RECLAMATION

Managing Water in the West

Evaluation of Capabilities and Needs for a Platte River Advanced Decision Support System (PRADSS) in Nebraska

Nebraska-Kansas Area Office
Great Plains Region

U.S. Department of the Interior
Bureau of Reclamation
Technical Services Center
Denver, Colorado

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Evaluation of Capabilities and Needs for a Platte River Advanced Decision Support System (PRADSS) in Nebraska

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Introduction

In recent years, increased use of ground and surface water within the State of Nebraska has created concern over the management of these resources. In response to this concern, the Bureau of Reclamation (Reclamation) partnered with the Nebraska Department of Natural Resources (NDNR) to undertake an evaluation of capabilities and the need for a Platte River Advanced Decision Support System (PRADSS). The following report will summarize the goal and objectives of the study, the process taken, investigations pursued, and the results of these investigations. Finally, recommendations for future analyses will be presented to enable the development of the PRADSS.

The need for a Decision Support System (DSS) in Nebraska has been discussed for several years. Reclamation and NDNR initially provided potential study partners in Nebraska with a survey dated June 25, 2000. This survey queried stakeholders about their desires and needs for modeling the Platte River system. A follow up meeting was held on July 11, 2000 to openly discuss the needs and goals of a PRADSS with these potential study partners. These same initial stakeholders were included in these most recent evaluation efforts through a series of meetings and conference calls between April and August 2005. The agencies represented in this group are:

- Bureau of Reclamation
- Nebraska Department of Natural Resources
- Nebraska Public Power District
- Central Platte Natural Resource District
- Central Nebraska Public Power and Irrigation District
- U. S. Fish and Wildlife Service
- Nebraska Game and Parks

The exchange of information provided by these stakeholders was instrumental to complete this initial evaluation and to formulate final recommendations.

Study Goal

The goal of this study was to assist managers in optimizing water resource management in Nebraska by identifying the needs for a DSS in the Platte River basin and by recommending DSS development activities based on the needs identified.

Study Objectives

The study goal was further defined by the following specific objectives:

1. Identify needs for a Platte River DSS that are most prominent.
2. Identify secondary needs for a Platte River DSS.
3. Evaluate alternative models to address primary DSS needs.
4. Recommend an initial model for development in the DSS.

The recognition of the most pressing water resource management needs enabled the identification of potential models for use in addressing these needs. Models were evaluated against the needs of Nebraska to recommend an initial model for development under the PRADSS. Other needs that could be addressed through a DSS were also identified and are presented herein.

DSS Needs in Nebraska

The need for a DSS was initially identified through discussions with the stakeholders. These discussions led to the identification of two categories of DSS needs. These needs are broken into the Primary DSS Needs, which were highly similar and can be addressed through the development of a single, initial DSS tool or model, and Other DSS Needs, which require additional tools to address.

Primary DSS Needs

The primary need for a DSS in the Platte River basins is to assist water resource managers in:

- Determining appropriate water releases to provide the legally required or requested flows to environmental, irrigation, power, and other requirements when needed.
- Minimize excess releases beyond those legally required.
- Optimizing both short and long-term water storage releases.

As a result of the primary needs, a water availability/operations model was recommended for initial development. Several software packages are available that could be used for development of this model. A model evaluation process was discussed and undertaken to assess the specific capabilities of available software packages to meet the needs for a DSS in the Platte River basin.

Other DSS Needs

Other DSS capabilities were identified beyond those provided by a river operations model. The following identified needs can be addressed through other tools or extensions of previously developed tools that could be incorporated into the final PRADSS:

- Development of a forum for exchange of information concerning river flows and diversions.
- Development of a place where current river flows and diversions along with predictive flows are displayed (perhaps on the NDNR website).
- Closer integration of surface and ground water management.

Other needs likely exist beyond those identified here. Further investigation is needed to fully assess how to address these needs as well as identify other needs.

Initial PRADSS Model

The identification of the primary DSS needs in the Platte River basin focused on short-term management of water resources and water rights. The goal and objectives of this initial modeling effort were developed through the group of stakeholders, which led to an initial description of the model. Finally, available software packages were evaluated against the needs and capabilities specifically identified for the Platte River basin. The following discussion will summarize the results of these efforts to determine how to meet the primary DSS needs.

Goal of Model

The primary DSS needs identified were formulated into a goal for the initial PRADSS model. The purpose of the model will be to assist managers in optimizing water storage releases by projecting short-term future water availability, gains, and losses with sufficient accuracy so that environmental, irrigation, power, and other releases provide the legally required or requested flows at those times needed, and releases in excess of those requirements can be minimized.

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Objectives of Model

The primary objectives of water quantity modeling of the Platte River were outlined through questions the model will be used to answer:

- How should Lake McConaughy and any other storage facilities be operated on a daily basis in an effort to optimize operations, i.e. minimize unnecessary releases, while releasing enough water for environmental, irrigation, and power requirements, as well as any other legally required releases or requested flows?

- How much water should be released at North Platte on an hourly basis to achieve a given flow at Grand Island (or at any other locations?) during a specific time period?

- What streamflow conditions are anticipated at Grand Island or any other downstream location given the current releases from Lake McConaughy and baseflow conditions?

- How much "environmental" water is available under wet, dry or normal target flows and if conditions change?

- How much should offset projects be managed to add sufficient water to the river to eliminate adverse effects of any depletions for which offsets are required and at what times will that additional water need to be made available?

Model Description

A concept of the initial PRADSS model was developed and refined through the course of several meetings with stakeholders. Initially, two different models were discussed to address this goal:

1. A mid-range predictive model that predicts possible flows up to a month in advance using a one-day time step. The model should be useful for reservoir operations, and able to utilize COHYST input on baseflows.
2. A short-range predictive model that will predict possible flows up to 48 hours in advance using a one-hour time step. The model should be able to assist in fulfilling specific predictive needs (i.e. given inflows and projected reach gain and weather what should we release at North Platte to achieve a given flow at Grand Island during a specific time period).

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Through open discussion, representatives demonstrated a greater interest in the short-range predictive model. A final conceptual model was agreed upon for initiation of the PRADSS, and this model can be described as:

The desired model will be an operational river system model that uses the hourly streamflow data available for the central section of the Platte River, i.e. between Lewellen, NE (above Lake McConaughy) to Chapman, NE. This model will be used in a predictive manner for the upcoming 14 days to estimate water availability and optimize reservoir operations. Although the model will run on hourly time steps, output data for days 8 to 14 will be aggregated in daily units before being published (potentially on a website). The estimates for the first 7 days will be provided in both hourly and daily units.

Modeling Software Evaluation

Several water quantity and river operations models are available that could be used to develop the initial PRADSS model. These models needed to be examined and compared to determine their applicability for accomplishing the goals of the initial PRADSS model. A discussion regarding model evaluation process will lead to an explanation of the model evaluation results.

Model Evaluation Procedure

A model evaluation process was used to compare the capabilities of available software packages for development of the initial PRADSS model. This process was cooperatively developed at stakeholder meetings to determine the appropriate process for evaluating and recommending a software package to decision makers in Nebraska. The following discussion will illustrate how the model evaluation process was developed and the steps involved in the final process.

Procedure Development

The development of the model evaluation process for the Platte River involved several initial steps:

- Review and discuss example processes that have been used before.
- Formulate the Platte River Model Evaluation Process.
- Select a coordinator to oversee the Platte River Model Evaluation Process.

Several model evaluation and selection processes have been developed in the past that could be used as basis for developing a process to select an appropriate modeling software package for the Platte River effort. Two example processes were discussed with the group, and one example was presented to the group in more detail. The two processes reviewed are documented in:

Texas Natural Resource Conservation Commission, 1998, Evaluation of Existing Water Availability Models: TNRCC Technical Paper #2., 63 pp.

Bureau of Reclamation, 2005, Draft Report on Red River Valley Water Needs and Options (in draft).

A summary and example from the evaluation process used during 2003 in Reclamation's Red River Valley Water Supply Project (RRVWSP) were presented to the group. These documents are provided in Attachment 1. The RRVWSP model evaluation process was developed to identify several models capable of meeting the goals and specific technical objectives of the project. This evaluation process enabled a quantifiable comparison of models that resulted in a recommended model for use.

