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Managing Catchment Inflows using Real-time Flow Forecasting

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Abstract: The Sydney Catchment Authority (SCA) protects and manages catchment areas, which provide water to greater Sydney and communities locally in the catchments. The catchments occupy about 16,000 square kilometres in total and extend from north of Lithgow and Blackheath in the upper Blue Mountains, south to the source of the Shoalhaven River near Cooma, and from Woronora in the east to the source of the Wollondilly River near Crookwell. The prediction, measurement and management of flows in a large and variable catchment such as this is a challenging task. The SCA has recently installed a GIS based real-time flow monitoring and in-flow forecasting system aimed at providing detailed baseline information for supporting the daily operation of the SCA's storages. A key feature of the system's success has been the ability to integrate existing hydrologic models and automate their operation with measured data real-time to produce real time forecasts of catchment inflows in the short to medium term.

Keywords: Flow forecasting; GIS; hydrological models

1. Introduction

The Sydney Catchment Authority (SCA) is a NSW Government agency created in 1999. Its task is to manage and protect Sydney's catchments and supply bulk water to its customers, which include Sydney Water and a number of local councils.

These customers then treat the water and distribute it to households, businesses and other users. Over four million people, or about 60 per cent of NSW's population, consume water supplied by the SCA.

Water has been vital to the survival and prosperity of Sydney since the first days of the new colony. The need to ensure a reliable water supply through times of drought and erratic seasonal rainfall has driven the development of several complex and innovative water supply systems.

Five catchment areas are under the protection of the SCA. The catchments as illustrated in Figure 1 are:

- The Warragamba Catchment;
- The Upper Nepean Catchment;
- The Woronora Catchment;
- The Blue Mountains Catchment; and
- The Shoalhaven Catchment.

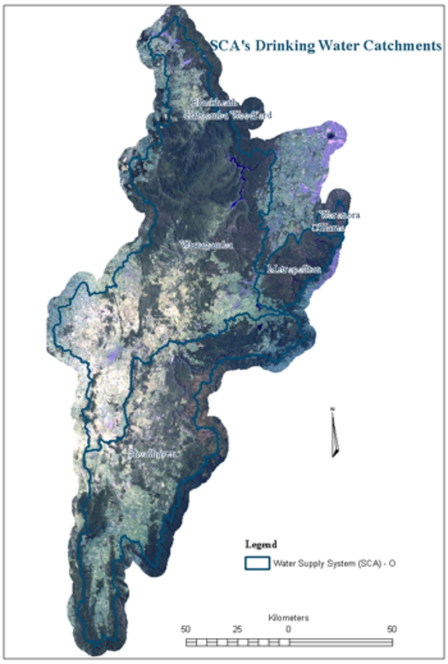

Figure 1: Overview of SCA Catchments

The catchments occupy about 16,000 square kilometres in total. They extend from north of Lithgow and Blackheath in the upper Blue Mountains, south to the source of the Shoalhaven River near Comma, and from Woronora in the east to the source of the Wollondilly River near Crookwell.

Management and operation of the storages is a complex process. Operational decisions affecting the management of the storages are made on a daily basis and require accurate and up to date information.

2.0 Review of Flow Management Decision Support

The characteristics of the SCA's catchments in terms of topography, land use, vegetation and soils etc vary considerably over their 16,000 square kilometre area. The variability of the catchment characteristics coupled with the considerable spatial variability of rainfall typically experienced over the catchment makes the prediction of catchment inflows at any point in time a considerable challenge.

The remoteness of much of the catchment area has limited the amount of catchment subject to detailed flow gauging. The SCA operates a telemetered data system for rainfall and flow data supplemented by hydrological modelling to determine the source, volume and timing of catchment runoff to the storages.

A review of the existing decision support process for storage operation identified several areas that could be improved.

2.1 Telemetered Data Collation and Review

The SCA's hydrometric network presently includes 278 hydrometric stations: 97 stream gauging stations, 142 rainfall stations, 19 thermister chains and 20 others. Approximately 50% of the hydrometric stations can be remotely accessed through singular or multiple telemetric links established through wireless radios and telephone connections.

