

**DEPARTMENT OF NATURAL RESOURCES  
COLORADO WATER CONSERVATION BOARD AND DIVISION  
OF WATER RESOURCES**

# **COLORADO RIVER DECISION SUPPORT SYSTEM OVERVIEW**

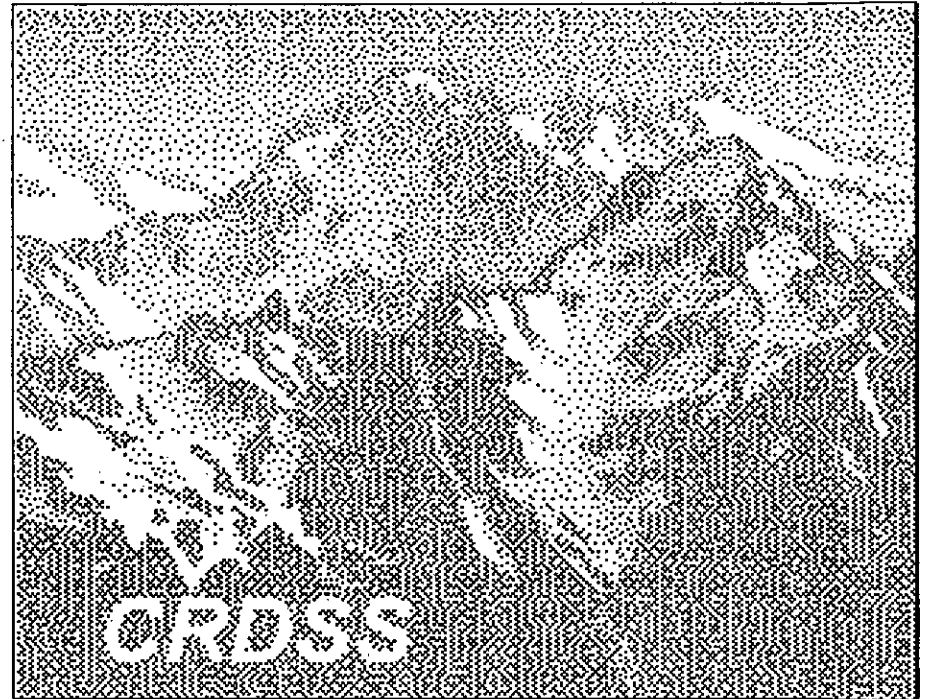
**I. COLORADO RIVER WATER MANAGEMENT ISSUES**

**II. COLORADO RIVER DECISION SUPPORT SYSTEM**

**III. CRDSS PROJECT**

**SELECTED ACRONYMS AND ACKNOWLEDGMENTS**

January 1995



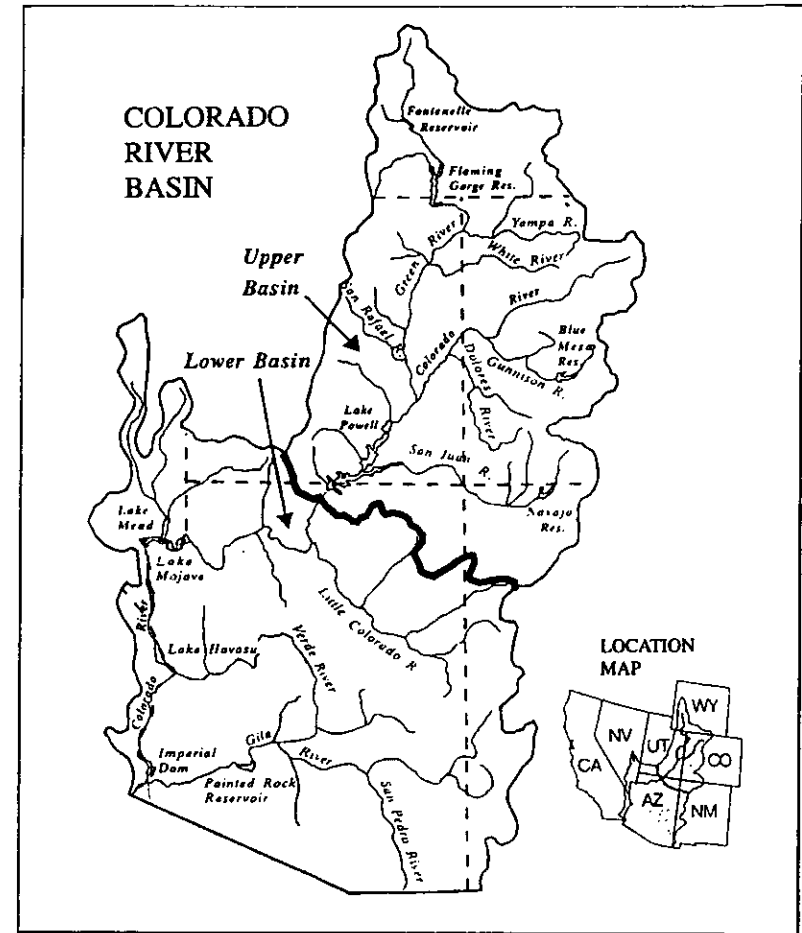
# I. COLORADO RIVER WATER MANAGEMENT ISSUES