A similar process to that used in the RRVWSP model evaluation process was agreed upon by stakeholders for use in the Platte River basin. The PRADSS model evaluation process was coordinated by Amy Lieb of Reclamation in Denver, CO, who served as the coordinator for Reclamation's RRVWSP model evaluation process.

Final Process Description

The model evaluation process will enable the comparison of model capabilities that are specifically requested for the initial PRADSS model. This process was modified slightly from that used in the RRVWSP and were approved by the group of stakeholders:

1. Define the goals and objectives of water quantity modeling efforts for the Platte River within Nebraska.
2. Identify model selection criteria specific to the objectives of the Platte River by reviewing user needs, desired functionalities, and ideal model characteristics.
3. Rate the necessity of each model selection criteria or model capability as either required or desired, and rate whether capabilities were of high, medium, or low importance.
4. Develop a questionnaire that will be provided to expert model users to assess the functionality of each model in regards to each model selection criteria or capability.
5. Determine which models will be evaluated.
6. Locate current model users or people highly familiar with each model and provide them with the questionnaire.
7. Evaluate available, conceptual models by comparing questionnaire responses against the model selection criteria and through the use of a matrix.
8. Determine a recommended model.
9. Present results to decision makers.
10. Estimate the cost for model development.

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Steps 1-8 were completed between April and September 2005 through a series of meetings with stakeholders, work carried out by Reclamation staff, and the cooperation of several expert model users and their respective organizations.

Model Selection Criteria

The stakeholders initially defined specific capabilities that should be included in the initial PRADSS model:

1. Capability for dealing with surface water – groundwater interactions and changing groundwater conditions.
    a. Capability to account for long-term depletions to surface water flow from groundwater depletions or other means.
    b. Capability to account for fluctuations in reach gain.
2. Capability to link with or provide input to other models like the Nebraska natural flow accounting model or COHYST.
3. Capability to link with websites for data input or output.
4. Capability of modeling distribution of storage flow using ownership accounts.
5. Capability of simulating environmental water accounts.
    a. Capability to simulate environmental release scenarios.
    b. Capability to show availability of environmental water under wet, dry, or normal target flows given changing conditions.
6. Capability of modeling distribution of natural flow using priority system.
7. Capability to run both hourly and daily time steps, as well as monthly time steps if possible.
8. Real time data should be accessed, including climate data.

These specific attributes provided the backbone of model selection criteria that were specific to the Platte River basin. These capabilities were developed into a standard set of model selection criteria, which were discussed, refined, and prioritized at a meeting on June 9, 2005. A questionnaire was developed based on these criteria. The final criteria are presented in Attachment 2, and the final questionnaire is presented in Attachment 3.

Models Evaluated

The modeling packages selected for evaluation were chosen based on their ability to handle hourly or daily data. A review of software packages was consulted to identify model capabilities (Wurbs, 2005). Although each of these models can handle operations at several different time steps (daily, monthly, etc), the following list designates each software package and their maintaining organizations under the each category of minimum available time step:

Hourly Models

- HEC-5 – U.S. Army Corps of Engineers
- HEC-ResSim – U.S. Army Corps of Engineers
- RiverWare – University of Colorado (CADWES)

Daily Models

- MODSIM-DSS – Colorado State University
- STATEMOD – State of Colorado
- CALSIM/WRIMS – State of California

The final questionnaire was provided to expert model users and/or model developers to assess each model's strengths and weaknesses. These responses were provided back to the model evaluation coordinator at Reclamation. A matrix was used to compare the questionnaire responses in relation to the specific needs the Platte River basin.

Model Evaluation Matrix

Completion of the model evaluation matrix was undertaken by the model evaluation coordinator at Reclamation, so that the comparison minimized subjective opinion that would arise from multiple evaluators. The process of completing the matrix entailed assigning ratings of 1-5 to each model, which was determined by comparing the responses to each question and by using general information about the models found in model documentation. In some cases, more than one question was asked regarding one specific criterion.
The score associated with each underlying question were averaged to ascertain a single score for each criterion. Each preliminary score was then multiplied by a factor based on the importance rating the group of stakeholders assigned to each model selection criterion. Rating numbers were multiplied by the following numbers based on the determined level of importance (high, medium, or low):

Importance	Multiplication factor
High	3
Medium	2
Low	1

For this initial PRADSS tool, no criterion was given a "Low" priority, thus every criterion score was multiplied by either 2 or 3. After multiplication factors were applied, the resultant ratings were summarized to make a total model evaluation number, which enabled the identification of the top three models.
Information regarding the top three candidate models was presented to stakeholders on August 16, 2005. The following section will describe the results of the model evaluation as presented to the stakeholders.

Model Evaluation Results

The top three models identified in the PRADSS model evaluation process and the order of ranking were found to be:

1. RiverWare – University of Colorado (CADWES)
2. CALSIM/WRIMS – State of California
3. StateMOD – State of Colorado

Additional comparative analysis was completed on these top three models. A short summary of each model and a short list of "pros" and "cons" were developed for each of these models and presented to the group of stakeholders. These summaries can be found in Attachment 4.

The model evaluation results illustrated that RiverWare has several unique capabilities that are not available in other software packages. These capabilities include the ability to aggregate data up to a larger time period. Although this capability would be highly useful, this work can also be completed through pre-processing of data and is therefore not necessary. This example illustrates the type of advanced features included in RiverWare. Although the basic foundation of RiverWare is comparable to other software packages, tremendous time and effort has been devoted to making RiverWare robust and comprehensive. Other unique capabilities of RiverWare include:

- Model can be shared in a read-only format (which is free)
- Data can be input a variety of ways
- Monte Carlo runs can be completed easily to assess model sensitivity
- Bank storage is specifically modeled

Of course, these unique improvements within RiverWare also require a greater financial investment over obtaining other modeling software packages. RiverWare requires an initial license fee, which varies between $3,000 and $11,500 depending on the organization's affiliation with government or academic institutions and number of license nodes needed, as well as an annual renewal licensing fee between $750 and $5,000. CALSIM/WRIMS also requires an initial investment in software that costs approximately $2,400, but does not require any annual licensing fees. Finally, StateMOD is available for free, but also is less flexible than both RiverWare and CALSIM/WRIMS. Ultimately, RiverWare provides substantial flexibility in a standard format that is peer-accepted.

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Recommendations

The results of model evaluation and these initial discussions provided the groundwork for future efforts, such as development of the initial PRADSS model and future PRADSS components. The final recommendations of this study are broken into primary and secondary recommendations. Within the primary recommendations, there are specific tasks that should be undertaken first with the remaining work to follow once the initial tasks are complete.

Primary Recommendations – Initial PRADSS Model

Through the preceding evaluation, RiverWare has been identified to meet the primary needs for the initial PRADSS model. As such, RiverWare is the modeling software package recommended for development of the initial PRADSS model, but some additional preliminary work is needed before this model can be developed. A cost estimate must be developed to provide decision makers information regarding what will be developed and the estimated funding required. This cost estimate will specifically need to describe the tasks associated with development of the model and the underlying database. To develop a cost estimate, further investigation is needed to determine:

- Can some of the primary DSS needs be met through analyses/tools other than the initial PRADSS model?
- What preliminary analyses and data are needed as input into the initial PRADSS model?
- Are these data available?
- What, if any, additional data need to be collected?

The development of a cost estimate which includes an investigation into this type of information is recommended at this time. This cost estimate should specifically discuss database development separate from model development, since this database could potentially be used for input into additional PRADSS tools or models in the future. Model development should proceed once this estimate has been provided to decision makers and the necessary funds become available.

Discussions with stakeholders also covered a broad range of topics and considerations. For example, the group anticipated that the NDNR would maintain the final DSS, while Reclamation or outside contractors may be used for initial PRADSS model development. Such decisions will also affect the model development costs and need to be decided before implementation. As such, personnel developing the cost estimate should engage the decision makers to discuss such information that can alter the final cost estimate.

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Secondary Recommendations - Remaining PRADSS Development

Since tremendous information was gained through this initial study, several secondary recommendations were generated. These recommendations extend beyond the initial objectives of this study, but contribute to the ultimate objective of assisting managers to optimize water resource management in the Platte River Basin of Nebraska by recommending future DSS development activities.

