GEOHYDROLOGICAL CONCEPTUALIZATION FROM A REMOTELY SENSED SIMPLIFIED WATER BALANCE IN THE SANDVELD, SOUTH AFRICA

Zahn Műnch[1], *Lesley A. Gibson*[2]

[1] CGA – Centre for Geographical Analysis, Stellenbosch University, Private Bag X/1, Matieland, 7602, zmunch@sun.ac.za
[2]Geohydrological and Spatial Solutions (Pty) Ltd, P.O. Box 12412, Die Boord, Stellenbosch, 7613, lgibson@geoss.co.za

1. INTRODUCTION

The Sandveld (Western Cape, South Africa), located on the Cape West Coast, is characterized by low rainfall and minimal river flows, however despite this limitation, significant aquifer systems are found [1]. The groundwater in the region supports extensive agriculture and supplies towns with water for domestic use. The use of remote sensing can influence the way in which groundwater resources can be managed despite the fact that it is a subsurface resource and therefore cannot be directly measured by remote sensing techniques. The G30F catchment in the Northern Sandveld is reported to be experiencing water stress due to increasing abstraction for domestic water supply and agriculture, particularly potato crops. As suggested by Brunner et al [2], we propose the use of the simplified water balance determined from remote sensing data to estimate recharge and discharge zones within the catchment. Furthermore, we propose that this method is a useful aid in the geohydrological conceptualization of this particular water system. Of particular interest is the use of the recently released MOD16 evapotranspiration (ET) data product together with a precipitation data product, highlighting the ease with which studies of this nature can now be executed.

2. STUDY AREA

The study area, quaternary catchment G30F (780 km^2 in area), extends from an elevation of 1312 m in the east and is drained by the non-perennial Langvlei River which terminates with the Wadrif pan against the Atlantic Ocean coast in the west. Situated in a winter rainfall region, the area experiences coastal fog and low unreliable rainfall averaging 285 mm/a [3]. Water resources in general and groundwater in particular, have been extensively mined for a considerable period of time since the late 1970s [4] with significant land clearing for potatoes (irrigated) and rooibos tea (dryland). Domestic water for Leipoldtville and Lambert's Bay are also extracted from this catchment. Geology plays a major role in controlling geohydrological conditions: located in

the catchment is the Wadrif primary aquifer which delivers high yielding boreholes (>5L/s), but the thick sands (>90m) make the flow paths and recharge mechanisms difficult to characterize. Geological faults within the Table Mountain Group with permeable bedding planes result in significant high quality groundwater from the secondary aquifer. Based on groundwater level responses to upland recharge; mixed groundwater chemistry signatures; and isotopic compositions, it is believed that there is a significant degree of interaction and mixing between the primary and secondary aquifers [5].

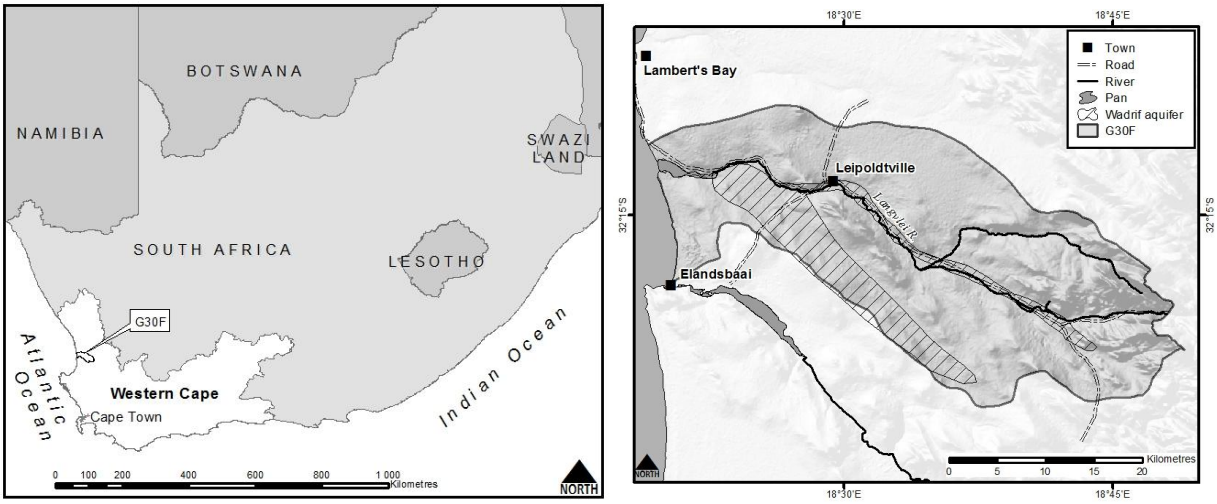

Figure 1: Location of the study area, the G30F catchment.

3. MATERIALS & METHODS

The research methodology is based on a simplified water balance. The difference between precipitation (P) and actual evapotranspiration (ET) is indicative of recharge or discharge over a period of time based on catchment average values [2] for a quaternary catchment. Due to the semi-arid nature of the study area, the surface runoff can be regarded as negligible. Thus the standard water balance equation for this semi-arid catchment can be reduced to a simplified water balance:

$$\Delta S = P - ET$$

Based on this assumption, catchment P and ET from existing earth observation data products are calculated independently of each other and are used to determine the water balance for the study period (July 2006 – June 2007).