## COLORADO RIVER BASIN

The Colorado River and its tributaries within Colorado drain over one third of the state's area. This area receives nearly 60% of the state's total precipitation but has only 12% of its population. Less than 20% of the Colorado River Basin lies inside Colorado, but about 70% of the water in the river at Lee Ferry Arizona (Compact Point) originates in the state.

Originating in the north central mountains of Colorado, the main stem of the Colorado River flows southwesterly, is met at Grand Junction by the Gunnison River, and continues west into Utah. The Yampa and White Rivers flow westward across the northwest quadrant of the state to the Utah border where they join the Green River, another tributary of the Colorado originating in Wyoming. The San Miguel and Dolores Rivers begin near the southwestern corner of the state and flow north along the western border. The San Juan River and its tributaries collect the water in the southernmost regions of Colorado west of the Continental Divide and carry it through northwest New Mexico and southeastern Utah to Lake Powell.

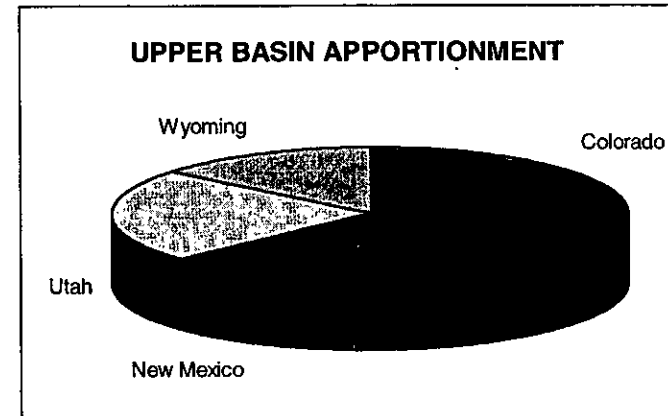
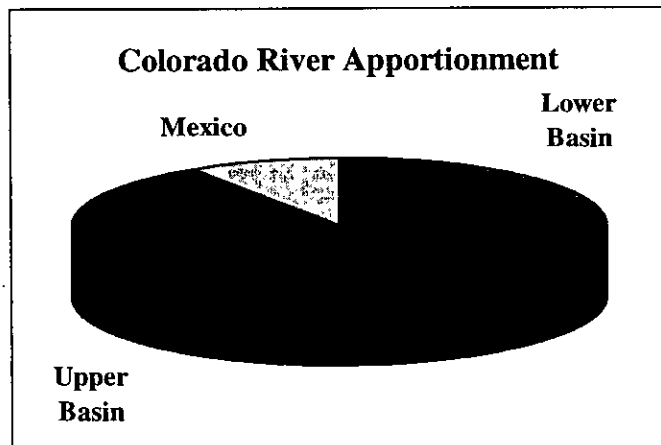
The Colorado River flows through Utah to Lake Powell, thence through the northwest corner of Arizona to Lake Mead. From Hoover Dam it flows southward to Mexico forming the border between Nevada, California and Arizona, and yielding major diversions to central Arizona and southern California. The river is the lifeblood of the southwestern US and its development and management have been the focus of attention by the member states for more than a century. Waters of the Colorado River System have been apportioned by a treaty with Mexico, compacts, and a Supreme Court decree to the seven basin states.