Future development of the PRADSS will need to go beyond the primary DSS needs. Some other needs have already been identified, but additional needs may also exist. Additionally, the final PRADSS has not been fully conceived, but could be quite comprehensive. Several DSS frameworks exist, but each of them generally have a similar format. As an example, Colorado's Decision Support System (CDSS) is presented below to illustrate how a neighboring state has structured their DSS, which Nebraska could follow to conceptualize the final PRADSS. This framework was discussed with stakeholders and provided a tenable concept for the group. The following description summarizes the CDSS framework and the process by which Colorado identifies the DSS needs in each river basin. Finally, a recommendation will be presented for developing future PRADSS components.

Colorado's Decision Support System

The CDSS incorporates a "data-centered" approach with a central database providing input to a variety of tools and models. Figure 1 illustrates the concept of the CDSS, where HydroBase is the central database and Data Management Interfaces (dmis) are used to send the most current data to each model or tool, as well as incorporate newly available data into the database.

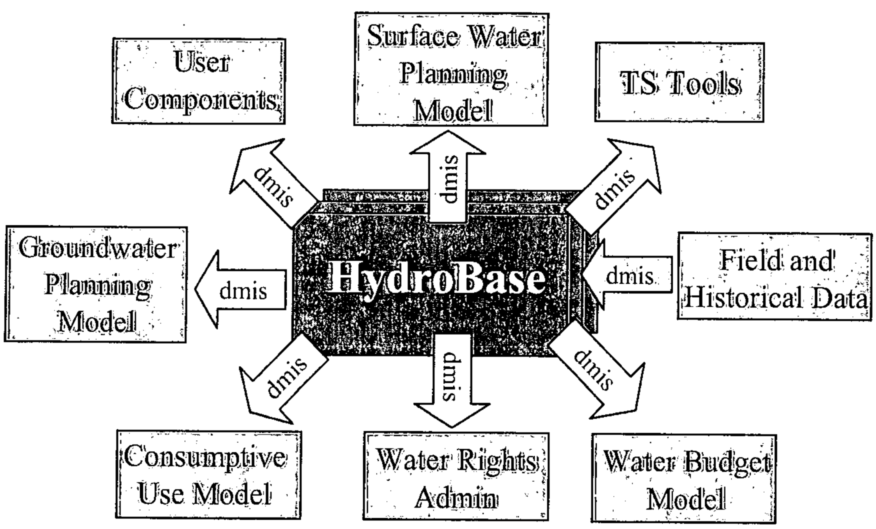

Figure 1. CDSS Data-Centered System Integration.

This framework allows for easy updates to the models with new data. Each tool or model is used to address specific needs identified in each river basin of Colorado, but certain river basin may not use one tool or another. For example, the CU Model, or Consumptive Use Model, may not be necessary in a specific area of the state if consumptive uses such as irrigation, municipal or industrial water use do not occur in that area.

Before DSS development begins in any river basin, Colorado undertakes an investigation to determine the specific water management needs of the basin. These investigations have been completed by outside contractors mainly through the use of interviews and public meetings and result in a report that includes four parts:

- **Needs Assessment** - Identified issues and needs
- **Data Assessment** - Additional data needed to be collected
- **DSS Component Assessment** - Models or tools to address these needs
- **Alternative Assessment** - Cost and schedule estimates for alternative packages of tools and data collection

Such investigations in Colorado have cost upwards of $200,000 per river basin (Ray Bennett, personal comm.), and their recommended alternatives have ranged between 5 (CWCB, 1998) and 20 million dollars (CWCB, 2001). These cost estimates are not applicable to PRADSS or Nebraska for a variety of reasons. For example, the needs being addressed in specific Colorado basins may not exist or be as important to managing water resources in the Platte River basin. Also, several tools and databases have already been developed in Nebraska that can contribute to the final PRADSS, thereby reducing DSS development costs.

Other PRADSS Needs and Components

A comprehensive assessment of needs for a PRADSS system, similar to those completed in Colorado, has not been completed. The secondary recommendations include a more comprehensive investigation to fully evaluate and address all the water management needs in the Platte River basin. This same type of investigation could also be used in other river basins of Nebraska in the future.

The final conceptual framework of the PRADSS should also be determined. Although a "data-centered" approach is not currently in place in Nebraska, several of the components have already been developed that could be used in a comprehensive PRADSS. Figure 2 illustrates the potential PRADSS framework, which includes the names of components already developed that could be integrated with the NDNR's Data Bank system to form a "data-centered" DSS.

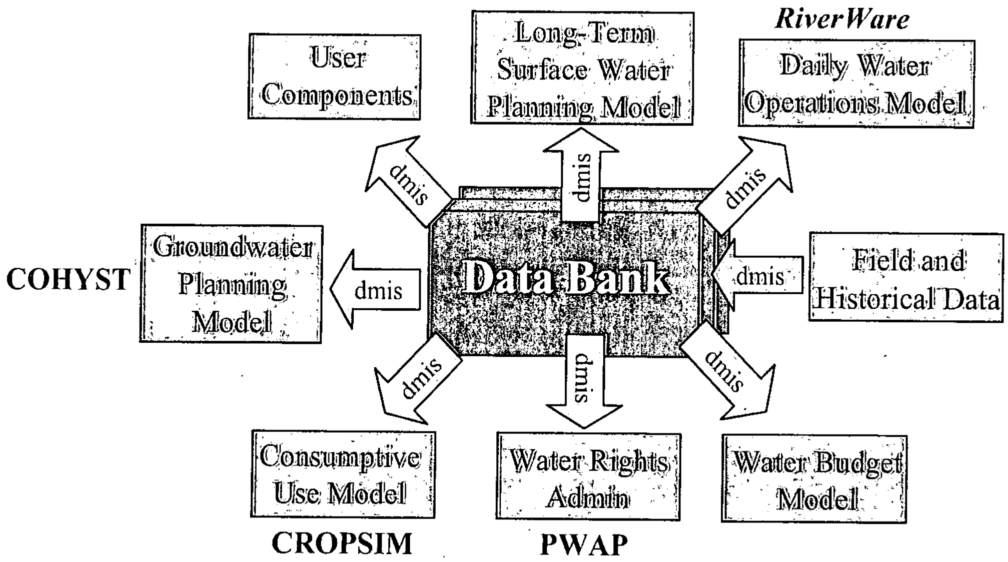

Figure 2. Potential Data-Centered Integration System for PRADSS.
BOLD indicates tools already developed in Nebraska.
Italics indicate potential tools that could be developed.

Since several components already exist, another secondary recommendation is to consider integrating currently available models and tools with a central database like Data Bank. An investigation into the data requirements and costs of developing and maintaining this system would provide the groundwork for implementation, but and investigation into the ability of the current models to address identified needs is also crucial.

Summary

An investigation was completed into the need for a DSS in the Platte River basin of Nebraska through an open dialogue with interested stakeholders. Several primary needs were identified, which provided the direction of initial PRADSS development. These primary needs were to help optimize water resource operations in the Platte River, which could primarily be addressed with the development of an initial hydrologic model. Several modeling software packages were evaluated for their applicability to the specific needs of the PRADSS, and RiverWare was identified to include several unique attributes that were most applicable to the Platte River basin.

The products of this initial study into PRADSS development are recommendations for further work. The primary recommendations of this study focus on the development of the initial PRADSS model, which can be summarized as:

- Generate a cost estimate for development of the initial PRADSS model in RiverWare and the necessary database by investigating and comparing the available data to the data requirements and identifying cost-effective ways to implement model and database development.
- Begin developing the database and initial PRADSS model once necessary funds have been procured.

The first of these primary recommendations should be undertaken as soon as possible. Stakeholders expressed a concern that a lack of funding would stall any further model development as has happened in the past. The cost estimate will require substantially less funds than model development while continuing the PRADSS development process.

Secondary recommendations were also identified for the benefit of decision makers. These recommendations provide additional guidance beyond the objectives of this study, yet identify other tasks needed for future expansion of the PRADSS. These secondary recommendations can be summarized as:

- Develop a comprehensive assessment of water management needs, available data, and the tools required to address those needs in the Platte River basin of Nebraska, as well as in other Nebraska river basins.
- Consider integrating available databases with available models.