The availability of the telemetered data network has resulted in automation of data transmission, collection and recording. To ensure the quality of data collected, experienced hydrographers visit the stations regularly to service the stations, undertake site maintenance and minor repairs and verify the data by making independent spot measurements.

Telemetry access to nearly 50% of the stations has not only facilitated the access to real time data, but also to frequent monitoring of station health. Collected data is quality checked by hydrographers for accuracy and reliability. In some instances data is edited to effect minor data corrections, and add comments and quality codes before archiving. The progressive installation of telemetered stations, with the most appropriate and up-to-date technology adopted in each phase has resulted in an overall system composed of several different telemetry systems with varying data delivery mechanisms and data formats.

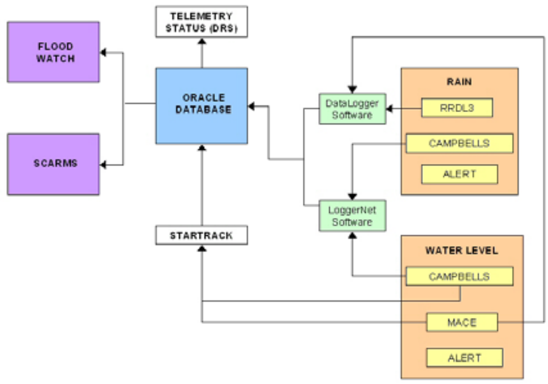

Figure 2: SCA Telemetry System

A brief description of the telemetry system and methods of telemetry access is given below:

- **Phones lines** to 135 stations are available. They consist of 118 PSTN connections, 6 GSM connections and 11 Satellite phone connections.
- **Startrack** provides access to 27 stations. Under the Startrack system, Data Collection Platforms at hydrometric stations transmit data through satellite technology to the ground station in Western Australia and the data is electronically transferred to a service provider and then to SCA computer network via the Internet.

Telemetry data obtained through the above means are disseminated through a number of ways for operational and regulatory purposes:

Daily Return System (DRS): A system based on the SCA's Intranet accessing data obtained through SCADA, ALERT, Startrack and telephones. Data are also manually entered when visual observations are made.

SCARMS: An SCA Reservoir Management System mostly dedicated to monitoring data of lakes and real-time modelling.

2.2 Hydrological Modelling

The SCA has developed a number of HSPF rainfall-runoff models over the SCA's catchments. These models enable the SCA to predict the volume of runoff generated by potential rainfall events over the catchments, where detailed real-time gauging does not provide the level of information required for operational decision making.

In their current state these models are held in an independent stand-alone structure making them inconvenient to operate. The daily process of accessing the latest available rainfall data and manually entering the data, simulating the models and processing the results is time consuming and labour intensive.

The difficulties experienced in processing data and simulating hydrological models in separate systems lead the SCA to investigate a more robust and integrated system.

3.0 Real-time Flow Forecasting System

The system adopted for integrated data assimilation and hydrological model simulation is DHI Water and Environment's MIKE Flood Watch.

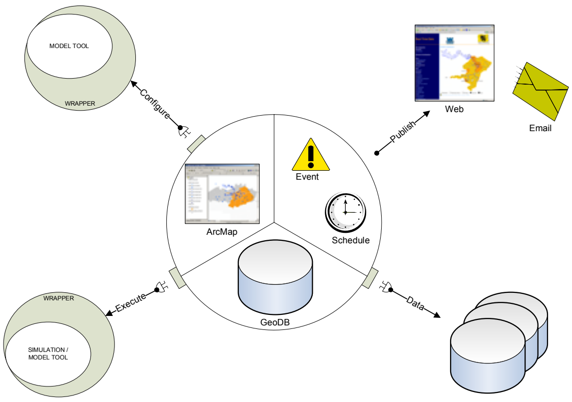

Figure 3: MIKE Flood Watch System Overview

MIKE Flood Watch is a tool for monitoring real-time data as well as running models. The system interfaces between external sources (SCADA system, internet etc), the internal database, the configured models and the output locations.

