INTEGRATED FORECAST AND RESERVOIR MANAGEMENT INFORM - A DEMONSTRATION FOR NORTHERN CALIFORNIA
PHASE 1 PROGRESS REPORT

by

Konstantine P. Georgakakos, Eylon Shamir, Stephen V. Taylor, Theresa M. Carpenter, and Nicholas E. Graham

in collaboration with

Aris P. Georgakakos and Huaming Yao
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The authors wish to thank the members of the Oversight and Implementation Committee (OIC) of INFORM for their continuing guidance and support of this demonstration project. They are identified in Appendix A. The work was performed in close collaboration with the staff of the National Weather Service California-Nevada River Forecast Center, the California Department of Water Resources, and the Bureau of Reclamation Central Valley Operations. The contributions of the staff of these Agencies in data gathering efforts and in the reciprocal technology transfer process between modelers and users for this demonstration project have been numerous and are gratefully acknowledged. Thanks are also extended to the staff of the Environmental Modeling Center of the National Weather Service National Centers for Environmental Prediction. The climate and weather forecast information they provide is paving the way toward using the advanced forecast and decision components of this project in Northern California water resources forecast and management operations.

Oversight and Implementation Committee of INFORM

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EXECUTIVE SUMMARY

The Integrated Forecast and Reservoir Management (INFORM) Project was conceived to demonstrate increased water-use efficiency in Northern California water resources operations through the innovative application of climate, hydrologic and decision science. Toward achieving this goal, the particular objectives of INFORM are to *(a)* implement a prototype integrated forecast-management system for the primary Northern California reservoirs, both for individual reservoirs as well as system-wise; and *(b)* demonstrate the utility of climate and hydrologic forecasts through near-real-time tests of the integrated system with actual data and management input, by comparing its economic and other benefits accruing from current management practices for the same hydrologic events. The project is a joint effort of the Hydrologic Research Center (HRC), a public-benefit research and technology transfer corporation in San Diego, California, and the Georgia Water Resources Institute (GWRI), a federally mandated research institute at Georgia Tech in Atlanta, Georgia. HRC is the lead organization for the forecast components of INFORM and GWRI is the lead organization for the reservoir management components of INFORM. Close collaboration between HRC and GWRI, and between these organizations and operational forecast and management agencies has been established to allow effective integration of system components and to pave the way for its use in Northern California operations.

Although the integrated system being developed is prototype and contains components that are products of recent and on-going research by both developing organizations, the INFORM project is primarily a demonstration project with significant resources devoted to the implementation of the system in a near operational environment through collaborative work with forecast and management agencies. Key operational agencies for the implementation of the demonstration project are the U.S. National Weather Service California-Nevada River Forecast Center, the California Department of Water Resources, the U.S. Bureau of Reclamation Central Valley Operations, and the U.S. Army Corps of Engineers. Other agencies and regional stakeholders are contributing through active participation in project workshops and, indirectly, through comments and suggestions conveyed to the INFORM Oversight and Implementation Committee (OIC). The INFORM OIC consists of representatives from funding agencies, from forecast and management agencies with a mandate pertinent to Northern California operations, and from the developing organizations (HRC and GWRI). The OIC purpose is to provide

independent review of the development and demonstration activities, to guide the INFORM project activities toward meeting the stated project goals, and to facilitate implementation of the integrated system components in a near-operational environment. An INFORM Core Office was established at HRC that serves as the information dissemination conduit for project activities.

The technical basis of INFORM is an integrated modeling system with the following components:

(a) large-scale ensemble climate weather forecasting and assimilation;

(b) downscaling of surface ensemble forecasts for the watersheds of interest;

(c) generation of ensemble reservoir inflow forecasts based on hydrologic modeling of snow accumulation and melt and surface and subsurface water transport in watersheds upstream and downstream of the main reservoirs;

(d) generation of dynamic reservoir regulation policies and tradeoffs accounting for forecast uncertainty and all applicable water uses; and

(e) forecast and policy evaluation by assessing the economic benefits for each site and for the system as a whole.