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Attachment 1: Red River Valley Water Supply Project Model Evaluation Process

Study Purpose and Objective

The purpose of the Red River Valley Water Supply Project is to identify reliable sources of water of sufficient quantity and quality to supply homes, businesses, industries, wildlife, and recreation in the Red River Valley within North Dakota through at least the next five decades. This project was undertaken in 2002 with the Bureau of Reclamation as the lead federal agency.

Model Evaluation Process

Water quantity and quality models exhibit diverse capabilities. For the Red River Valley Water Supply Project, a model evaluation process was developed to identify several models capable of meeting the goals and specific technical objectives of the project. This evaluation process enabled a quantifiable comparison of models that resulted in a recommended model for use.

A model evaluation process was necessary to evaluate and compare the applicability of available models within a limited timeframe of only a few months. A model evaluation process developed by the Texas Natural Resource Conservation Commission[1] provided a basic framework and was modified as needed. The Red River Valley process relied heavily on input from interested parties at monthly meetings of the Red River Project Needs and Options Report's Technical Team. Separate model evaluation processes were completed to evaluate water quality and water quantity models for use in the Red River Valley Water Supply Project.

The surface water quantity model evaluation process for the Red River Valley Water Supply Project included eight steps:

1. Define the goals and objectives of water quantity modeling efforts within the Red River Water Supply Project.

[1] Texas Natural Resource Conservation Commission, 1998, Evaluation of Existing Water Availability Models: TNRCC Technical Paper #2., 63 pp.

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2. Identify model selection criteria specific to the objectives of the Red River project by reviewing user needs, desired functionalities, and ideal model characteristics.
3. Rate the necessity of each model selection criteria or model capability as either required or desired, and rate whether capabilities were of high, medium, or low importance.
4. Develop a questionnaire that will be provided to expert model users to assess the functionality of each model in regards to each model selection criteria or capability.
5. Determine which models will be evaluated.
6. Locate current model users or people highly familiar with each model and provide them with the questionnaire.
7. Evaluate available, conceptual models by comparing questionnaire responses against the model selection criteria and through the use of a matrix.
8. Determine a recommended model and present results to decision makers.

The recommended water quantity model, STATEMOD, was selected by decision makers for use in the Red River Valley Water Supply Project.

As an example, the following list includes a more detailed description of each step taken to evaluate surface water quantity models for the Red River Valley Water Supply Project:

1. **Define the goals and objectives of water quantity modeling efforts within the Red River Water Supply Project.**

   Water Quantity Modeling Purpose:

   The primary objectives of the monthly water quantity modeling in the Red River Project were outlined through questions the modeling needed to answer:
   - Will the current surface water sources in the Red River Basin used for Municipal, Rural, and Industrial (MR&I) provide enough water for MR&I in the year 2050 if a 1930's type drought occurred?
   - What is the probability of having shortages at the current and probable future MR&I points of interest, and how severe would the shortages be?
   - Will the different alternatives evaluated provide enough additional water to eliminate projected MR&I shortages?

   The monthly surface water modeling of the Red River basin imposed the basin's projected 2050 MR&I surface water demands on a naturalized (or unregulated) streamflow database. Some shortages are expected to be found, so various alternatives to supply these shortages will also be modeled. Therefore, the primary purpose of the surface water modeling efforts for the Red River Project is to:

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- Examine water supply conditions to determine any present and potential future water supply shortages, and
- Assist in the evaluation of alternatives for meeting future water needs.

2. **Identify model selection criteria specific to the objectives of the Red River project by reviewing user needs, desired functionalities, and ideal model characteristics.**
   Water Quantity Model Criteria:
   Model selection criteria were developed to identify the capabilities of a surface water model that were necessary to achieve the modeling goals. During Reclamation's past water quantity modeling efforts, a modeling committee developed modeling objectives, required capabilities and desired capabilities. The recommendations of this modeling committee served as a starting point for developing model selection criteria. Criteria were further developed by technical representatives of various agencies, including Reclamation, North Dakota State Water Commission (NDSWC), Minnesota Department of Natural Resources (MNDNR), and U.S. Geological Survey (USGS). By identifying user needs, desired functionalities, and ideal model characteristics, the model selection criteria were formulated and arranged into four general categories:

   - Water rights related criteria
   - Functionality related criteria
   - Operational related criteria
   - Information technology related criteria

3. **Rate the necessity of each model selection criteria or model capability as either required or desired, and rate whether capabilities were of high, medium, or low importance.**
   Members of the Technical Team determined which model capabilities were required or desired, as well as whether capabilities were of high, medium, or low importance.

4. **Develop a questionnaire that will be provided to expert model users to assess the functionality of each model in regards to each model selection criteria or capability.**
   The final model selection criteria were used to develop a questionnaire. This questionnaire was used to identify capabilities and limitations of the models of interest. See Attachment 1 for an example.

5. **Determine which models will be evaluated.**
   Models used in previous phases of the Red River Valley studies were evaluated along with other models available. The models to be evaluated had to meet several basic criteria:

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- Already be available
- Be able to function at a monthly time step
- Developed for use in water supply or water management studies
- Able to simulate water rights

Reclamation and members of the Technical Team cooperatively focused the model evaluation on seven pertinent models. The models selected to be evaluated and their maintaining organizations are as follows:

- HEC-5 – U.S. Army Corps of Engineers
- HYDROSS – Reclamation
- MIKE BASIN – Danish Hydraulic Institute (DHI)
- MODSIM-DSS – Colorado State University
- RiverWare – University of Colorado (CADWES)
- STATEMOD – State of Colorado
- WRAP – Texas Natural Resource Conservation Commission

6. **Locate current model users or people highly familiar with each model and provide them with the questionnaire.**
   This same questionnaire was provided to experts familiar with each model by a model evaluation coordinator. This person was responsible for ensuring every question was answered. The evaluation coordinator reviewed all answers received and sought clarification when answers were unclear.

7. **Evaluate available, conceptual models by comparing questionnaire responses against the model selection criteria and through the use of a matrix.**
   A matrix was used to compare the models' strengths and weaknesses in relation to modeling the Red River basin. Completion of the model evaluation matrix was undertaken by one person, the model evaluation coordinator, so that the comparison minimized subjective opinion that would arise from multiple evaluators. The process of completing the matrix entailed assigning ratings of 1-5 to each model, which was determined by comparing the responses to each question and by using general information about the models found in model documentation. Each of these preliminary ratings was then multiplied based on the importance rating each model selection criterion was given, since each question directly related back to a specific criterion. Rating numbers were multiplied by the following numbers based on the determined level of importance (high, medium, or low):

Importance	**Multiplication factor**
High	3
Medium	2
Low	1

After multiplication factors were applied, the resultant ratings were summarized to make a total model evaluation number, which was presented in a report by the evaluation coordinator.

8. **Determine a recommended model and present results to decision makers.**
The results of the model evaluation were reviewed by members of the Technical Team. The model with the highest total model evaluation number was recommended for use in the Red River Valley Water Supply Project and was presented to Reclamation for final decision. The recommended water quantity model, STATEMOD, was selected by decision makers for use in the Red River Valley Water Supply Project.

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Red River Valley Water Supply Project - Water Quantity Model Selection Criteria

NOTE: These criteria were developed to specifically address water quantity modeling concerns in the Red River Valley Water Supply Project and should not be directly applied to other modeling efforts that have different objectives.