## WATER MANAGEMENT ISSUES

Compacts, an international treaty, a Supreme Court decree and numerous Federal and State laws play an important role in Colorado River water management. The Colorado River Compact of 1922 divided the use of waters of the Colorado River System between the Upper and Lower Colorado River Basin. It apportioned in perpetuity to the Upper and Lower Basin, respectively, the beneficial consumptive use of 7.5 million acre feet (maf) of water per annum. It also provided that the Upper Basin will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75 maf for any period of ten consecutive years. The Mexican Treaty of 1944 allotted to Mexico a guaranteed annual quantity of 1.5 maf. These amounts, when combined, exceed the river's long-term average annual flow.

Another compact, the Upper Colorado River Basin Compact of 1948, divided the consumptive use of waters available to the Upper Basin states in the following proportions: 50,000 AF/yr to Arizona; of the remainder, Colorado (51.75%), New Mexico (11.25%), Utah (23.00%), and Wyoming, (14.00%).



Within Colorado water allocations are based on the Doctrine of Prior Appropriation or the First-in-Time, First-in-Right Doctrine. This doctrine is found in most arid states because when there is too little water to satisfy all users, sharing of the remaining water would be of little value to any user. Also, some guarantee of water is required to secure the value of investments. These appropriative rights are administered by Division of Water Resources (DWR) officials who follow state law and established procedures in administering and allocating water to users according to decreed priorities.

It is of great interest to the State and other water users to be able to assess the impacts of water rights transfers or water resource developments. Water rights in Colorado can be viewed as private property whereby a individual owns the rights to beneficial use of the water. These rights can be changed from one type of use to another or from one place to another, but only if no other water right is injured. Such changes require water court approval. Because changes of agricultural ditch and reservoir rights to municipal use are fairly common, concerns arise over whether a transfer of water will affect the supply available to owners of other decreed water rights.

Colorado is constantly evaluating management of its water resources in response to population and demand growth, droughts and reductions in federal water programs funding. Management and more efficient use of existing supplies is receiving greater attention by both water users and state agencies. Water management issues include:

- Interstate Compact Issues
- Water Resource Planning Issues
- Water Resource Administration Issues

### **Interstate Compact Issues**

Demands for water by the Lower Basin States, beyond their compact apportionment, pose management challenges throughout the Basin. These demands place an additional burden on an already over-appropriated system. A severe sustained drought could impact Upper Basin uses, and cause curtailment of Upper Basin uses in order to meet compact delivery obligations. In response to these pressures, the State of Colorado through the Colorado Water Conservation Board continues to protect its compact entitlements and avoid costly and devious litigation. River and reservoir operating policy modifications can be evaluated to minimize local impacts, shortages and reduce interstate compact conflicts.

### **Water Resources Planning Issues**

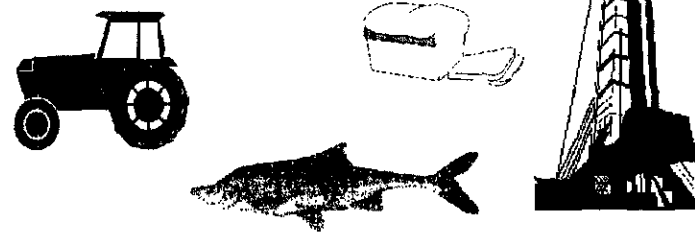
A variety of planning issues arise from increased water demands and environmental protection requirements. Cities are buying more agricultural water rights from farmers and from more distant areas. Endangered fish are being studied to determine flow conditions necessary to protect and recover the species. Water development proposals and water rights transfers need to be reviewed to avoid adverse impacts to established water rights and to support loan authorizations for various projects. International conditions could lead to another rush to develop Colorado's energy resources, and an increase in water demands to support such development. In each case state agencies and water users would review water transfers and instream flow proposals, and in collaboration with the interested parties, seek to identify and resolve conflicts.

### **Water Resources Administration Issues**

The DWR has responsibility for administering the water rights in Colorado's rivers. This is a challenging task made complicated by changing flows and reservoir levels, and increased uses of the state's waters. State water managers are seeking more efficient administration to maximize conservation and prevent waste. Recreation and tourism have become the state's second leading industry in recent years. Water is needed to support fishing, whitewater rafting, and other water-based recreational activities. The water supply available to the different interests can be increased through the use of comprehensive real-time information and prediction tools contained in the Colorado River Decision Support System (CRDSS).

## **CRDSS Purposes**

- Interstate Compact Analysis
- Water Resource Planning
- Water Rights Admin.



