IMPORTANT NOTE RE REPORT 1428

Should the Ms.Word-files for this report ever be required in future, please remember that this report was submitted in 12 separate files. File 1428#3 (the file for Chapter 2) is incorrect in the sense that the figure numbers are incorrect and could not be changed in Word. All have been corrected in the PDF.

Page 2-50 and 2-59, although displaying correct as landscape setting in Word, does not print as that in PDF. The printers were requested to use the Word-format of these two pages in the printing process.

R Sutton
0 7/09/2009

METHODS AND GUIDELINES FOR THE LICENSING OF SFRAs WITH PARTICULAR REFERENCE TO LOW FLOWS

Report to the
Water Research Commission

by

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Acknowledgements

This project was born from a realisation that the low flow components used in assessing stream flow reduction activity license applications was in need of review and refinement. By initiating the project, the Water Research Commission (WRC) enabled a process of scientific discussion across several relevant sectors, from which coordinated action for further research as well as governance issues could take place. We are most grateful to the WRC as well as the representatives of the various government departments and research agencies that participated so constructively in this project.

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Executive Summary

Introduction

This project arose in response to a realisation that the low flow components used in assessing stream flow reduction activity license applications was in need of review and refinement. This was an issue that was raised as a concern in a previous report by Gush et al. (2002) and which became clearer as the tools developed in that project were applied in the assessment of SFRA license applications. Furthermore, there is increasing concern regarding the potential for large scale land use change, and associated potential water resources impacts, driven by various factors, most notably the need to improve livelihood security through improved dryland crop production through methods such as runoff harvesting and conservation agriculture and the recent interest in large-scale biofuel production.

Thus, the aims of this project considered the need to improve the existing modelling tools for hydrological analyses of land use change, but also the need to develop management protocols to utilise these. A Terms of Reference for a solicited project was drawn up by the WRC and subsequently the research contract was awarded to a consortium led by the School of Bioresources Engineering and Environmental Hydrology at the University of KwaZulu-Natal.

Summary of Project Achievements

The various project aims have been achieved through a number of approaches as detailed below.

The incorporation of an intermediate soil zone and consideration of the hillslope, together with improved evaporation estimates through consideration of canopy resistance using the Granier-Lohammer approach have provided for improved estimates of low flows and the impact of these by forestry with the ACRU model. This improved low flow routines in the model should only be applied when detailed analysis and planning are required as the input parameters of soil depth, hillslope length and canopy conductance are not readily available.

Improvements in national scale estimates of water use by SFRAs and sugar cane have been achieved through the application of the School of Bioresources Engineering and Environmental Hydrology's Quinary Catchments Database. Through the integration of this database with a new software system known as the SFRA Assessment Utility, improved and more spatially representative information regarding rainfall, soils, potential evaporation and baseline vegetation are provided, leading to more spatially explicit estimates of water use with less uncertainty than those previously available.

Consideration of evaporative water use in the form of Green Water Flows may provide a useful approach to the consideration of assessing whether a land use should be considered an SFRA or not. Two approaches to estimating Green Water Flows, one for the measurement of evaporation in the field using a large aperture scintillometer, and another utilising remote sensing data, were assessed for future use as described in Chapter 5. Both these technologies are considered very useful for future assessment of SFRAs. However, a key message is that the tools applied to estimate the water use of SFRAs must match the accuracy required

by the decision-maker to the spatial and temporal scales of the assessment. A framework to guide the decision-maker in this regard and in the consideration of Green Water Flows has been developed and is described in Chapter 4 and in a separate project deliverable, i.e. Guidelines for licensing SFRAs. At the inaugural workshop for this project, many stakeholders highlighted a concern that the SFRA assessment procedures used by DWAF were not compatible with those in determining the Reserve, leading to extensive delays in the processing of SFRA license applications. Through the approach described in Chapter 4, the SFRA and Reserve assessment procedures have been aligned. Extensive training of DWAF personnel in these procedures was undertaken as detailed in Appendix III.

One of the most significant areas of uncertainty in estimating the water use of SFRAs is the uncertainty associated with the baseline against which SFRAs are quantified, whether using national scale WR90 or ACRU based Acocks estimates. This is an area where further research is critical, if uncertainties arising in the estimation of water use by SFRAs are to be reduced.

An study of water use by sugar cane highlighted that the use of “exchange ratios” to facilitate a change in land use from sugar cane to forestry or vice versa by a land owner, is problematic and needs far more detailed analysis before being supported as a management tool. Sugar cane was shown to be a significant water use in some inland catchments, but not on the coastal areas.

Evaluation of Objectives

The original Terms of Reference for this project listed 11 objectives for this project. Following the inaugural workshop of the project, an additional aim, i.e. the consideration of “Exchange Ratios” as a water resources management tool was added. The following table lists the project objectives together with a brief summary of the project products, and an evaluation of the extent to which these have been met.