The system has a GIS front-end (ArcGIS by ESRI) for the daily operation and configuration. Once configured most procedures are conducted automatically through scheduling of tasks to carry out. Everything is configurable in a Windows environment.

The system allows for scheduling of tasks such as automatic execution of data import and model tools.

The alarm framework of MIKE Flood Watch offers the possibility of the system to react to incoming data and different system states. A response to an alarm is to carry out another pre-defined task, which could be any number of relevant tasks such as: run another model simulation, send an email, publish data etc…

3.1 Integration with Real-time Telemetered Data

MIKE Flood Watch imports the real-time telemetered data from the SCA database at regular intervals.

The data is used for different purposes in the SCA:

- Monitoring. During import, the data is validated against defined thresholds for the different locations and if a transgression has occurred the system will alert the staff by issuing an email with a status report;
- Modelling. The data acts as input to Hydrological Models;
- Visualisation. After the import, another task will create a series of predefined web pages with tabular data output and time series plots, thus updating an intranet site with the latest information.

The interface between MIKE Flood Watch and the database is a custom made script, which has the integrated logic to extract the required data from the database to port into MIKE Flood using a standard data interface.

The data types used in the SCA system are:

- rainfall;
- evaporation;
- water level/flow rate;
- storage water levels;
- storage volume; and
- spill.

During the import the data is also adjusted to produce 24 hour accumulated rainfall of hourly values. The data is validated against defined valid ranges allowing only data suitable for use in the model suite to enter the system.

3.2 Integration of Existing Hydrological Models

The SCA has used the public domain modeling software HSPF for hydrological modeling for some years.

Through a custom made model "wrapper", the MIKE Flood Watch system is able to configure input data time series and then execute this model.

Models covering two of the five SCA catchments mentioned above have been configured into the Flood Watch system; Upper Nepean and Shoalhaven.

Coupled with the most up to date gauged rainfall data and a rainfall forecast, MIKE Flood Watch can be used as a predictive tool for flow forecasting.

The built-in data hierarchy of MIKE Flood Watch allows for specification of a range of different rainfall forecast scenarios, which SCA staff use in turn operationally to forecast potential inflow scenarios to the storages. The forecast scenarios have been designed to assist SCA staff to make informed decisions regarding the storage operations. Flood Watch automatically simulates the catchment models for the forecast scenarios and presents the model forecast outcomes in the GIS interface for ease of interpretation.

Observed data and model simulation results are also published on the intranet, allowing for easy inspection from anywhere within the organisation.

4.0 Planned Extensions for the Real-Time System

The SCA plans to extend MIKE Flood Watch by incorporating the new real-time radar-derived rainfall estimation product, RAINFIELDS. This program has been developed at the Research Centre of the Australian Bureau of Meteorology (BOM) and is designed to produce quantitative radar estimates of rainfall information, in georeferenced grids, in real time.

The updated version of MIKE Flood Watch will have a built-in support for dfs2 animations.

Integration of RAINFIELDS and the new updated version MIKE Flood Watch will enable the SCA to:

- animate the radar image time series inside ArcMap;
- create maps overlaid with the radar data;
- extract point time series to be used as other rain gauge data; and
- aggregate data across catchment.

For flood forecasting purposes the BOM uses the latest radar image in an auto-regressive model to push the rainfall forward in time, advecting the different scales to produce the forecast accumulations. Such a radar based forecast allows assessing up to one hour ahead, where to expect rainfall and which intensity the rainfall is likely to have.

This spatial rainfall forecast is planned to be integrated with the flood forecasting system set up within MIKE Flood Watch to provide real-time flow forecasting.

5.0 Conclusions

The integration of real-time telemetered data and hydrological models using a common interface has greatly enhanced the efficiency, timeliness and quality of flow prediction for the SCA's storages.

This flow monitoring system provides the SCA with multiple levels of notification during flood events in accordance with water supply needs and regulatory requirements. Both the monitoring and predictive information produced by the model enables more immediate responses to operational and flood type incidents.

Also, in drought times particularly, the model is an invaluable tool for operational planning to help the SCA manipulate and configure the water supply system to optimise system yield.

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7.0 Acknowledgments

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