	Purpose for Study	Importance	Required or Desired?
CATEGORY: Water Rights Criteria			
Doctrine---Western: Appropriation (first in time,first in right) & Eastern: Riparian.	Model needs to account for various operating plans of reservoirs, alternatives and water users--it is not certain that specific water rights modeling is needed.	High	Required
Use Category: Municipal, Industrial, Irrigation.	Model needs to distinguish between sectors of use. Minimum needs are that it be able to segregate Municipal/Industrial and Irrigation	High	Required
Supplemental Rights: Add on to an original water right.	Model needs to be able to split water rights with differing priority dates (I.e. due to additional acreage added to the same diversion.	Medium	Desired
Project vs Non- Project Rights	The model needs to have the ablity to segregate and target individual project water supplies from non-project water supplies, e.g. baseflow, with respect to storage, streamflow, return flow, water rights and imported supply.	High	Required
Storage Allocation Rights	Model needs to be able to allocate storage in a reservoir to specific water rights and priority dates.	High	Desired
Monitor instream flow objectives/requirements (instream flow rights)	Model needs to simulate operating plans that allocate a certain portion of the river flow to instream flow requirements.	High	Required

CATEGORY: *Functionality Criteria*			
Simulate movements of surface water (mass balance accounting not dynamic routing)-	Needed to evaluate past, present and future water management and development effects upon streamflow conditions and alternative water supply solutions.	High	Required
Model diversions from, and inflows to river & res. system @ various locations	Model needs to account for quantity of inflows and outflows at any desired location.	High	Required
Water quality modeling capabilities	It would be beneficial if the model contained a water quality extension to model at least conservative water quality parameters.	High	Desired
Simulate the location and magnitude of water shortages	Need to know the location and magnitude of shortages so alternatives can be evaluated/sized.	High	Required
Total water losses	The user needs to keep track of the total amount of water lost from the system, especially any losses occurring from the rounding of numbers.	High	Desired
Model based on a maximum of a monthly time step.	Monthly time steps may be adequate for analyzing water supply scenarios, longer time steps are less useful.	High	Required
Shoter time steps than monthly.	Monthly time steps may not be adequate for analyzing aquatic impacts or brief shortages. A daily time step could be used.	High	Desired
Simulate & input a number of diverse alternatives(no solution, in-basin, out-of-basin)	The model needs to be capable of simulating alternatives.	High	Required
Able to use streamflow records and capable of handling large historical or stochastic streamflow databases	Modeling will be based upon surface water flow records rather than rainfall-runoff or full water budget methods.	Medium	Desired
Model river reaches gains & losses--	Losses & gains need to be subtracted or added to river quantities to represent the system.	High	Required
Reach Efficiency	Model needs to be capable of generally simulating gains and losses that occurs between various nodes due to groundwater interaction and bank storage.	Medium	Required
Routing	Model needs to be capable of simulating gains and losses that migrate between various nodes.	High	Required
Routing and Efficiency	It would be beneficial if the model allowed routing of losses from canals or conveyance systems, and/or on-farm/site of use losses based on efficiency of use.	Medium	Desired
Losses to deep percolation	The model needs to allow routing of losses to deep percolation that are assumed to be lost from the modeled system.	High	Required
Ungaged watersheds or minor tributaries	Model needs to account for inflow from tributary areas between gaging stations.	High	Required
Regional Scaled model	The model should be one that is generally used to model areas as large as the Red River Basin.	High	Required
River Reach sizes	The model should allow varying degrees of detail, from river reaches that represent several miles all the way up to 100 miles.	High	Required
Lagging of return flows	The model should allow return flows, or parts of return flows, to be returned to the system in the next few months, not just within the month the water was withdrawn.	High	Required

CATEGORY: Operational Criteria			
Simulate main-stem, & offstream reservoir operations using:	**The model needs to simulate reservoir operation plans so the impacts of reservoir operations can be determined.**	High	Required
Elev.-Area-Capacity Relationships	Impacts of reservoir operations.	High	Required
Stage-Discharge (uncontrolled & controlled spillways)	Impacts of reservoir operations.	High	Required
Min, Max elevation	Impacts of reservoir operations.	High	Required
Elev. & release targets (normal, flood operations)	Impacts of reservoir operations.	High	Required
Evaporation losses	Losses due to reservoir storage/operations.	High	Required
Seppage losses	Routing of losses to deep percolation or other nodes.	High	Required
Capacity losses due to sedimentation	Losses of storage over time due to reservoir sedimentation.	Medium	Desired
Accounting for reservoir multiple use storage allocations	**Model needs to simulate multiple-use (complex) reservoir operating plans.**	High	Required
Deviate from normal operating plans in low flow periods	**The ability to deviate operating plans of reservoirs in low-flow times could be used to simulate any drought contingency plans.**	High	Desired

CATEGORY: *Information Technology Criteria*

Minimal Training	Model needs to be user friendly so that excessive learning curves are avoided.	High	Desired
Adequate Model Documentation	The model should be adequately documented with respect to computational methods used, assumptions, user input requirements, description of the source code, and error checking/troubleshooting methods.	High	Desired
Graphical User Interface	Input of data to the model needs to be convenient.	Medium	Desired
User support capabilities	Support for the users is important.	High	Desired
The model is presently developed, has been used for similar studies elsewhere, and is peer accepted.	Model has successful track record and is generally accepted by professionals for similar work.	High	Required
PC Compatible with windows, 95, 98, NT, XP, or DOS	PC's are in widely used and universally available...access to other operating systems and mainframe computers is less widespread.	High	Required
Windows version	The version of windows the model works best in should be a more recent version, otherwise a separate older computer will have to be used, which may be a hassle for the modeler.	High	Required
Non-proprietary or one-time fee models are preferred.	Fees to use model need to be avoided or minimized.	High	Desired
Input -- Ability for the model to utilize both flat files or database structures for input/output.	Flexibility of the model to import or use various input formats would add convenience to model set up.	Medium	Desired
Output---tabular report, time-series graphs	Model output needs to be in a convenient form for presentation and data analysis. The ability to output data in to various formats is integral.	High	Desired
Easy Method for evaluating model error(sensitivity analysis)	The ability to easily do a sensitivity analysis would be beneficial.	High	Desired
Reproduce stream flow records based on past demand input	The ability to calibrate the model and reproduce observed results builds confidence in the model results.	High	Required
Model ownership and ability to manipulate code	The ability for the user to be able to modify the model code for specific conditions or for tailoring the model to a unique component of the basin operations is occasionally important in generally applied "off the shelf" models.	Medium	Desired
GIS Capabilities	The ability of the model to interface with GIS could allow for better presentation of results and processes.	Medium	Desired
Data requirements	The model should not require extensive amounts of data beyond that which is currently available. It is understood that some assumptions will have to be made for use of any model, but the amount of data needed to run the model should be investigated to estimate the models applicability.	High	Required

Attachment 2: Platte River Advanced Decision Support System – Water Operations Model Evaluation Criteria

CATEGORY: Water Rights Criteria	Purpose for Study	Importance (High, Medium, Low, Not at All)	Required, Desired, or Not Desired?
Doctrine: Western Water Rights Appropriations.	Model needs to account for various operating plans of reservoirs, including water rights modeling based on western water right appropriations.	High	Required
Use Category: Municipal, Industrial, Irrigation.	Model needs to distinguish between sectors of use. Minimum needs are that it be able to segregate Municipal/Industrial and Irrigation.	High	Required
Supplemental Rights: Add on to an original water right.	Model needs to be able to split water rights with differing priority dates (I.e. due to additional acreage added to the same diversion.	High	Required
Project vs Non- Project Rights	The model needs to have the ablity to segregate and target individual project water supplies from non-project water supplies, e.g. environmental accounts, baseflow, return flows, water rights and imported supply.	High	Required
Storage Allocation Rights	Model needs to be able to allocate storage in a reservoir to specific water rights and priority dates.	High	Required
Monitor instream flow objectives/requirements (instream flow rights)	Model needs to simulate operating plans that allocate a certain portion of the river flow to instream flow requirements.	High	Required