## II. COLORADO RIVER DECISION SUPPORT SYSTEM

### MOTIVATION FOR A DECISION SUPPORT SYSTEM

As Colorado enters a new era of water management, cooperation among state agencies, water providers and water users is essential so that informed decisions can be made. A comprehensive decision support system is needed that will provide Colorado agencies, water users and managers a better means for organizing, accessing and evaluating a wide range of information and alternative strategies, and to establish informed and factual positions regarding the major issues.



In 1992, the Colorado State Legislature authorized the CWCB to conduct a needs analysis and feasibility study for a Colorado River Decision Support System. In 1993, the Board was authorized to design and implement the CRDSS. The Governor's Executive Order of July 1992 established the Colorado River Policy Advisory Council and the associated Decision Support System Advisory Committee to address Colorado River matters and provide advice and guidance regarding CRDSS.

### CRDSS GOALS AND OBJECTIVES

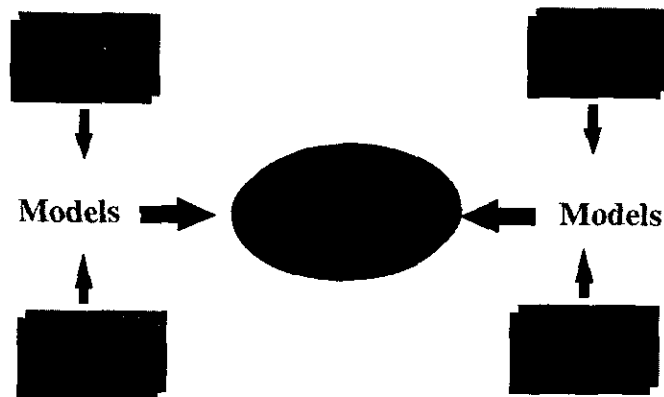
The principal goal of the CRDSS is to provide the capability to develop credible information on which to base informed decisions concerning management of Colorado River water resources. The CRDSS will:

- o Develop accurate, user-friendly databases helpful in the administration and allocation of waters of the Colorado River and its tributaries.
- o Provide data and models to evaluate alternative water administration strategies which can maximize utilization of available resources in all types of hydrologic conditions.
- o Be a functional system that can be used by decision-makers and others, and be maintained and upgraded by the State.
- o Have the capability to accurately represent current and potential Federal and State administrative and operating policies and laws.
- o Promote information sharing among government agencies and water users.

The CRDSS will consist of databases and models which will provide improved data and decision making capability for many critical Colorado River planning, administrative and operational issues. The CRDSS is centered around databases containing historical information on streamflow, climate and water uses, as well as tabulations of water rights and water management policies. Data are keyed to locations in the river basin using a geographic information system. This computer-based system will allow decision makers to access water resource data and to simulate potential decisions and policies, and examine potential consequences related to the following:

- o **Interstate Compact Policy**, including evaluation of alternative reservoir and river operating policies, determination of available water for development, and maximization of Colorado's apportionment.
- o **Water Resource Planning**, including development and use of a water resource planning model (i.e. new projects, water exchanges, operating plans) and evaluation of impacts of instream flow appropriations (e.g., endangered fish flow, minimum flows).
- o **Water Rights Administration**, including optimization of water rights administration, on-line sharing of information between water users, and administration of water rights within compact allocations (i.e., alternative strategies of administration which will enable the maximum use of available resource).

### CRDSS DATA-CENTERED CONCEPT



## III. COLORADO RIVER DECISION SUPPORT SYSTEM PROJECT

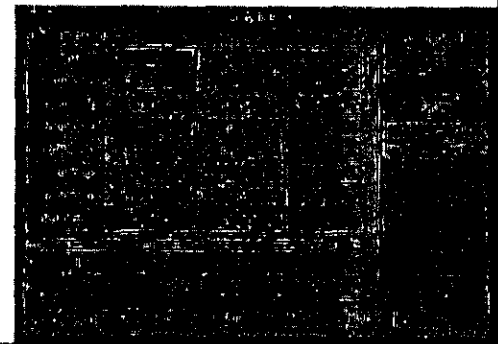
### PROJECT ELEMENTS

Colorado River Decision Support System (CRDSS) project elements have been organized into work tasks that, when completed, will dovetail into a computer system which fully addresses the original goals. To achieve an effective, user-oriented CRDSS, the development team will focus on five critical elements.

