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An integrated water resource management tool for the Himalayan region

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Abstract

The Himalayan region of Nepal and northern India experiences hydrological extremes from monsoonal floods during July–September to periods of very low flows during the dry season (December–February). While flooding causes significant damage to local populations and infrastructure, the lack of water during the dry season impacts people's agriculturally based livelihoods. Furthermore, competition for water for irrigation, domestic supply, industrial uses and hydropower is at a maximum during the dry season. Successful management of water resources is dependant on an ability to balance the natural availability of water with the pressures exerted by water-users. A software system has been developed to assist water resource practitioners in the region to meet these goals. The software incorporates regression-based hydrological models that enable long-term average monthly recession flows to be estimated in ungauged catchments. Recessions are the periods of successively decreasing flows that occur during the dry season. Users are able to compare predicted flows with observed flows recorded at gauging stations. The impact of existing and future water use scenarios on dry season flows can be simulated by characterisation of seasonal water use at points within the catchment. The user-friendly interface is Geographical Information System based, providing the ability to add contextual spatial data to enhance the application of the conceptual model. Standard display and output formats provide a consistent set of reporting tools. This paper describes the components of the system and presents a case study implementation in the West Rapti catchment (Nepal).

Keywords: Recession curve; Low flows; Water resource management; Software tool; Regionalisation; Himalaya; FRIEND

1. Introduction

Successful water resource management involves balancing the needs of a wide range of water-users with the needs of the environment. Integral to the process is a requirement to be able to assess the availability of water in a given catchment. A recent review of international catchment management organisations identified the assessment of water availability as a key issue for the development of successful and sustainable integrated water resource management (Walmsley et al., 2001). Furthermore, there is a need to separate the natural from the anthropogenically influenced flow components to enable assessments of the impact of water use to be examined. Final management decisions are driven by a combination of local, regional and national policies, such as the European Water Framework Directive (2000/60/EC) or the South African Water Act 1998, environmental needs and the

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requirements of local stakeholders and water-users. Several such national policies from around the world are described by Letcher and Giupponi (2005).

In Northern India and Nepal agriculture is a major water-user. Irrigation water is required for food crops (rice, wheat, maize, barely, millet and pulses) and fodder crops grown for livestock (buffalo, cattle, sheep and goats). Irrigation tends to be restricted to the plains and lower to middle mountain areas (approximately <1500 m) with rain-fed agriculture dominant at higher elevations (Tripathi and Sah, 2001). Rapid population growth rates, in excess of 2% per annum, in this region have caused accelerated development of land for agriculture to grow food crops and generate income. Over the last 30 years, a 10–25% increase in agricultural land area of the middle mountain area of Nepal has occurred (Collins et al., 1999). Consequently, water supply systems associated with agricultural development have been placed under increasing pressure to meet the rising demands of irrigation. Sixty percent of farmers surveyed from the middle mountains of Nepal stated that a lack of irrigation was the main constraint to agricultural production (Brown and Shrestha, 2000). There is a real need to manage water resources in the region more effectively to ensure the sustainability of agriculture and the security of local people's livelihoods.

The FRIEND project (Flow Regimes from International Experimental and Network Data) of the UNESCO International Hydrology Programme is an international framework for the implementation of hydrological research, which aims to improve the scientific and technological basis for the development of regional methods for the management and development of water resources (CEH-Wallingford, 2002). As part of the Hindu Kush-Himalayan (HKH) FRIEND, a project was established to prototype a software tool which would assist water resource practitioners to assess both the natural availability and impact of water use in ungauged catchments and hence improve the development and management of surface water resources in the region.

2. Background

In gauged catchments, water availability assessments are made using the flow data recorded at the gauging station. However, in many instances such assessments are required for catchments where no gauging station exists. The issue of assessing the natural availability of water in ungauged catchments is faced by water resource managers all over the world. Typically, it is addressed by the development of regional models, which estimate the flow statistics required for the assessment process, using catchment characteristics as explanatory variables. The models are commonly in the form of regression equations, for example, the low flow models developed by Nathan and McMahon (1992) for application in Australia and those developed by Gustard et al. (1992) for estimating mean flow and flow duration statistics in the United Kingdom (UK). Ries and Friesz (2000) developed both regression models and models incorporating observed data from index catchments to estimate flow statistics. Recently in the UK, Holmes et al. (2002) developed data-based techniques which estimate flow duration statistics for an ungauged catchment, based on recorded statistics in similar catchments, where similarity is based on hydrogeological characteristics.

In the Himalayas, a number of regional models for predicting the availability of water resources have been developed to enable the hydropower potential of ungauged catchments to be assessed. The Water and Energy Commission Secretariat of Nepal produced the "WECS" method for estimating flow duration statistics in ungauged catchments in Nepal using linear regression-based models (WECS, 1990). In northern India, Singh et al. (2001) developed regional flow duration curves for nine regions in the Himalayas for the purpose of planning micro-hydropower projects. Other models for estimating flows at ungauged sites in the region include those developed by Alford (1992) relating annual specific discharge and catchment elevation; and the statistical relationships between runoff and glacial cover developed by Braun et al. (1993). Delft Hydraulics (1995) used observed recession behaviour to calibrate slow flow drainage coefficients in a two-layer Sacramento rainfall runoff model.

The regionalised flow estimation method developed by Rees et al. (2002) enables flow duration curves to be predicted using catchment characteristics in Himachal Pradesh (India) and Nepal. These hydrological models were deployed within the HYDRA hydropower estimation software system, to enable consistent, rapid desktop assessment of the small-scale hydropower potential of prospective catchments to be made. Globally, the development of software tools for water resource management purposes has been shown to be important to enable the effective uptake of scientific research by the user community. In South Africa, the desktop reserve model described by Hughes and Hannart (2003) is used to estimate in-stream ecological flow requirements. In the UK, the Low Flows 2000 software system is used widely for water resource assessments (Young et al., 2003).

This paper describes a prototype, planning-level software tool that provides water resource practitioners with rapid, consistent and reproducible estimates of natural water resource availability in Himalayan catchments. Hydrological models, developed as part of the HKH-FRIEND project, were implemented within the system to provide the underlying estimates of natural flows during the post-monsoon recession period.