CATEGORY: *Functionality Related Criteria*	Purpose for Study	Importance (High, Medium, Low, Not at All)	Required, Desired, or Not Desired?
Simulate movements of surface water (mass balance accounting and/or dynamic routing)-	Needed to evaluate past, present and future water management and development effects upon streamflow conditions.	High	Required
Model diversions from, and inflows to river & res. system @ various locations	Model needs to account for quantity of inflows and outflows at any desired location.	High	Required
Simulate the location and magnitude of water shortages	Need to know the location and magnitude of shortages.	High	Required
Total water losses	The user should be able to track the total amount of water lost from the system, either through the model summarizing losses for the user or through post-processing of output data.	High	Desired
Model based on hourly time steps	Hourly data is readily available, so a model that operates at an hourly time step is preferred.	High	Required
Model based on daily and hourly time steps	A model that has the ability to run scenarios at either hourly or daily time steps would also be useful.	High	Desired
Aggregate time steps up to longer time steps	It would be beneficial if the model could aggregate hourly data up to larger time steps, like daily, weekly, or monthly.	Medium	Desired
Types of input data	Modeling will be based upon surface water flow records and past precipitation records. Soil moisture data is also available.	High	Desired
Rainfall-runoff data	The model should either contain a rainfall-runoff model for input into the system, or should be able to accept output data from this type of model.	High	Desired
Model river reaches gains & losses--	Losses & gains need to be subtracted or added to river quantities to represent the system.	High	Required
Bank Storage	Model need to account for the effects of bank storage.	High	Required
Reach Efficiency	Model needs to be capable of generally simulating gains and losses that occurs between various nodes due to groundwater interaction and bank storage.	High	Required
Routing	Model needs to be capable of simulating gains and losses that migrate between various nodes.	High	Required
Routing and Efficiency	It would be beneficial if the model allowed routing of losses from canals or conveyance systems, and/or on-farm/site of use losses based on efficiency of use.	Medium	Desired
Losses to deep percolation	The model needs to allow routing of losses to deep percolation that are assumed to be lost from the modeled system.	High	Required
Ungaged watersheds or minor tributaries	Model needs to account for inflow from tributary areas between gaging stations.	High	Required
Groundwater modeling	Model needs to model groundwater interaction or be able to interact with models capable of doing so.	High	Required
Regional Scaled model	The model should be one that is generally used to model areas as large as the Platte River Basin.	High	Required
River Reach sizes	The model should allow varying degrees of detail, from river reaches that represent up to several miles.	High	Required
Lagging of return flows	The model should allow return flows, or parts of return flows, to be returned to the system over time, not just within a short time of when the water was withdrawn.	High	Required

CATEGORY: Operational Related Criteria	Purpose for Study	Importance (High, Medium, Low, Not at All)	Required, Desired, or Not Desired?
Simulate main-stem, & offstream reservoir operations using:	**The model needs to simulate reservoir operation plans so the impacts of reservoir operations can be determined.**	**High**	**Required**
Elev.-Area-Capacity Relationships	Impacts of reservoir operations.	**High**	**Required**
Stage-Discharge (uncontrolled & controlled spillways)	Impacts of reservoir operations.	**High**	**Required**
Min, Max elevation	Impacts of reservoir operations.	**High**	**Required**
Elev. & release targets (normal, flood operations)	Impacts of reservoir operations.	**High**	**Required**
Evaporation losses	Losses due to reservoir storage/operations.	**High**	**Required**
Seepage losses	Routing of losses to deep percolation or other nodes.	**High**	**Required**
Accounting for reservoir multiple use storage allocations	**Model needs to simulate multiple-use (complex) *reservoir operating plans.***	**High**	**Required**
Deviate from normal operating plans in low flow periods	**The ability to deviate operating plans of reservoirs in low-flow times could be used to simulate any drought contingency plans.**	**High**	**Required**
Optimization capabilities	**Model needs to have optimization capabilities (for water delivery).**	**High**	**Required**

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CATEGORY: *Information Technology Related Criteria*	Purpose for Study	Importance (High, Medium, Low, Not at All)	Required, Desired, or Not Desired?
Minimal Training	Model needs to be user friendly so that excessive learning curves are avoided.	Medium	Desired
Structured model training available	Model training needs to be available to allow model users to learn at an accellerated pace.	High	Desired
Adequate Model Documentation	The model should be adequately documented with respect to computational methods used, assumptions, user input requirements, description of the source code, and error checking/troubleshooting methods.	High	Required
Graphical User Interface	Input of data to the model needs to be convenient.	High	Required
Able to run model without GUI (command line)	Ability to run the model from the command line or in a non-interactive 'batch-mode' facilitates the automation of model runs (overnight, on a schedule, etc).	High	Desired
User support capabilities	Support for the users is important.	High	Desired
Longevity	The model developer(s) have a long-term development plan to ensure continuing support and maintenance.	High	Required
The model is presently developed, has been used for similar studies elsewhere, and is peer accepted.	Model has successful track record and is generally accepted by professionals for similar work.	High	Required
Broad user base	Model has a strong user base, both within and outside Reclamation, to ensure available expertise/support.	High	Desired
PC Compatible with windows, 95, 98, NT, XP, or DOS	PC's are in widely used and universally available...access to other operating systems and mainframe computers is less widespread.	High	Required
Windows version	The version of windows the model works best in should be a more recent version, otherwise a separate older computer will have to be used, which may be a hassle for the modeler.	High	Desired
Non-proprietary or one-time fee for model use.	Fees to use model need to be avoided or minimized.	High	Desired
Input -- Ability for the model to utilize both flat files or database structures for input/output.	Flexibility of the model to import or use various input formats would add convenience to model set up.	Medium	Desired
Output---tabular report, time-series graphs	Model output needs to be in a convenient form for presentation and data analysis. The ability to output data in to various formats is available.	High	Desired

CATEGORY: Information Technology Related Criteria (cont.)	Purpose for Study	Importance (High, Medium, Low, Not at All)	Required, Desired, or Not Desired?
Interactive linkage with external models	Ability to interactively link the model to external models can allow for the simultaneous modeling of water quality, groundwater, sediment transport, runoff, etc.	Hired	Desired
Ability to link with websites for data input or output	Data input and results could be updated *daily through websites*, so it would be beneficial if ability to link to websites has already been developed.	Medium	Desired
Ability to share entire model with stakeholders	The model needs to be able to be shared with stakeholders, such that they can make runs, run scenarios, understand the underlying calculations, and have confidence in model results.	High	Required
Ability to share model in a read-only format	The model needs to be able to be shared with stakeholders in the same manner we have determined to be best, i.e. in a read-only format where the user cannot change coefficients, just input data.	High	Desired
Easy Method for evaluating model error(sensitivity analysis)	The ability to easily do a sensitivity analysis would be beneficial.	High	Desired
Reproduce stream flow records based on past demand input	The ability to *calibrate the model and reproduce* observed results builds confidence in the model results.	High	Required
Ability to customize basic-specific methods in the model.	User needs the ability to use scripting, programming, or rules to add basin-specific calculations. This programming may either be within the model framework or external to it (as an add-on module).	High	Required
GIS Capabilities	The ability of the model to interface with GIS could allow for better presentation of results and processes.	Medium	Desired
Data requirements	The model should not require extensive amounts of data beyond that which is currently available. It is understood that some assumptions will have to be made for use of any model, but the amount of data needed to run the model should be investigated to estimate the models applicability.	High	Required
Number of flow nodes	The model should be able to run adequately with a sufficient number of flow nodes to represent the Platte River system.	High	Required

Attachment 3: Platte River Advanced Decision Support System – Water Operations Model Evaluation Criteria

Name of Model Reviewer: Model Name: Date:

Water Rights Questions			Please Put Answers Here
1	Doctrine: Western Water Right Appropriations.	Is the model able to easily account for water rights from rivers and structures, such as reservoirs?	
2	Doctrine: Western Water Right Appropriations.	Can the model differentiate water right priorities based on date or a general priority numbering system?	
3	Use Category: Municipal, Industrial, Irrigation.	Does the model differentiate between different types of water use (diversions)? Specifically, does the model differentiate between Municipal, Industrial, and Irrigation water use?	
4	Supplemental Rights: Add on to an original water right.	Can the model split out portions of water rights with differing priority dates (I.e. due to additional acreage added to the same diversion at a later time period)?	
5	Project vs Non- Project Rights.	Can the model segregate and target individual project water supplies from non-project water supplies ("color the water")? e.g. ability to separate baseflow from water designated for downstream users which was released from upstream storage(reservoir), or water coming from return flows and or imported supply?	
6	Storage Allocation Rights.	Can the model allocate storage in a reservoir to specific water rights (owners) with various priority dates?	
7	Monitor instream flow objectives/requirements (instream flow rights).	Can the model monitor instream flow requirements? More specifically, does the model indicate when a designated target flow is not met and by how much it was not being met?	
8	Monitor instream flow objectives/requirements (instream flow rights).	Can the model simulate operating plans that allocate a certain portion of the river flow to instream flow requirements?	