#### 1. DATABASE DEVELOPMENT

The data-centered architecture recommended for the CRDSS makes the database a critical element of the system. The database will include a relational database management system (RDBMS) and a geographic information system (GIS). The RDBMS will be used to store information suited to tabular formats (e.g., flow records, diversion structure owner), and will interface with the DWR's HYDROBASE which is under development by the DWR. The GIS will allow efficient storage, retrieval, analysis and display of spatial information (e.g. irrigated lands). Irrigated acreage is being delineated on aerial photos by the USBR and field checked by the DWR in a CRDSS related effort.

- Streamflow records
- Diversion records
- Water rights
- Climate data
- User data



## 2. MODELS

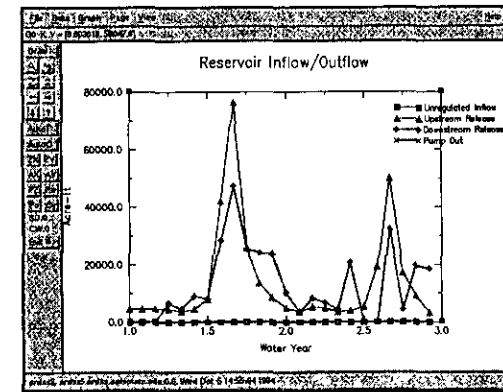
Computer models enable the simulation of the river system, so that possible alternate management scenarios can be evaluated. Emphasis in the first 2 years will be placed on developing a Colorado River Basin Simulation Model, a Water Resource Planning Model and a Consumptive Use Model.



The Colorado River Basin Simulation Model (Big River Model), presently being developed by the Bureau of Reclamation, will be used to evaluate river and reservoir operations throughout the Colorado River System and allow examination of present and future interstate compact policies and operating criteria.

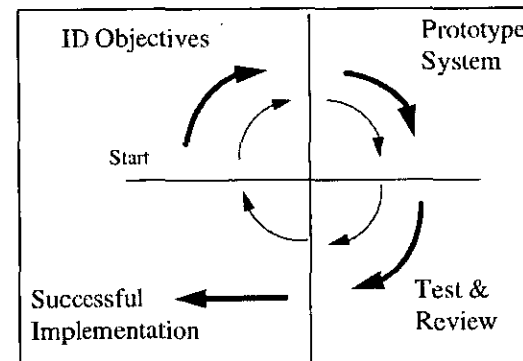
The Water Resource Planning Model will allow the evaluation of existing and proposed water systems within Colorado, including reservoir operations, water rights transfers, exchanges and impacts of instream flows on other resources.

The Consumptive Use Model can be used to calculate the amount of water used by agriculture, including crops and livestock by municipal, domestic and industrial users and depletions from other miscellaneous uses. These estimates are central to determining present and future uses of compact entitlement and water resource development. Accepted models for these purposes already exist, and will be used in the CRDSS.



## 3. SYSTEM INTEGRATION

The wide variety of water resource data and computer models that are under development for the CRDSS project need to be integrated into a cohesive functional system. System integration activities are the "glue" that makes a system of the individual components work. A primary focus of System Integration is the development, communication and maintenance of design standards so that the individual components have a similar 'act and feel' and such that those individual components can be accessed through common interfaces. System Integration occurs throughout the spiral model of software development and enhancement.



#### 4. USER INVOLVEMENT

The intent of the user involvement program is to solicit users' input into the design and development of the CRDSS, and to provide training in its use. User involvement helps ensure that the system meets users' needs and facilitates their acceptance and continued use of the system. The user involvement program includes installation of prototypes on the Briefing Room system at the CWCBC offices, meetings, workshops, and development of tutorial materials. The Briefing Room is open to the public and interested persons are invited to review the CRDSS prototype.

