Final Report from Partners and Cooperative Project

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Partners or Cooperative Project: COMET

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SECTION 1: PROJECT OBJECTIVES

The objective of this operational research study was to determine the point of diminishing returns between the quality and quantity of input data and a given threshold for the quality of the model output. The point was sought where model output quality was no longer increasing with an increase in the quality and quantity of data input. As the amount of input data was increased there was likely to be a nonlinear increase in model performance. St-Hilaire *et al.* (2003) showed that denser networks more accurately quantify precipitation estimation. At some point, the increase in performance should diminish with increased input data. Operationally this is significant with the finite financial constraints inherent in operational hydrology, and raises the question of how the operational community can gain the greatest improvement in model performance for the least amount of financial investment.

An interesting aspect of this project was the quantification of the combined quantity and quality of the input data. In flat terrain a plot of simulation accuracy versus number of gages should show a clear relationship as to how simulation results deteriorate as the number of gages was reduced. However, in the mountains it is not only the number of gages but their elevation that will determine the simulation results. The effect of each variable on the simulation results were tested by reducing one network, e.g. temperature, while leaving the other network, precipitation, the same. Theoretically temperature was a more conservative data type (i.e. has less spatial variation) than precipitation. Reducing the temperature network by a certain amount should have less of an effect on the results than a reduction in the precipitation network by the same number of stations. It was expected that different statistics could be necessary to qualify the effects of degrading the network for each variable; while temperature primarily affects the timing of snowmelt, precipitation primarily affects the volume of snowmelt.

SECTION 2: PROJECT ACCOMPLISHMENTS/FINDINGS

The quality and quantity of hydrometeorological data (temperature and precipitation) that are used as input to the National Weather Service River Forecast System (NWSRFS) hydrologic model were varied and the output was compared to observed historical flows. The NWSRFS was calibrated to model a portion of the snowmelt dominated Yampa River watershed in northwest Colorado using all available station data (15 stations) for a 17 year period (1984-2001). The main calibration factors for this base case were the snow correction factor, which was increased to reduce the overall snow accumulation in the basin, and the melt factor parameter, which was lowered to delay the peak snowmelt runoff, in essence broadening the hydrograph.

An analysis scheme was followed to capture the model's dependence on representative meteorological stations located in an around the modeled basin. Mean areal precipitation and temperature values for the modeled zones were developed individually in each analysis scheme by the arrangement of stations used in each sensitivity analysis. Specifically the different analysis schemes were 1) the geographic snow dependence sensitivity which used a) the six stations with the highest annual average precipitation (Tower SNOTEL site, Marvine Ranch, Steamboat Springs, Marvine, Pyramid, Hamilton), b) the five stations having the lowest annual average precipitation (Browns Park, Rangely, Dinosaur, Maybell, Massadona), c) the three stations that are located within the basin boundaries (Tower SNOTEL site, Steamboat Springs, Yampa), and d) data from the six closest stations (add Hayden, Craig, Hamilton to c); 2) the model sensitivity to quantity of stations which started with the base case and reduced the number of stations by eliminating the further station until only 1 station remained; 3) the rainfall event sensitivity to two events (late May, 1997 during the height of snowmelt runoff and September 15-18, 1997), and 4) the mean areal temperature effect on snow.

A statistical analysis of the relative difference between simulated and observed streamflow was performed. Results from the different schemes varied as the precipitation for each scheme was adjusted to the long term average precipitation, yielding a compensation for under and over-estimates. Overall, the average baseflow was underestimated in the winter and fall months while the peak streamflow associated with snowmelt was simulated well (Figure 1). Individual hydrographs did vary more than the 17-year average monthly hydrographs (e.g., Figure 2). Statistics summarizing these streamflow variations are pending. Initially reducing the number of stations decreased the simulated runoff volume. With less than eight stations the net runoff volume then increased until there were five stations. The simulated volume remained constant until there were two stations. With only one station, the volume was the least of any combination.