	Functionality Related Questions		Please Put Answers Here
9	Simulate movements of surface water.	Can the model be used to evaluate past, present and future water management and development effects upon streamflow conditions and alternative water supply solutions?	
10	Simulate movements of surface water.	Does the model perform mass balance accounting of water or dynamic routing?	
11	Simulate movements of surface water.	Does the model present the user with the overall water balance of the system modeled, i.e. summarize who got how much water, what shortages occurred, etc.	
12	Model diversions from, and inflows to river & res. system @ various locations.	Does the model allow diversions from and inflows to river systems at any desired location, particularly into reservoirs?	
13	Simulate the location and magnitude of water shortages.	Does the model track the location and magnitude of shortages?	
14	Simulate the location and magnitude of water shortages.	Does the model differentiate between natural and project shortages?	
15	Total water losses.	Does the model track, or is the user able to track how much water is being lost from the system? Does the model summarize the amount of water no longer available for use due to losses to deep percolation, etc? Or does the user need to track these losses with post-processing?	
16	Model based on shorter time steps, like daily or hourly.	Does the model function at an hourly or daily time step? If so, can it just do one, or can the model be run at either daily or hourly time steps?	
17	Aggregate time steps up to longer time steps.	Does the model aggregate hourly data up to larger time steps, likely daily, weekly or monthly?	
18	Types of input data.	Does the model depend on gaged surface water records, naturalized streamflow, or "baseflow" inputs? Also, does the model accept precipitation data or other climatic data? Does the model use any soil moisture content data?	

Functionality Related Questions (cont.)			Please Put Answers Here
19	Rainfall-runoff data.	Does the model include any rainfall-runoff calculations, or can the model accept rainfall-runoff data?	
20	Model river reaches gains & losses:	Does the user have to define the coefficients for losses & gains from groundwater? Or does the model create such coefficients based on streamflow at known locations?	
21	- Bank Storage.	Does the model simulate gains and losses associated specifically with bank storage, or is bank storage incorporated into a more generic "loss" calculation?	
22	- Reach Efficiency.	Is the model capable of simulating gains and losses that occur between various nodes due to groundwater interaction and bank storage?	
23	- Routing.	Does the model route streamflow through the system?	
24	- Routing.	Can the model simulate gains and losses that may be returned to another node?	
25	- Routing and Efficiency.	Does the model allow for routing of losses from canals or conveyance systems, and/or on-farm/site of use losses based on efficiency of use?	
26	- Losses to deep percolation.	Does the model allow for routing of losses to deep percolation that are assumed to be lost to the modeled system?	
27	- Ungaged watersheds or minor tributaries.	Does the model allow inflows from tributary areas between gaging stations?	
28	Groundwater modeling	Does the model simulate groundwater interaction? Or can the model accept groundwater information from another external groundwater model?	
29	Regional scaled model.	Is the model used to simulate regional surface water systems?	
30	River reach sizes.	Does the model allow varying sizes of river reaches between nodes? And is the model generally used in this way?	
31	Lagging of return flows.	Does the model allow return flows, or partial return flows, to be returned to the system over time? If so, how far out can return flows be lagged?	

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Operational Related Questions			Please Put Answers Here
32	Simulate main-stem, & off stream reservoir operations using:	Does the model allow the simulation of various reservoir operation plans?	
33	- Elev.-Area-Capacity Relationships.	Does the model accept area-capacity curve data?	
34	- Stage-Discharge	Does the model accept stage-discharge information?	
35	- Min, Max elevation.	Does the model use the maximum and minimum elevations for simulating reservoir operations?	
36	- Elev. & release targets (normal, flood operations).	Does the model accept specified release targets?	
37	- Reservoir Spills	Can the model utilize and/or bypass reservoir spills?	
38	- Evaporation losses.	Does the model calculate losses due to reservoir storage/operations?	
39	- Seepage Losses.	Does the model allow for seepage loss estimates from reservoirs and can it route these losses to other areas or remove them from the modeled system, e.g. losses to deep percolation?	
40	- Capacity losses due to sedimentation.	Does the model track and/or accept losses of storage over time due to reservoir sedimentation? Does the model accept multiple area-capacity curves?	
41	Accounting for reservoir multiple use storage allocations.	Can the model simulate multiple-use (complex) reservoir operating plans?	
42	Accounting for reservoir multiple use storage allocations.	Does the model allow various ownership in reservoirs, e.g. by percentages of total releasable capacity?	
43	Deviate from normal operating plans in low flow periods.	Does the model allow deviations to operating plans of reservoirs in low-flow times, e.g. to simulate drought contingency plans?	
44	Hydropower generation.	Does the model simulate hydropower generation in reservoir and/or run-of-river power plants?	
45	Optimization capabilities.	Does the model optimitize for specific objectives like water delivery or hydropower generation?	

Information Technology Related Questions			Please Put Answers Here
46	Minimal Training.	Is the model considered to be user friendly? Or is there a steep learning curve?	
47	Structured model training available.	Is model training available? If so, how is the training delievered, e.g. *on*-line tutorial, face-to-face class, workbook exercise, and what costs (other than labor for the student's time) are associated with obtaining this training?	
48	Adequate Model Documentation.	Does the model have adequate documentation with respect to computational methods used, assumptions, user input requirements, description of the source code, and error checking/troubleshooting methods?	
49	Graphical User Interface.	Can the input of data be done through using a Windows based Interface? Also, is there a GUI that illustrates the water system, e.g. using boxes for flow nodes or triangles for reservoirs?	
50	Able to run wtihout GUI (command line).	Can data be inputted or can the model be run from the command line or in a non-interactive 'batch-mode', so that model runs can be automated, e.g. to run overnight?	
51	User support capabilities.	Is there any support for the users?	
52	Longevity.	Do the model developers have a long-term development plan to ensure continuitng support and maintenance of the model?	
53	The model is presently developed, has been used for similar studies elsewhere, and is peer accepted.	Does the model has successful track record, i.e. have other water supply systems used the model and been satisfied with the results?	
54	Broad user base.	Do other entities or agencies use this model? If so, who do you know uses this model and please indicate if they have answered questions or provided help to you?	
55	PC Compatible with Windows XP or DOS.	Is the model able to be run on a PC, e.g. contains a GUI and model actually runs in DOS, or does it require a UNIX type system to run?	

Information Technology Related Questions (cont.)			Please Put Answers Here
56	Windows version.	Is the model able to be run in any Windows format, or does it work better in particular versions of Windows?	
57	Non-proprietary or one-time fee for model use.	Does the model require any fees for use or support?	
58	Input -- Ability for the model to utilize both flat files or database structures for input/output.	Can the model accept input data from a database, or does it only accept flat text files?	
59	Output---tabular report, time-series graphs.	Does the model automatically generate plots or graphs of output data? Or is the output data strictly in tabular format? Can the model format data so it can easily be plotted with other applications, such as Excel?	
60	Interactive linkage with external models.	Can the model interactively link to external models to allow for simultaneous modeling of water quality, groundwater interaction, runoff, or aquatic habitat?	
61	Ability to link with websites for data input or output.	Has a link been developed to input or export model data to or from websites?	
62	Ability to share entire model with stakeholders.	Can the model and all of it's input data be easily shared between stakeholders, so that they can run scenarios also?	
63	Ability to share model in a read-only format	Is there a way to share a read-only version of the model in which stakeholders can change input data, releases, and possibly some operational rules, while the majority of parameters are locked?	
64	Easy Method for evaluating model error(sensitivity analysis).	Does the model include the ability to evaluate model error, e.g. doing a sensitivity analysis?	
65	Reproduce stream flow records based on past demand input.	Have past calibration efforts been successful? How difficult was this calibration, or how long did it take?	
66	Reproduce stream flow records based on past demand input.	Does the model allow the user to "tweak" factors such as reach gains & losses in order to calibrate the model?	
67	Ability to customize basic-specific methods in the model.	Does the model allow for basin-specific calculations by adding scripts, rules, or programming, either within the model framework or through external scripting and programming?	

Information Technology Related Questions (cont.)			Please Put Answers Here
68	GIS Capabilities.	Is the model able to interface with a GIS? Also, does the model simply illustrate the basin using GIS information, or does the model use GIS for data input or output? Also, does the model have a GUI window that does not utilize GIS to illustrate the system, e.g. using boxes to illustrate flow nodes or triangles for reservoirs?	
69	Data requirements.	What types of input data is required to evaluate surface water availability for use by water supply? E.g. Naturalized streamflow database, future water demands, crop irrigation requirements.	
70	Number of flow nodes.	What is the maximum number of flow nodes at which the model has difficulty simulating?	