- o **Information Products**

- o **Review and Feedback**

- o **Enhance Communication**

- o **Policy Analyses**

#### 5. DOCUMENTATION

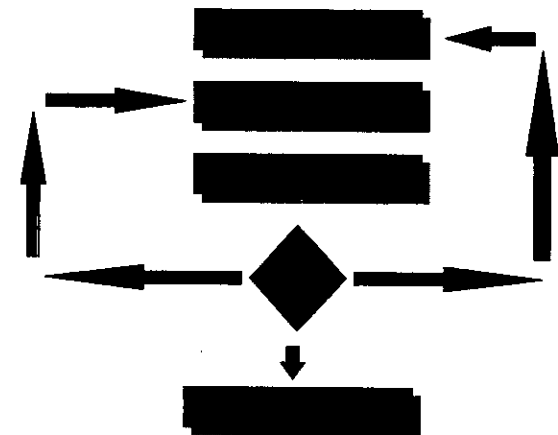
Software documentation (on-line and written) will be an ongoing task throughout CRDSS development. Documentation will be critical to the long-term success of the system and will provide the State with complete information for maintenance and upgrading of the CRDSS. Objectives of the documentation effort are to provide a feedback mechanism early in development, facilitate sharing of software between developers, support system maintenance and future development, and provide basic training materials.

#### APPLICATION SCENARIOS

The utility of the CRDSS can be illustrated by describing candidate scenarios for its application. An application is cast in the context of a user accomplishing her/his job in addressing a particular water management issue. To illustrate, three examples are described below:

##### Scenario Using Spatial Database - Determine Irrigated Acreage

The spatial database functions of CRDSS could be used to review one or more of the data sets incorporated into the CRDSS. For example, a State Legislator may request that the DWR determine the irrigated acreage in their district. The DWR engineer can use the Spatial Data Browser to display a map of irrigated acreage at any location in the Colorado River Basin in Colorado. The engineer could display the regional map, select a subpart of the region pertaining to the area of interest, and display the irrigated lands for that area. Total irrigated acreage for the selected area can then be computed and a table of all irrigated acreage and crop types printed out.



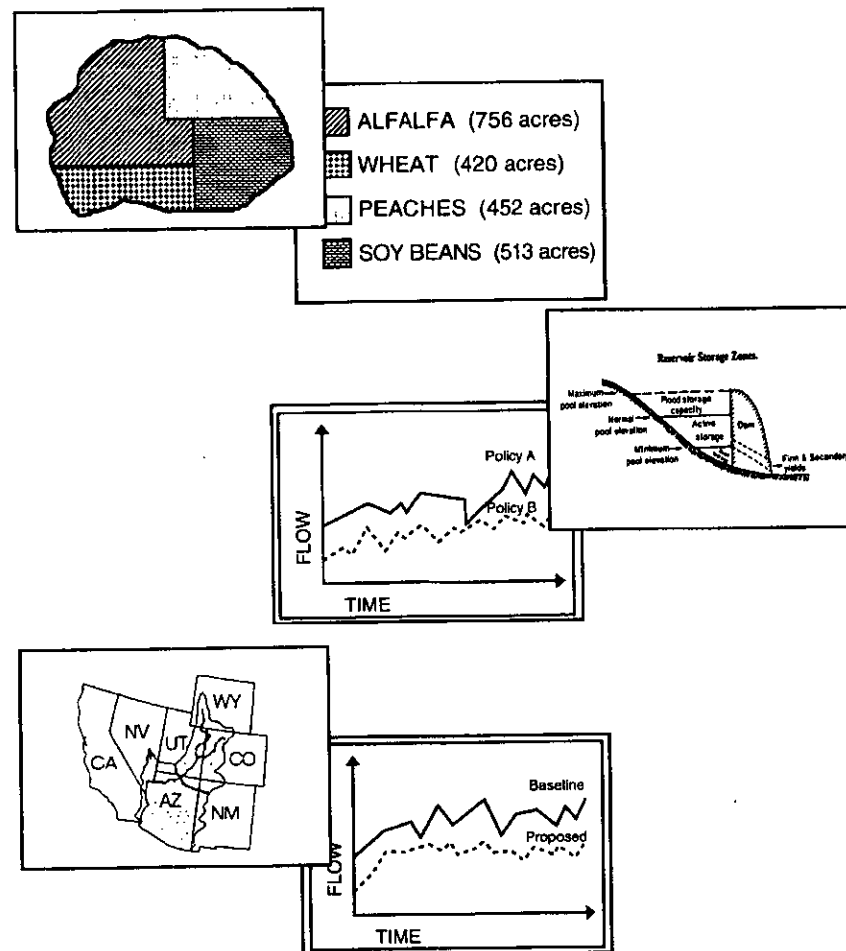


### Scenario on Water Resource Planning - Evaluate Basin Development Proposal

The water resource planning model of CRDSS could be used by CWCB personnel to evaluate a proposed water project on a river on the western slope. The CWCB personnel could identify a level of project development that would not adversely impact decreed water rights and that establishes the project's feasibility on a technical and economic basis. Information development actions can be performed using data management and modeling functions accessed through the CRDSS interface. The Map Utility can be used to identify possible locations for development. A development plan can be defined using a spreadsheet utility to compile and edit water rights priorities, amount, and timing. These data can then be merged with the other basin water rights and baseline conditions to establish input to the Water Resource Planning Model. An overplot of the time series output for the baseline or comparison case can be obtained to assess the impact of the proposed project on other water resources.