For the first rainfall event, reducing the number of stations used resulted in a larger over-estimation of streamflow. For the second event, the hydrographs were delayed, yet very similar for all station scenarios (Figure 3).

Disregarding the higher elevation station in estimating the mean areal temperature yielded an earlier peak in the snowmelt hydrograph. This is expected as the temperature was increased. Snow water equivalent (SWE) for the three different elevation zones were compared to observed SNOTEL SWE to provide insight into model results.

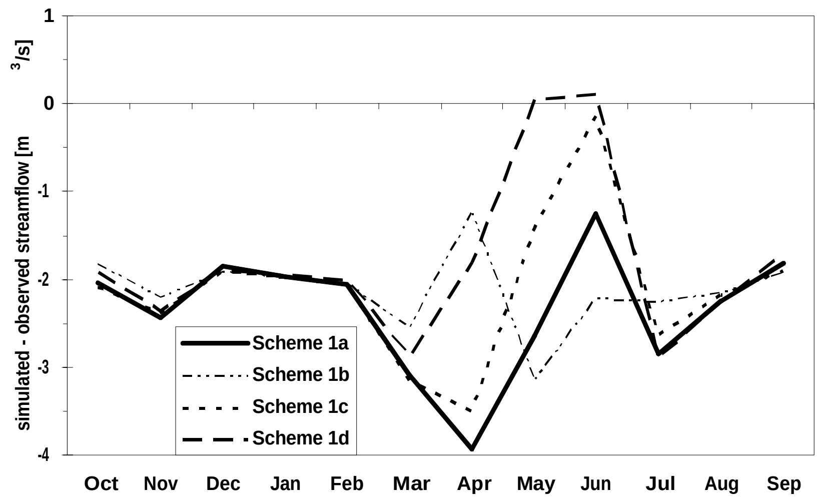

Figure 1. Difference between the 17-year average simulated minus observed streamflow for the four cases of Scheme 1 (geographic snow dependence sensitivity).

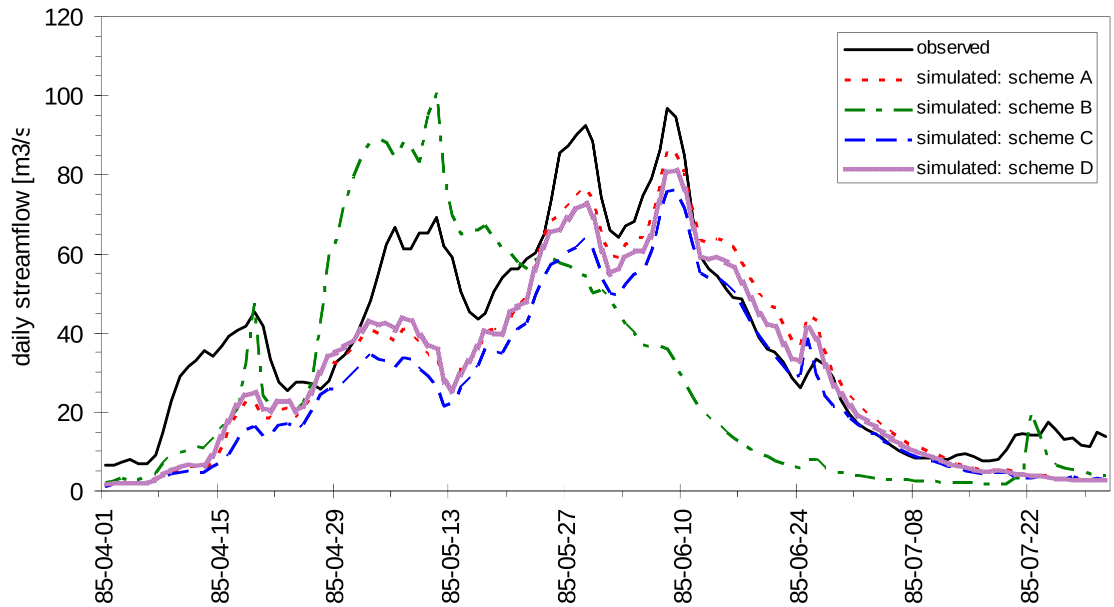

Figure 2. Simulated (schemes A to D) and observed discharge for April through July 1985.