The ARC-ISCW decadal rainfall grid is a data product created from downloaded satellite rainfall data from the African Data Dissemination Service and automatic weather station rainfall data [6], which are combined and

interpolated to create a 1 km rainfall grid representing precipitation for a ten day period across South Africa. Each grid identifies the actual decadal rainfall total in mm at a 1 km resolution, whereas the resolution of the original satellite rainfall estimate is 8 km. These data were summed to obtain the total rainfall over the study period.

The MOD16 ET products are regular 1-km^2 global land surface ET datasets for vegetated land areas at 8-day and monthly intervals [7]. The ET products are created using MODIS global landcover (MOD12Q1), a daily meteorological reanalysis data set from NASA's Global Modelling and Assimilation Office, and MODIS biophysical parameters (albedo[1], Leaf Area Index[2] and Enhanced Vegetation Index[3]) as input into the Penman-Monteith equation. The MOD16 data product (mm per month) [7] at a resolution of 1km was downloaded (ftp://ftp.ntsg.umt.edu/pub/MODIS/Mirror/MOD16/) for the study period and summed to determine an annual ET amount for the catchment.

4. RESULTS

The results of the summed catchment precipitation for the study period reveal a catchment average P of 294 mm and a catchment average ET of 222 mm for the study period resulting in a catchment average P-ET of 72 mm. This result suggests that for the study period, the catchment received more water through precipitation than was lost through evapotranspiration and that in the catchment as a whole (without taking into account water exported from the catchment for domestic supply to Lamberts Bay to the North), recharge occurred. To identify particular recharge and discharge zones within the catchment, the P-ET of each pixel in the catchment is shown in Figure 2. It is apparent that distinct zones of recharge and discharge can be delineated in this catchment with the highest recharge occurring in the mountainous regions in the east. This can be contextualized with existing literature on the hydrogeology of the area. Contrary to literature reports, this catchment does not appear to be experiencing water stress.

[1] Global 8-day standard MODIS surface reflectance product (MOD43C1)
[2] Global 8-day standard MODIS Leaf Area Index (LAI) product (MOD15A2)
[3] Global 8-day standard MODIS Enhanced Vegetation Index (EVI) product (MOD13A2 EVI)

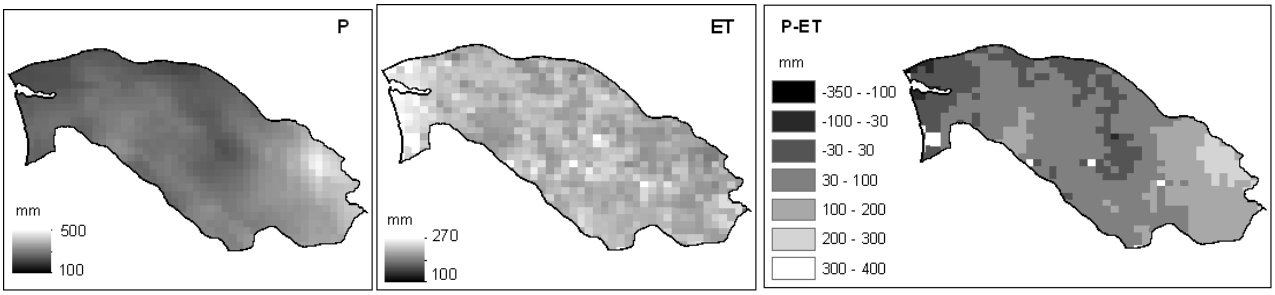

Figure 2: Catchment G30F showing the results in mm for the study period (July 2006 – June 2007) for precipitation (P), evapotranspiration (ET) and recharge (P-ET).

5. CONCLUSIONS

The final paper will provide the geohydrological context for the results of the remote sensing based simplified water balance. In addition, the validity of the results will be discussed and a validation of the precipitation and the ET results will be presented. It will be concluded that there is scope for this method to be expanded across the Sandveld however, analysis of plant water source via isotope analysis will be recommended before the method can be fully endorsed.

6. REFERENCES

[1] CapeNature, Groundwater Assessment of the North-West Sandveld and Saldanha Peninsula as an Integral Component of the Cape Fine-Scale Biodiversity Planning Project. Component 5.1, Fine-scale biodiversity planning. Consultancy Report submitted by GEOSS to CapeNature. November 2006. Cape Town, 2006.

[2] P. Brunner, P. Bauer, M. Eugster and W. Kinzelbach, "Using remote sensing to regionalize local precipitation recharge rates obtained from the Chloride Method", *Journal of Hydrology*, vol. 294, pp. 241–250, 2004.

[3] B.J. Middleton and A.K. Bailey, Water resources of South Africa, 2005 STUDY (WR2005). WRC Contract K5/1491. Water Research Commission, Pretoria, South Africa, 2008.

[4] GEOSS, Sandveld preliminary (rapid) reserve determinations. Langvlei, Jakkals and Velorenvlei Rivers, Olifants-Doorn WMA. Volume 1 – Reserve Specifications. DWAF project number 2002-227. May 2003. Stellenbosch, 2003.

[5] GEOSS, Groundwater Reserve determination required for the Sandveld, Olifants Doorn Water Management Area, Western Cape, South Africa. Prepared for the Department of Water Affairs and Forestry, Pretoria. Prepared by GEOSS, Stellenbosch, 2006.

[6] ARC-ISCW, Ten Daily Rainfall Estimate Grids. Grid metadata, 2005.

[7] Q. Mu, F.A. Heinsch, M. Zhao and S.W. Running, "Development of a global evapotranspiration algorithm based on MODIS and global meteorology data", *Remote Sensing of Environment*, vol. 111, no. 4, pp. 519–536, 2007.