### Scenario on Evaluating Operational Strategies for the Colorado River

The Colorado River Basin Simulation Model can be used to evaluate the impact of modified operating criteria on reservoir elevations and contents, on water supply, power generation, Upper Basin Yield and various other system components. For example, the impact of adopting various Lower Basin shortage and surplus criteria can be modelled to determine their impact on Upper Basin reservoir elevations and contents, and Upper Basin yield, both on a short and long term basis. This would allow policy makers to make a decision on this issue based on sound technical information.



## **DEVELOPMENT TEAM**

CRDSS development is sponsored by the Colorado Water Conservation Board (CWCB) and the Division of Water Resources (DWR) under the overall guidance of the Department of Natural Resources. The DNR administers programs dealing with water, forests, parks, wildlife, minerals, geology and development of a state resource policy. It also coordinates natural resource activities. The CWCB formulates and implements policy with respect to water development programs, administers flood plain regulations and water project construction funds, and appropriates minimum instream flow water rights. The DWR has overall responsibility for administration of the State's surface and ground waters through the seven water divisions. The Division Engineers act under the supervision of the State Engineer to enforce the laws of the State relative to the distribution of water. Water divisions comprising the tributaries of the Colorado River basin include Divisions 4 through 7.

The CRDSS Project Management Team consists of a contract Project Manager and senior staff of the CWCB and DWR. A Technical Advisory Committee of major Colorado River water users is helping guide the Project. Mr. Ross Bethel is the State's CRDSS Project Manager. Mr. Bethel is experienced in Colorado water resources engineering and has authored computer programs similar to those required for the CRDSS. Key senior management team members include Gene Jencsok (CWCB) and Dick Stenzel (DWR), both of whom have been instrumental in developing the CRDSS concept. Ray Alvarado (CWCB) and Ray Bennett (DWR) are contributing members of the management team.

A consulting team headed by Riverside Technology, inc. of Ft. Collins was selected in January 1994 to design and develop the CRDSS. Dr. Larry Brazil is the RTi Project Manager. RTi has broad experience in the development of computerized systems for river basin management. RTi heads a development team that includes water resources and computer systems professionals from Colorado State University (modeling and databases), W.W. Wheeler and Associates, Inc. (water resource planning), and the University of Colorado at Denver (user involvement).

## **Technical Advisory Committee**

The State has established a Technical Advisory Committee (TAC) to provide guidance and feedback to the CRDSS development team. The TAC is headed by CWCB Board Member David Harrison and includes representatives from the following organizations:

### State Agencies:

Dept. of Natural Resources - (J. Lochhead, Executive Director)  
Colorado Water Conservation Board - (C. Lile, Director)  
Division of Water Resources - (H. Simpson, State Engineer)  
Information Management Commission

### Water Users:

Colorado River Water Conservation District  
Denver Water Department  
Northern Colorado Water Conservancy District  
Arapahoe County  
Southeastern Colorado Water Conservancy District  
Colorado Springs  
Environmental Defense Fund  
Northwest Council of Governments  
City of Aurora  
Southwestern Colorado Water Conservation District

### Federal Agencies:

US Bureau of Reclamation  
US Fish and Wildlife Service

Technical Subcommittees within the TAC have been formed to assist CRDSS development in the major areas of: 1) databases, 2) water resource planning model, 3) consumptive use model, and 4) user interfaces. Members of the TAC, State representatives, and experts from the engineering community are participating in the Technical Subcommittees.

## DEVELOPMENT SCHEDULE

### Feasibility Study

(November 1992 - January 1993).

A CRDSS needs analysis and feasibility study has been completed which provides a plan for the development and continuing operation and maintenance of the CRDSS. It contains an inventory of the various needs for such a system as communicated by a wide variety of water users, and describes the models, data, user interfaces, and system architectures required to support these needs. Preliminary cost estimates for the CRDSS were also made.