Table 1. Summary of project objectives and the extent to which the project has achieved them.

1	To re-analyse, and improve upon, conceptual modelling methods and input data utilised in WRC project K5/1110 (Estimation of stream flow reductions resulting from commercial afforestation in SA). This will entail:	A large part of the research effort in this project was spent on developing an improved conceptualisation of the hydrological processes which influence the generation of low flows and the development of routines which describe these. Focus was on soil water movement in the sub-surface and on improved conceptualisation of evaporation, transpiration and their relationship with root water uptake as detailed in Chapter 3.
a.	*Consideration of alternative methods for calculating low flows and selection of the most appropriate one (e.g. driest three months vs. flows below the 75th percentile),*	Tools to analyse streamflow at daily, monthly and annual timesteps are available through a software package known as the SFRA Assessment Utility. This allows the user to use the low flow index most applicable to the task at hand. Default options are for annual Flow Duration Curves or exceedance tables based on daily flows.
b.	*Use of the latest baseline vegetation descriptors in terms of model input parameters,*	A method for aligning output from ACRU modelling baseline estimates with those of the WR2005/Pitman approach is described in Chapter 4.
c.	*Use of more detailed catchment descriptor parameters (e.g. soils, rainfall, altitude data) in a distributed form as opposed to a lumped form,*	The use of the recently developed Quinary Catchments database allows for better resolution input for all ACRU parameters as described in Chapters 4 and 6. The improved routines for low flow simulation require detailed biophysical input in catchments and catchment delineation can continue from the hillslope scale.
d.	*Better accounting for the full storage capacity of the soil profile and the year-to-year carry over of water storage or usage (i.e. annual amounts of water used in evaporation not to be limited by annual rainfall), and*	Revised ACRU routines are described in Chapter 3. An additional (intermediate) soil layer has been introduced and options for lateral flow of water within the soil profile have been developed.
e.	*The reconsideration of methods used for the derivation of confidence limits from the above project, and the incorporation of these into the proposed guidelines.*	This aspect of the project has been dealt with indirectly through the various improvements to the model. A qualitative assessment amongst stakeholders highlighted "moderate-high" confidence that the important impacts of the impact of land use change on the hydrological cycle are known, but low confidence that these are adequately represented and parameterised in the existing hydrological models.
2.	Analyses of different flow components (quickflow, interflow, baseflow & groundwater discharge) to determine how these are affected by afforestation and by dry and wet cycles as well as the determination of the relative importance of the flow components between catchments and the impacts of afforestation on the flow components.	This aspect of the research is described in detail through various forms of analysis of time series from the South African paired catchment experiments. Various hydrograph separation methods are applied and both statistical and graphical analyses were undertaken. An additional output is the development of a suite of statistical models to describe the impact of afforestation in these catchments as an addition to those developed by Scott et al., 2002. Detailed analyses of data from Cathedral Peak and Jonkershoek in particular, but also other catchments have highlighted the relative importance of quickflow and delayed flows in the flow regime as well as the role of the soil as a buffer in delaying catchment response. These findings are reported in Chapter 2 and were used as input to the conceptualisation of the new flow generation routines.
3.	Through these analyses, and with input from related process study research, to improve the simulation of low flows in the ACRU Agrohydrological Modelling System through improved conceptualisation of low flow generation processes and the translation of these into model code.	Improved routines to simulate soil water movement and evaporation and transpiration from forests are described in Chapter 3. The applications of the improved routines to the Weatherley and Two Streams catchments are described. Process studies from available research catchments have highlighted the importance of considering the evaporation and transpiration processes in different vegetation types. Consequently, the Grannie-Lohammer modifications for the Penman-Monteith equation have been incorporated into the ACRU model and model parameter values suggested as described in Chapter 3.