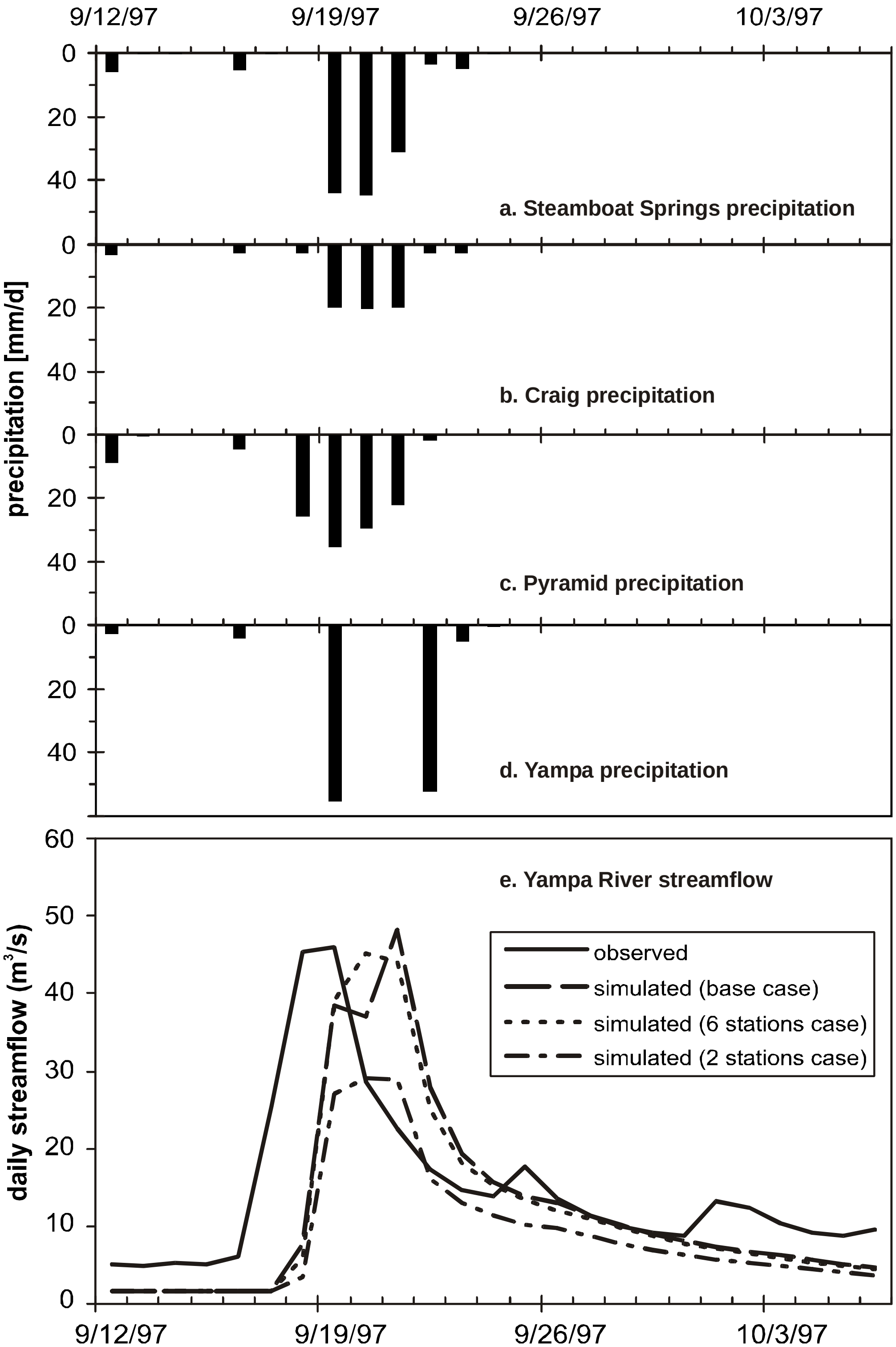

Figure 3. Precipitation at four stations and simulated streamflow for Storm 2.