### Design and Development (1994-1998).

#### Phase I (January 1994 - May 1994).

Phase I was the discovery, evaluation, and preliminary design period of the CRDSS project, and was approximately 4 months in duration. Phase I involved an inventory of existing databases, basin simulation models, water resource planning models, and consumptive use models. After the inventory was complete, databases and models were evaluated. The products of Phase I were a database roadmap, and recommended models for basin simulation, water resource planning, and consumptive use. The data required for the models were identified and cross-referenced against the database road map.

#### Phase IIa (May 1994 - January 1995).

Phase II consists of the remainder of Years 1 (Phase IIa) and 2 (Phase IIb). The early part of Phase II consists of detailed design and model porting. The latter part involves implementation of the models and population of the databases.

The CRDSS database will be designed with the flexibility to incorporate additional types and amounts of data. A prototype system will be designed to demonstrate "proof of concept" for the following models (and associated databases): a) USBR "Colorado River Basin Simulation

Model (Big River Model)", b) Water Resource Planning Model, and c) Consumptive Use Model. The Water Resource Planning Model and the Consumptive Use Model will be implemented for the Gunnison River Basin in the prototype system by the Year 1. Also during this period, data collection will be initiated in other river basins to facilitate Year 2 model development.

A key component of the user involvement program is establishment of a prototype computer system in a Briefing Room at the CWCB. This system will allow potential users to test the CRDSS as it is being developed and provide feedback to the CRDSS Project Team.

#### Phase IIb (2nd Year, 1995/1996).

Database and model development efforts will continue in Year 2. Operational water resource planning and consumptive use models will be developed for the Yampa, Upper Colorado, San Juan, White and Dolores Rivers. It is also expected that the USBR Colorado River Basin Simulation Model will be operational at the end of the second year.

#### Phases III and IV (3rd and 4th Year, 1996/1998).

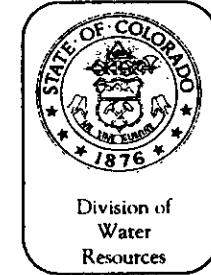
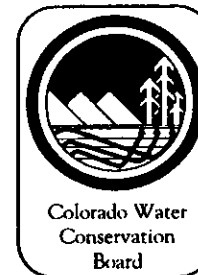
The last two years of the CRDSS project will include real time data collection, the development of a water rights and administrative model, river forecasting model, stochastic flow model and demand forecast model.

## ACKNOWLEDGMENTS

This report was assembled using documents prepared by the CRDSS development team and other sources. Executives and staff of the Department of Natural Resources reviewed the original draft and suggested revisions to better reflect agency policies and procedures. Special thanks is made to the CRDSS State Management Team and the Development Team Task Leaders for their guidance and work in developing this publication.

## SELECTED ACRONYMS

|       |   |
|-------|---|
| AOP   | Annual Operating Plan                               |
| BRM   | Big River Model                                     |
| CRDSS | Colorado River Decision Support System              |
| CRPAB | Colorado River Policy Advisory Board                |
| CRSM  | Colorado River Simulation Model                     |
| CRSS  | Colorado River Simulation System                    |
| CRWCD | Colorado River Water Conservation District          |
| CSU   | Colorado State University                           |
| CWCB  | Colorado Water Conservation Board                   |
| DMI   | Data Management Interface                           |
| DNR   | Department of Natural Resources (State of Colorado) |
| DSS   | Decision Support System                             |
| DWR   | Department of Water Resources (State of Colorado)   |
| ET    | Evapotranspiration                                  |
| GIS   | Graphical Information System                        |
| GUI   | Graphical User Interface                            |
| IMAP  | Information Management Annual Plan                  |
| IMC   | Information Management Committee                    |
| MAF   | Million Acre Feet                                   |
| NCWCD | Northern Colorado Water Conservancy District        |
| RDBMS | Relational Database Management System               |
| RTi   | Riverside Technology, inc.                          |
| SEO   | State Engineer's Office                             |
| TAC   | Technical Advisory Committee                        |
| UCD   | University of Colorado at Denver                    |
| USBR  | United States Bureau of Reclamation                 |



**Colorado  
State  
University**

**W. W. Wheeler and Associates, Inc.  
Water Resources Engineers**