4.	To devise and implement a process whereby research and management needs are pursued in parallel in order to ensure optimal applicability and useability of the products of SFRA related research. This necessitates tours of all the regional DWAF offices in SA which license forestry, to try and identify exactly what the software outputs from this project should look like and how they will most effectively complement the license application procedure.	The research team has maintained close contact with DWAF, their consultants as well the sugar and forestry industries throughout this project. Through these interactions the concerns and requirements of these stakeholders has been considered and tools and recommendations arising from this research have been shaped by them. In addition, the project Reference Group includes representatives from all these groups, as well as other researchers.
5.	To provide a link between researchers involved in hydrological process studies of the effects of land use change on low flows (e.g. WRC Projects K5/1061 [Weatherley] and K5/1284 [Two Streams]), and managers and other Interested and Affected Parties involved in this field. The objective is to demonstrate the value of process-based research and how it complements water resource based legislation and decision-making.	This has been achieved through close collaboration with the CSIR and the consultants to the DWAF SFRA sub-directorate. Model routines have been tested at two of the country's active research catchments. Development of SFRA assessment tools and training in the application of these tools has been undertaken in collaboration with Water For Africa as described in the Capacity Building report in Appendix II. The inclusion of findings from the Weatherley and Two Streams research catchments have highlighted their importance in providing hydrological understanding on which the conceptualisation of the new ACU routines was based. The use of a large aperture scintillometer to estimate dryland sugar-cane described in Chapter 5 use further highlighted the importance of sound field based research.
6	To refine the guidelines for dealing with scale and resolution in the quantification of SFRs developed by Ninham Shand and the University of Stellenbosch.	This is an aspect of the project that has been addressed through the framework described in Chapter 4, although this does not explicitly address the issues raised by the Ninham-Shand study. The application of the revised ACRU model at large spatial scales is described through an application of the model to the "nested" Weatherley_Mooi River catchment system in the Eastern Cape as described in Chapter 5.
7	To provide guidelines for the potential declaration of additional SFRAs (e.g. Jatropha curcas or Bamboo), with recommendations regarding licensing if necessary.	Guidelines for the consideration of other land uses which may eventually be declared SFRAs are provided in Chapter 4. In essence, the guidelines recommend a "Green Water" approach for the identification and declaration of additional SFRAs and a "Blue Water" approach to their regulation. Broad scale tools such as SEBAL or soil water budget based evaporation estimation models are recommended for identification and declaration of SFRAs, while land use sensitive distributed hydrological models are recommended for the regulation of SFRAs at appropriate management scales.
8	To develop and implement in DWAF regional offices, and existing CMAs, a Decision Support System and associated guidelines, to assist in hydrological assessments for the consideration of water use licence applications (for forestry, being the only declared SFRA).	In collaboration with Water for Africa, a methodology for the assessment of SFRAs by DWAF (Regional Offices, SMAs, etc.) has been developed. User guidelines have been established and training undertaken. This aspect is detailed in Appendix III.
9	To ensure the compatibility of Reserve determination methodologies and the results thereof with SFRA and other water use estimates and available hydrological information through consideration of specific months and daily flow records for various assurance of supply levels	A methodology for the consideration of the Reserve when assessing SFRA license applications has been developed and training material in this regard has been developed and delivered through collaboration with the Institute for Water Research, Rhodes University and Water for Africa. The process for consideration of the Reserve is described in Chapter 4 and training in this approach in Appendix III. The SFRA Assessment Utility is a user-friendly software tool that has been developed and is designed to integrate with existing Reserve planning tools and uses a SPATSIM compatible database for storage of SFR information.

10	To test these products through the application of the guidelines in at least four catchment case studies.	The framework described in Chapter 4 requires a wider range of tools than originally envisaged. Consequently, a wide range of products in addition to ACRU based estimates of SFR have been applied. These include the SEBAL and Penman-Monteith based methods for estimating total evaporation. The application of these in various catchments is described in Chapters 5 and 6 of this report.
11	To improve the research capacity in South Africa in the field of land use hydrology and Integrated Water Resources Management and the skills of water resources managers involved in water use licensing, particularly SFRAS.	Both undergraduate and postgraduate students have made significant input to this project. Training to DWAF personnel responsible for the management of SFRA licensing has been provided. Both of these aspects are detailed in Appendix II.
12	To conduct preliminary investigations into Exchange Ratios, Area Exchanges and Environmental Taxes within the licensing process. These would include considering changes from an SFRA land use to an alternative land use (e.g. sugar cane, kikuyu pasture, tea plantation, etc.), and the trade implications thereof. This task will be complemented by process-based (scintillometer) research into the water use of dryland sugarcane in the KZN midlands.	The usefulness and application of "Exchange Ratios" is discussed in Chapter 4 as part of the framework for the consideration of SFRAs in water resources management and planning. In recent years, the use of large aperture scintillometers has been found to provide for accurate estimation of total evaporation from land surfaces at a range of spatial scales. For full details of the method, the reader is referred to the recent WRC report K5/1335 by Prof Mike Savage and colleagues. The School of BEEH purchased a large aperture scintillometer in 2004. This has been be used in several projects, including an MSc project undertaken by Mr Luke Wiles and a PhD project by Mr Victor Kongo (see capacity building report), both of which form part of this research project. In this component, field measurements using the scintillometer to provide estimates of total evaporation as well as soil moisture measurements are utilised to provide improved estimates of water use by sugar cane, a potential SFRA as well as other land uses, in selected sites in KwaZulu-Natal. The scintillometer study and an additional study on the water use of different land uses where the remote sensing technology, SEBAL, is applied are described in Chapter 5.

Capacity Building

The project team fostered capacity building activities within the University whenever possible. In the end the project served 2 PhDs, 1 Masters, 5 Honours and 2 Others. Seven out of these 10 students were South African Citizens, two African (Kenya and Namibia) and one European (UK). 70% of the students are specialised in Hydrology, the others in Civil Engineering. Full details are provided in Appendix II.

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