SECTION 3: BENEFITS AND LESSONS LEARNED: OPERATIONAL PARTNER PERSPECTIVE

3.1 (To be completed by forecaster partner) Please list the benefits to the NWS office resulting from the collaboration (promising new forecasting technique, heightened interest in research in the office, better understanding of new observing systems, potential new hires, use of university personnel as resource, etc.). Please be as specific as possible, particularly in regard to any improvements in forecasting operations resulting from this project (see examples).

The calibration of the NWSRFS hydrologic model is a very important task at the River Forecast Centers. This study has provided guidance on the selection of gages for use in the calibration and operation of the model. A well-calibrated model results in good hydrologic forecasts. The results of the study also demonstrate the need for more gage data and allows the NWS to define a desired density of gages within drainage basins for best results.

SECTION 4: BENEFITS AND LESSONS LEARNED: UNIVERSITY PARTNER PERSPECTIVE

The student involved with the project has developed a deep understanding of the workings of the NWSRFS, and its use as a forecast tool. The project illustrated the model's effectiveness in adjusting precipitation using long term climate data and the water balance. The MS thesis presentation summarized these findings to 15 other students in attendance at the defence.

The partnership between CSU and the APRFC has developed a collaboration that will continue in the future. APRFC personnel helped with various parts of the project including provide advice where needed. The CBRFC also helped by providing model segments.

The hydrometeorological data that were collated for the project were subsequently reassembled for use in several other projects on the same basin. A second project has examined the influence of land cover mapping on the hydrology of a larger portion of the Yampa River basin, i.e., downstream to Maybell.

SECTION 5: PRESENTATIONS AND PUBLICATIONS

At present, there have been no formal publications or presentations.

The student who was funded by the COMET grant, Scott McKim, presented the results of the water balance for his study area to the APRFC in December 2004. Scott successfully defended his MS thesis on June 29th, 2005, and submitted the final version of his thesis in December (McKim, 2006). He will officially graduate in May 2006.

There are no current plans to present the work at a scientific meeting, but this will occur if convenient. The results will be submitted for consideration as a journal publication, such as the AMS Journal of Hydrometeorology or the ASCE Journal of Hydrological Engineering. A draft of this manuscript is currently being prepared.

The final thesis results will be shared with researchers at the NWS National Headquarters and River Forecast Centers.

SECTION 6: SUMMARY OF UNIVERSITY/OPERATIONAL PARTNER INTERACTIONS AND ROLES

The primary role of the APRFC and CBRFC was to support the researcher on the configuration of the NWSRFS model on the researchers' computer and on the model calibration process. The primary role of the University was guiding the researcher in the scientific aspects of the project. The University and NWS both contributed to the research in discussions of the scope, resolution of problems, and final defense of the thesis.

REFERENCES

McKim, S.D., 2006: *The Effects of Input Data Degradation on Hydrological Model Performance for a Snowmelt Dominated Watershed*. Unpublished M.S. thesis, Watershed Science Program, Colorado State University, Fort Collins, Colorado, USA, 76pp + appendices.

St-Hilaire, A., Ouarda, J., Taha B. M., Lachance, M., Bobee, B., Gaudet, J., and Gignac, C. 2003: Assessment of the impact of meteorological network density on the estimation of basin precipitation and runoff: a case study. *Hydrological Processes*, **17**, 3561-3580.