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Attachment 4: Platte River Advanced Decision Support System – Model Evaluation Results

Model	*Pros*	*Cons*
RiverWare	- Model can be run at an hourly time step - System can be built and run through a GUI - Model can be shared as read-only (which is free) - Data can be input a variety of ways, - Monte Carlo runs can be done to assess model sensitivity - Can aggregate hourly data up to daily time steps - Bank storage is specifically modeled - Can link to USGS Precipitation Runoff Modeling System - Basin-specific calculations can be incorporated	- Software must be purchased and has annual fees - Stakeholders that want to "play" with model must purchase - Training and support costs additional money - Optimization solver is an additional cost - No GIS interface
CalSim/WRIMS	- Basin-specific calculations can be incorporated - Optimization of operations is a primary use - Can link to external models - Input of data can be through text files or database	- Minimum time step is daily, not hourly - Streamflow routing is not included, but user can add - Bank storage is not specifically modeled - Model software has a one-time fee - Training and support costs additional money - GUI available to run model, but not for building model - No ability to share model in read-only format - No GIS interface - Have to build your own rules for every object
STATEMOD	- Performs complex water rights - System can be built and run through a GUI - Errors due to arithmetic rounding is documented - Model can show structure locations using GIS - Support and training is free of charge - Updates to model are free of charge - Highly scrutinized on whether results mimic historical flow	- Minimum time step is daily, not hourly - No links to other external models - No scripting capability, changes must be done by authors - Daily reservoir operations may need to be updated - Input of data only through flat files, no database - Input of data through GUI can be difficult - Bank storage is not specifically modeled - No optimization capabilities - No ability to share model in read-only format

A. Reservoir and River Operation Model (RiverWare)

The U.S. Bureau of Reclamation (Reclamation) and Tennessee Valley Authority (TVA) jointly sponsored development of the RiverWare (Reservoir and River Operation) model at the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) of the University of Colorado. RiverWare provides the basic hydrologic capabilities associated with routing streamflow inflows through a river/reservoir system. The primary processes modeled are volume balances at reservoirs, hydrologic routing in river reaches, evaporation and other losses, diversions, and return flows. Features are also provided for modeling groundwater interactions, water quality, and electric power economics.

RiverWare provides the model-user with a kit of software tools for constructing a model for a particular reservoir/river system and then running the model. The model-building tool kit includes a library of modeling algorithms, several solvers, and a language for coding operating policies. The tools are applied within a point-and-click graphical user interface. Input data may be typed manually through the graphical user interface, entered by loading data files, or entered through the data management interface, which allows retrieving large datasets through an external program. Various options are available for tabular and graphical displays of the model results. The user-selected time step may range from an hour to a year. Hydrologic streamflow routing methods include lag, variable time lag, storage, and Muskingum. Hydraulic routing methods include kinematic, Muskingum Cunge, and MacCormick. Bank storage and other gains and losses may be included in routing flows through a river system. RiverWareTM is a proprietary software product, which costs $6500 for initial purchase as a government entity and has a $2500 per year renewal fee for a single site license. Information regarding obtaining the software, documentation, and training is available at the CADSWES web site.

The TVA applies RiverWare in optimizing the daily and hourly operation of the TVA system of multiple-purpose reservoirs and hydroelectric power plants. Reclamation uses RiverWare as a long-term planning model and mid-term operations model of the Colorado River as well as a daily operations model for both the Upper and Lower Colorado Regions. Reclamation has also applied the model in the Rio Grande, Yakima, and Truckee River Basins. The Lower Colorado River Authority (LCRA) has applied RiverWare in daily time step modeling of water supply operations of the six LCRA reservoirs on the Colorado River of Texas.

PROS:

- Model can be run at an hourly time step
- System can be built and run through a GUI
- Model can be shared as read-only (which is free)
- Bank storage is specifically modeled
- Monte Carlo runs can be done to assess model sensitivity
- Can aggregate hourly data up to daily time steps
- Able to link to USGS Precipitation Runoff Modeling System (PRMS) of basin
- Basin-specific calculations can be incorporated through external scripting or internal methods
- Data can be input a variety of ways, e.g. flat files, databases, or through GUI

CONS:

- Software must be purchased and has annual fees
- Stakeholders that want to "play" with model must purchase the software
- Training and support costs additional money
- Optimization solver is an additional cost
- No GIS interface

B. Water Resources Integrated Modeling System (CalSim/WRIMS)

The generalized model used in CalSim (California Water Resources Simulation Model) is called the Water Resources Integrated Modeling System (WRIMS). The WRIMS model of the operation of both the State Water Project (SWP) and Central Valley Project (CVP) of California is called CalSim. WRIMS evolved from an older model called Department of Water Resources Simulation Model (DWRSIM), which was developed based on modifying HEC-3.

The generalized WRIMS is designed for evaluating operational alternatives for large, complex river systems. The modeling system integrates a simulation language for defining operating criteria, a linear programming solver, and graphics capabilities. Although CalSim has been developed at a monthly time step, WRIMs can be run at a daily time step. CalSim is a simulation model based on a linear programming formulation that minimizes a priority-based penalty function of delivery and storage targets. Rather than specifying detailed operating rules, the user specifies a series of objectives in the form of relative priorities or weights for water allocation and storage. The LP model is solved for each time step. Adjustment computations are performed after the LP solution to deal with more complex nonlinear aspects of modeling complex system operations.

A feature called the Water Resources Engineering Simulation Language (WRESL) was developed for the model based on the Java language to allow the user to express reservoir/river system operating requirements and constraints. WRESL statements are written by the model-user using any text editor. The user-supplied statements written in the WRESL language are used by the model to define the linear programming formulation. At runtime, the WRESL statements are converted to Fortran code by a parser-interpreter program. Computations are performed by programs written in Fortran. The XA solver (Byer 2001) is incorporated into the model to perform the linear programming solution that is repeated one or more times at each time step. Time series data are stored using the Hydrologic Engineering Center Data Storage System (HECDSS).

PROS:

- Basin-specific calculations can be incorporated through WRESL scripting
- Optimization of operations is a primary use
- Can link to external models
- Input of data can be through text files or database

CONS:

- Minimum time step is daily, not hourly
- Streamflow routing is not included, but user can add
- Bank storage is not specifically modeled
- Model software has a one-time fee
- Training and support costs additional money
- GUI available to run model, but not for building model
- No ability to share model in read-only format
- No GIS interface
- Have to build your own rules for every object

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C. Stream Simulation Model, State of Colorado (StateMod)

The Colorado Water Conservation Board and the Colorado Division of Water Resources have developed decision support systems for water management in the Colorado, Rio Grande, South Platte, and Arkansas River Basins. The generalized StateMod serves as the reservoir/river system modeling component of these decision support systems. StateMod is a water allocation and accounting model for simulating alternative water management strategies. Either a monthly or daily time step may be used. Hydrology, water rights, and system operating rules are combined in the model. Water rights are categorized as: direct flow, instream flow, reservoir storage, well, and operational. Water rights are simulated in priority order.

The State of Colorado made numerous enhancements to StateMod to model scenarios unique to the river basins of their state. StateMod supports the priority water rights system and many issues related to water resources planning, including direct diversions and instream flows. StateMod has been applied to all of the Western Slope Basins in Colorado. The model is coded in FORTRAN with GUI capabilities for PCs using Java.

StateMod supports complex water rights, exchanges, and importing operations. The model has numerous field applications. StateMod is in the public domain, is free to use, and is maintained by the State of Colorado.

PROS:

- Performs complex reservoir allocations
- System can be built and run through a GUI
- Error due to arithmetic rounding is documented
- Model can show structure locations using GIS
- Help with model is free of charge
- Updates to model are free of charge
- Highly scrutinized on whether results mimic historical flow
- Training is available free of charge

CONS:

- Minimum time step is daily, not hourly
- No links to other external models
- No scripting capability, changes must be done by authors in source code
- Daily reservoir operations may need to be updated
- Input of data through GUI can be difficult
- Input of data only through flat files, no database
- No ability to share model in read-only format
- No optimization capabilities
- Bank storage is not specifically modeled
- No ability to share model in read-only format