DEVELOPMENT OF A SEMI-DISTRIBUTED CATCHMENT HYDROLOGY MODEL FOR SIMULATION OF LAND-USE CHANGE STREAM-FLOW AND GROUNDWATER RECHARGE WITHIN THE LITTLE RIVER CATCHMENT, NSW

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This paper outlines how PhD research was developed to investigate the ability of a rainfall-runoff, recharge-discharge model to accurately simulate the hydrology of a catchment at various scales. Catchment attributes are utilised to obtain values for conceptual model parameters. This way modelling can take place in an ungauged catchment without the need for stream gauge data to perform calibration. Two hydrological models were used as a starting point for model development. These were a lumped conceptual rainfall-runoff model (IHACRES) (Jakeman & Hornberger 1993) and a physics-based conceptual groundwater discharge model (Sloan 2000). The modelling aims to appropriately disaggregate the catchment in order to improve on previous catchment or sub-catchment hydrology models, so that hydrological modelling can be carried out at the management scale.

SCALE OF CATCHMENT DISAGGREGATION AND MODELLING

To disaggregate the catchment into meaningful hydrological units requires manipulation of a Digital Elevation Model (DEM) using a number of steps within a Geographic Information System (GIS). These steps include (in order): estimation of flow direction and flow accumulation surfaces; stream links based on a threshold flow accumulation; and, stream ordering. Once the stream orders were determined, outlet points are estimated based on the maximum flow accumulation of each stream order link. Using these outlet points sub-catchments are created for each stream order. Modelling can then take place based on 1^{st}, 2^{nd}, 3^{rd} or 4^{th} order sub-catchments.

Within these sub-catchments it was seen as favourable to form hydrological response units (HRUs), in which all water passes directly to the stream. This was seen as important so that individual soil-vegetation combinations within these HRUs can be connected or unconnected on a hill-slope. In this way the level of model hydraulic connectivity may be further tested and/or model complexity may be reduced. This reduction in model complexity centers on whether the lateral movement of water from one unit to another on a hill slope is included in modeling. The units in the model have their own catchment moisture store (deficit) and supply recharge and lateral flow directly to the aquifer and the stream respectively. It is hoped that the sum of these management units effectively characterise the hydrologic response of each HRU within each sub-catchment.

Each sub-catchment is required to be comprised of three units to ensure all the water from each unit passes directly to the stream. These are the left, right and headwaters of the stream. To form these units the locations of stream dangling nodes were used as outlet points in the formation of new sub-catchments. By joining these new sub-catchments with the streams and original sub-catchment coverage, new units were formed that represented the left, right and headwaters of each stream. Figure 1 illustrates the formation of these hydrologic response units in each sub-catchment and the soil-vegetation-management units within them.

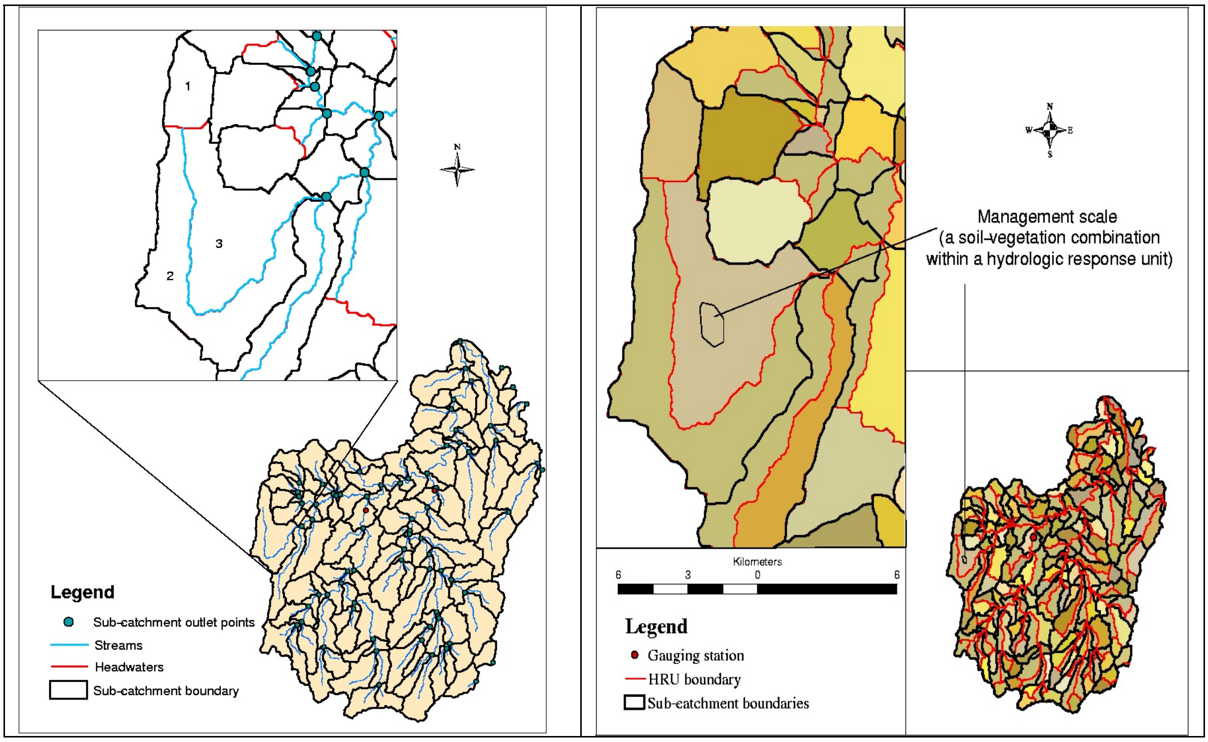

Figure 1: Illustrating the development of sub-catchments by defining left, right and headwaters

