years of rainfall records. Secondly, daily time step models provide a vast array of potential and realistic and, in the context of the National Water Act and integrated water resource management (IWRM), highly relevant output which monthly models do not. The advent of quality controlled daily integrated radar and satellite derived rainfall values is likely to improve distributed hydrological modelling in South Africa, with major benefits to many facets of IWRM.

Conclusion

Significant progress has been made in developing skills to automate the delineation of nested sub-catchment boundaries for South Africa, stemming from:

- The release of the updated quaternary catchments GIS layer and associated ancillary GIS layer;
- Piloting of different software packages and rules for sub-catchment delineation within this project.

In addition, the project team has harnessed much knowledge that has been developed over the years through related WRC projects on how to scientifically develop estimates of daily hydrological, daily climatic, soils and land cover data, and summarise these into different sub-catchment boundaries.

The river network quinary catchments build successfully on the knowledge and lessons learnt during the delineation of sub-quaternary catchments for the NFEPA project. The river network quinary catchments delineated in this project are defined as nested hydrological catchments around the river reach of the 1: 500 000 DWA river network and major dams.

A key recommendation is that up until the quinary level, the nested hierarchical catchments are watershed delineated, but at the sixth catchment level, altitudinal catchments are useful as they reflect the relatively homogenous hydrological response zones, based on elevation and thus changes in rainfall, soils, land use and with that changes in runoff. The concepts of the methods for altitudinal and river network quinary catchments need to be used as a point of departure for a follow-on project and be used to produce a merged layer of relatively homogenous response zones (in terms of hydrology, soils and land use).

As a standalone layer, the altitudinal quinary catchments and the river network quinary catchments are limited in their application, but if the layers are merged they can form a powerful tool for many applications around water resource planning and management, and assessment of ecosystem services.

The confidence that can be afforded to the hydrological data is highly dependent on the proximity of the rainfall stations to catchments, as well as effective monitoring of trends at the rainfall stations. Strategic decisions need to be taken on which rainfall stations are a priority to maintain in the South African monitoring network of stations, as well as to identify potential gaps in the network where new rainfall stations should be sited.

Endorsement and naming conventions need to be established to facilitate the attachment of additional research data. Additional data sets can be taken into account, especially those currently collected at a quaternary level, for example, alien vegetation, FEPAs, ecosystem service data, and baseflow data.

Further reading:
To order the report, *Delineating river network quinary catchments for South Africa and allocating associated daily hydrological information* (**Report No. 2020/1/12**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za, or Visit: www.wrc.org.za to download a free copy.