The INFORM modeling system uses as input the operational ensemble climate and weather forecasts produced by the National Centers for Environmental Prediction (NCEP) of the U.S. National Weather Service and various parametric databases pertaining to operational hydrologic and reservoir management models. Upon completion, the forecast-decision system will provide the following outputs:

(a) ensemble precipitation and flow forecasts for key regions within the INFORM Northern California area;

(b) multi-objective trade-offs associated with each reservoir and for the entire system pertaining to inter-annual, seasonal, and operational time scales;

(c) dynamic reservoir regulation policies associated with any tradeoff selection by the management agencies; and

(d) quantitative evaluation of benefits and risks associated with various operational scenarios.

Retrospective feasibility studies with historical data that used a more limited version of this system for the Folsom reservoir showed that increases up to 15-18% in annual average energy and decreases of up to 50% in unnecessary spillage are possible without increasing flood damage and with increased water supply made available for agricultural, municipal and environmental uses. The explicit account of uncertainty throughout the forecast and management system components and the dynamic decision support component of the system are mainly responsible for the improved performance.

During this first phase of the INFORM Project, the following main tasks have been completed:

(a) design and development of a climate and weather data ingest component for operational data produced by NCEP, and downscaling of the information to scales appropriate for hydrologic modeling of reservoir inflows and downstream flows;

(b) development of an efficient precipitation downscaling model to map ensemble climate and weather information from scales of 100x100 km^2 or greater to scales of 10x10 km^2 for Northern California, and testing of the model with historical data for several Folsom reservoir drainage sub-areas;

(c) development of a stand-alone hydrologic simulation model that includes snow, soil water and channel models for producing reservoir inflow from upstream watersheds, and testing of the model for the American River upstream of Folsom reservoir;

(d) validation of operational hydrologic simulations of snow accumulation and melt and of reservoir inflow for Folsom and Oroville reservoirs and their upstream sub-areas;

(e) development and testing of a reservoir control model hierarchy including models for turbine load allocation, short range reservoir control (hourly time resolution over a period of one day), and mid range reservoir control (daily time resolution over a period of several months) for Folsom and Oroville;

(f) development and testing of an assessment model for quantifying the benefits and risks of forecasting schemes, reservoir regulation policies, and demand scenarios;

(g) development of a decision system database and user-data-model interface for easy data entry and quality control, model usage, and result presentation and archiving.

Close collaboration with operational forecast and management agencies was maintained throughout this first phase of the INFORM project. Coordination with NCEP and the NWS California-Nevada River Forecast Center (CNRFC) was essential for the design of the weather and climate data system ingest and the tests of the downscaling precipitation component. The operational flow simulation validation and the design of the stand-alone hydrologic system for INFORM was done in close collaboration with the CNRFC, while the development of the decision support system for Folsom and Oroville was performed in close collaboration with staff of the Bureau of Reclamation Central Valley Operations, the California Department of Water Resources and the U.S. Corps of Engineers. Two meetings of the INFORM OIC during this first phase ensured overall system coordination and feedback from all participating agencies, including the funding agencies.

As of the time of this writing, the targets of the first phase of the INFORM project have all been met except from the testing of the climate and weather information ingest and downscaling for historical data. This is due to the fact that the requisite historical data will only be available from NCEP in the summer of 2004. It is expected that the activities of this on-going task will be concluded some time in the fall of 2004. The present report documents the activities and results obtained in each of the tasks completed. The chapters are self contained with conclusions drawn in each, and each chapter contains its own references for convenience. Chapter 1 presents a brief overview of the INFORM objectives, plans and early feasibility studies. Chapter 2 discusses the climate and weather forecasts and the design of their ingest system. It also presents a parsimonious orographic model for precipitation downscaling over the INFORM region. Chapter 3 focuses on the hydrologic modeling activites with emphasis on the validation of the operational hydrologic forecasts for Folsom and Oroville drainages. The design of stand alone hydrologic model that mirrors the operational system behavior is also presented together with an evaluation with historical data for Folsom drainage. Chapter 3 in addition discusses ensemble forecasting using the operational ensemble streamflow prediction method and an ensemble prediction method conditioned on climate forecasts. Chapter 4 is devoted to the presentation of the design of the decision support system for INFORM and its use in Folsom and Oroville. The reservoir control model components and the assessment model are presented, and the salient features of the pertinent software are described. Several Appendices contain ancillary material and detailed data and graphical products. It is emphasized that this report pertains to the first Phase of the INFORM project. On-going work continues model development, implementation and testing with close agency collaboration in all topical areas of the project.

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