MODEL DEVELOPMENT

The IHACRES model consists of two modules: a non-linear loss module to convert rainfall to excess rainfall; and, a linear module to convert effective rainfall to stream-flow. Effective rainfall is defined as the rainfall that is not lost to evapotranspiration and is therefore available for stream-flow (Post & Jakeman 1996). The non-linear loss module uses temperature and rainfall to estimate a relative catchment moisture store index. This in turn determines the proportion of rainfall that becomes excess rainfall. Unit hydrograph approaches are used to identify the quick flow (runoff) and slow flow (base flow) components.

Although the IHACRES model identifies a base flow component it is spatially lumped and does not take into account the heterogeneous nature of groundwater aquifers, or their storage and discharge characteristics. If we were able to estimate recharge, however, it would be possible to feed this recharge into a groundwater model which takes into account the varying properties of aquifers. Figure 2 shows the conceptualization of the IHACRES model joined with a groundwater discharge model (Croke *et al.* 2002, Sloan 2000).

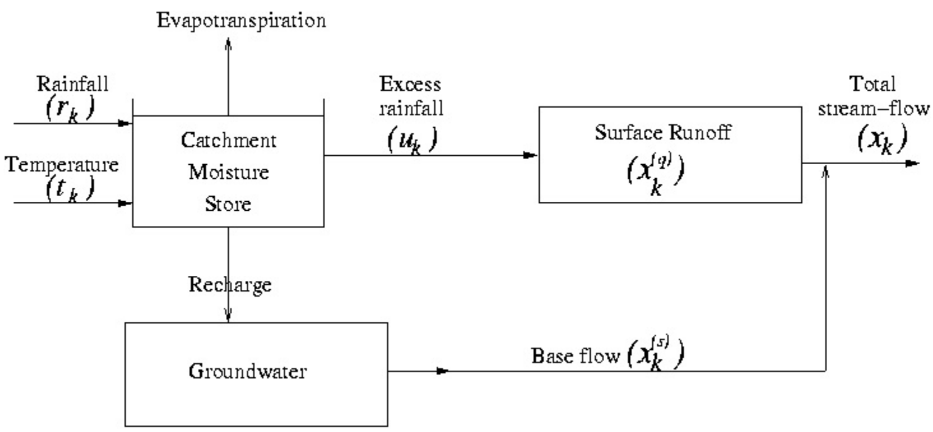

Figure 2: Conceptualised IHACRES model including groundwater recharge.

ESTIMATING TRANSPIRATION AND RECHARGE

Evapotranspiration and recharge were estimated by utilizing a Soil Water Infiltration Model (SWIM). SWIM uses numerically efficient solutions of Richard's equation for water flow in a one-dimensional heterogeneous vertical soil profile to simulate runoff, infiltration, redistribution, plant transpiration, evaporation, deep drainage and leaching (Verburg *et al.* 1996). By modeling the hydrological response of various vegetation types on different soil types, relationships where identified for input into a semi-distributed catchment hydrology model. Figure 3 shows the transpiration drying curves for various vegetation types on a sandy soil. From these curves it was possible to identify the potential transpiration rate, profile moisture content (when water becomes limiting) and an equation describing the reduction in transpiration following periods of no rainfall. Similar relationships for recharge were also identified for all vegetation-soil type combinations and utilized in the model.

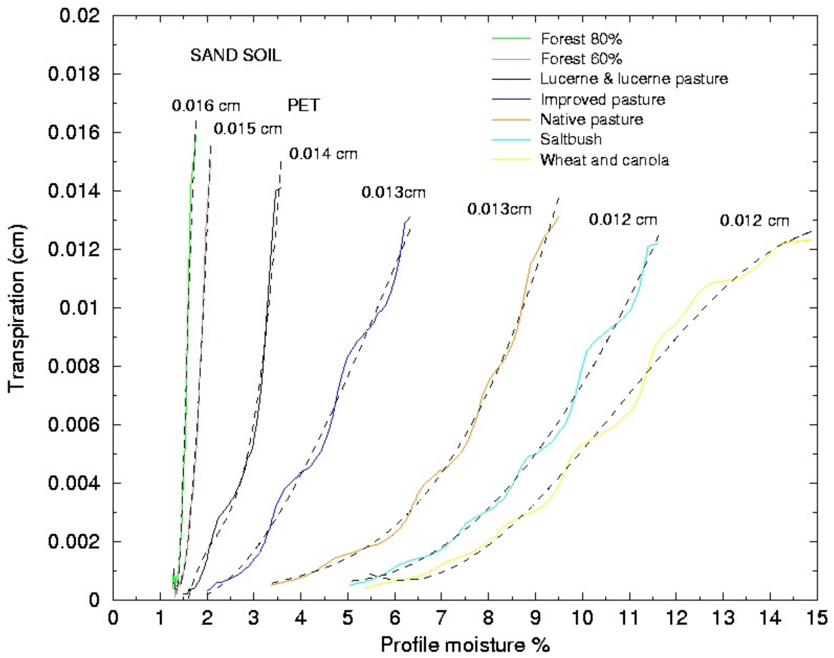

Figure 3: Modeled and actual transpiration drying curves for various vegetation types within the study area.

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