COLORADO WATER
CONSERVATION BOARD
DIVISION OF WATER RESOURCES

SOUTH PLATTE DECISION SUPPORT SYSTEM FEASIBILITY STUDY

FINAL REPORT

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INTRODUCTION

State agencies, water providers and water users are constantly evaluating management of water resources in response to increases in population and demand, droughts, endangered species issues and reductions in Federal water program funding. A comprehensive decision support system (DSS) is being developed for each of the major river basins in Colorado. These will provide State of Colorado agencies, water users and managers a better means for organizing, accessing and evaluating a wide range of information and alternative strategies for managing their water resources. This, in turn, will help DSS users make informed decisions regarding major water issues and policy positions.

This report presents the results of an investigation to determine the feasibility of developing a decision support system for the South Platte and North Platte River basins in Colorado. This feasibility study was done for both the Colorado Water Conservation Board (CWCB) and the Division of Water Resources (DWR).

The South Platte Decision Support System (SPDSS) will encompass the entire South Platte and North Platte River basins. The South Platte River basin study area includes all of Water Division 1 except Water Districts 49 and 65 that discharge to the Republican River drainage and Water Districts 48 and 76 that discharge to the North Platte River. The North Platte River basin study area includes Water District 47 in Water Division 6 and Water Districts 48 and 76 in Water Division 1. The level of application for the SPDSS will vary between geographic regions from one alternative to the next, due to differences in data and analysis tool needs.

The SPDSS will consist of data that characterize the hydrologic and hydrogeologic features of these basins and tools that provide enhanced water administration and water resource planning capabilities. The purpose of the SPDSS is to assist water users and State officials in developing, managing and preserving the water resources of the North Platte and South Platte River basins for the people of Colorado.

The SPDSS will be the third decision support system developed by the State of Colorado. A decision support system for the Colorado River basin (CRDSS) has been developed and is currently being used in that basin for water management and development purposes by both state agencies as well as local and federal entities. For example, the surface water data sets and associated surface water model (StateMod) are being used by the CWCB to determine sources of water supply for meeting Colorado's requirements for the Endangered Species Recovery Program in the Colorado River basin and DWR is using the administration tool to help in the administration of the Colorado River. A decision support system for the Rio Grande basin (RGDSS) is nearing completion. Applications of that system are expected to include the development of rules and regulations for new well development in the San Luis Valley as well as analysis of the Closed Basin Project and Interstate Compact operations.

Development of the SPDSS will build upon the experience, databases, tools and models already completed for the CRDSS and RGDSS. The South Platte River basin, however, is a more complex river basin from hydrologic, hydrogeologic and institutional perspectives than either the Colorado River or the Rio Grande basins. Consequently, in order to produce a working SPDSS it will be necessary, in some instances, to develop new data and enhance or develop new analysis tools and models.

This feasibility study is based on the needs identified by water users, the CWCB and DWR as expressed in a series of interviews and meetings. An original set of 71 interviews was conducted with water users and State officials in late 2000 and early 2001 to determine these needs. This was supplemented with three public meetings located throughout the basin and numerous individual meetings with water users that have continued throughout the feasibility study. A core advisory group has been formed and met twice. Their guidance is expected to continue throughout development and implementation of the SPDSS. Technical advisory groups are also expected to form during implementation to provide input and guidance on specific SPDSS components.

SPDSS ALTERNATIVES

Based on the needs identified by the water users, the CWCB and DWR, the feasibility study consulting team evaluated the components necessary to provide the specified functionality. In some cases, a need could be addressed purely by a data component (e.g., additional data collection). In other cases, a need could be addressed only through the use of modeling or implementation of a new tool. Where a tool was needed, existing CDSS components were evaluated and enhancements identified, if necessary. Through this process, three alternative levels of development for the SPDSS were identified:

- Alternative 1 gives the water users, CWCB and DWR a "good start alternative" that begins to collect data and develop tools for administration and planning. It includes a data collection program that is required to better manage the system, develops monthly water resource planning tools and provides limited support for improving water administration. It also includes updating the existing SB 96-74 groundwater model of the Denver Basin. Because alternative 1 is the "good start alternative", neither the data collection nor planning tools will meet many of the needs of the CWCB, DWR or water users in the near future nor all the needs listed in Chapter 2.
- Alternative 2 is the "recommended alternative" that provides the water users, CWCB and DWR a cost effective DSS that collects necessary data and develops appropriate tools for administration and planning. Alternative 2 builds on the activities listed under Alternative 1, plus the additional data collection and components that will be needed by the CWCB and DWR to efficiently carry out their respective duties both at the monthly and daily level. Alternative 2 expands the data collection program to include diversions that represent 85 percent of the average recorded diversions annually. Additional monitoring wells will be constructed, providing needed information on the geologic structure and aquifer properties of the groundwater basins. The surface and groundwater planning tools will be expanded to enable water users, the CWCB and DWR to address

present and future water policy, development and administration issues in a timely, efficient and cost effective manner.

- Alternative 3 is the "full-featured alternative" that provides water users, the CWCB and DWR a DSS that collects data and develops tools for administration and planning at a detailed, but expensive, level. Alternative 3 includes everything from Alternative 1 as well as Alternative 2, plus additional data collection and components. The additional data collection includes augmentation plans, substitute supply plans, transfer decree data, installation of additional stream gages and additional monitoring wells. Alternative 3 would produce an SPDSS that would meet nearly all of the expressed needs of the water users as well as all of SB 96-74 recommendations applicable to the SPDSS.

RECOMMENDATIONS

The CWCB and DWR management team and the consultant team consider Alternative 2 to be the most cost-effective alternative that: (1) satisfies the DSS needs as specified by the CWCB and DWR to aid in addressing the current and future water resources issues before them, (2) addresses the expressed needs of water users as determined during the needs assessment interviews, (3) provides a level of data collection necessary to provide the information needed by the DSS applications, and (4) is consistent with the DSS developments completed or under development in other parts of the State.

In general, the data and components for each alternative are inter-dependent. Each alternative identifies and anticipates the modeling and tool needs for the SPDSS so that a data collection program can be developed and implemented during the first two years of SPDSS development. The components identified for each alternative require that a certain level of data collection activities be carried out to meet the needs of that alternative. If Alternative 1 were initially selected and then a later decision were made to implement Alternative 2, additional data collection tasks would be needed, with resultant increases in time and costs due to the loss of economies of scale. This delay would potentially prohibit the CWCB and DWR from addressing water resource issues in a timely and effective way. For example, Alternative 1 includes only the expansion of the existing SB 96-74 Denver Basin MODFLOW model to include the overlying alluvium. If Alternative 1 was initially selected and three years later it was decided that a MODFLOW model for the Lower South Platte Alluvium region was required, three years of needed data collection for this new effort would have been lost. It would then be necessary to design a new data collection program at a higher cost and longer time frame than if Alternative 2 had been selected initially, keeping the CWCB and DWR from making potential policy decisions on using the best available data and tools.

Consequently, the consultant team and the State management team recommend Alternative 2 for implementation. By providing the data and analysis tools outlined in Alternative 2, the SPDSS will enhance the current CDSS and allow for more widespread participation and use through the integration of more user-friendly state-of-the-science DSS technology.

ALTERNATIVE 2 BENEFITS

Development of SPDSS tools and data at the Alternative 2 level of effort, which includes all components and data from Alternative 1, will give the CWCB, DWR and water users more data and robust and flexible tools to use in the development, management and administration of Colorado's water resources.

Data

The data required for SPDSS implementation will serve two uses: (1) as basic information for the CWCB, DWR and water users to fulfill their own specific needs, and (2) as model input and calibration information for use by the State and water users. In this way, benefits to SPDSS users, including both water users and the State, will begin immediately after data collection begins. Alternative 2 will create more complete and accurate database records that will be beneficial to CWCB, DWB and water users. In addition, Alternative 2 will provide tools for viewing, manipulating and analyzing data. Tools developed in Alternative 2 will offer more flexibility to users with different information and analysis needs. The following lists some of the data and data tools that will be produced under Alternative 2:

- More complete and more accurate streamflow, diversion, transmountain diversion, reservoir and water rights data in HydroBase that can be easily accessed and viewed
- Access to real-time provisional streamflow and diversion data with an upgraded administration tool (CWRAT) which will allow data input to spreadsheets
- Provide ready access to the current year's real-time data
- Two new stream gages on the South Platte River at Julesburg and Atwood
- A two-year point-flow stream gaging program on the mainstem of the Lower South Platte River to better understand gains and losses on deliveries of water.
- A two-year point-flow stream gaging program in thin alluvium valleys overlying the Denver Basin aquifer per SB 96-74 recommendations (used in coordination with groundwater component to evaluate the accuracy and validity of groundwater models).
- Eight new satellite monitoring systems installed at key diversion points in the basin including six diversions and two transmountain diversions
- Ability to determine calling water rights on mainstem South Platte River and tributaries
- Computer generated straight line diagrams showing locations and distances of the stream system and diversions
- An expanded database that enhances the ability to document augmentation plans and instream flow data
- Distribution and updates of the State's database, HydroBase, via compact disc (CD)
- Faster and easier data access via the Internet
- Documentation directed to new users in order to make data access easier

- Implementation of training programs to facilitate access to data by water users
- Increased effort in an existing Division 1 program to accurately locate most non-exempt wells within the Division
- Constructing approximately 66 monitoring wells to provide additional geologic structure, aquifer property and water level data for the Denver Basin and Overlying Alluvium Region and the Lower South Platte Alluvium Region, thereby fulfilling many of the recommendations of Senate Bill 96-74 (SB 96-74)
- Performing field studies at approximately 40 sites to characterize streambed conductance
- Conducting aquifer pumping tests at 8 sites using existing pumping wells
- Estimation of municipal well pumping based on user interviews, population data and water use data
- Estimation of irrigation pumping based on crop irrigation requirements which have been calibrated with actual pumping records
- Access to improved consumptive use and irrigated acreage data, including estimates of phreatophyte consumptive use in the basin
- Development of, and access to, transit loss data
- Easier access to additional and improved well location, water level and pumping data
- Expansion of Stream Depletion Factors (SDF) into tributary areas where they do not presently exist
- Development of a Geographic Information System (GIS) database (e.g., streamflows, diversions, wells, irrigated lands and ditch service areas) available to all users
- Improved tools to access data and models, e.g., StateView, StateMod graphical user interfaces, time series tools and groundwater model displays
- More efficient access to data for input to models and tools developed by others, e.g., access to crop coefficients for importation to the South Platte Mapping and Analysis Program (SPMAP)
- Faster access to data as a result of upgraded hardware and software
- Periodic updates and database refreshing
- Graphical and visual displays of data
- Mapping of current land use, including irrigated areas, crop types and vegetation (within the groundwater modeling areas) using multiple satellite images from the 2000 season.
- Mapping of approximately 1500 diversion structures and approximately 500 irrigation distribution systems with water use linked to the irrigated acreage
- Mapping of historic land use for three historic time periods including one each from the 1950s, 1970s and late 1980s.

Administration Tools

Each alternative includes enhancements of existing State administration tools that will increase the ability of the State Engineer to efficiently and effectively administer the State's water resources. However, easier access to more data is included in Alternative 2. Both historic and real-time data, as well as improved tools, will provide practical assistance to the State Engineer and the Division 1 Engineer in administration of the South Platte River. This improved access to better information about the "state-of-the-river" will not only aid the State Engineer but also the CWCB and other users who are accounting for their water rights use as well.

The following administration tools make Alternative 2 the most cost-effective alternative:

- Automated call notification so that water users can efficiently manage their resources
- Improved access to real-time streamflow and diversion data to assist with administration
- Development of improved tools and procedures to allow direct entry of data by users into a provisional real-time database to facilitate river administration
- Better access to historic river call, augmentation plan, substitute supply plan and transfer decree data
- Improved ability to perform bulk analysis of real-time or historic data to help summarize the effects of current conditions or administrative decisions
- Access to animation tools for presentation and visualization of real-time and historic satellite and Water Information Sheet data

Planning Tools

The development of planning tools for the SPDSS fulfills many of the needs of the CWCB and DWR as well as Colorado water users who require tools and models they can trust to develop predictions and determine outcomes of particular events. Alternative 2 will provide better tools and models for:

- Evaluating the success of Platte River species of concern efforts
- Improving the applicability of streamflow depletion factors for groundwater analysis in both the Denver Basin and Overlying Alluvium and the Lower South Platte Alluvium Regions
- Determining the effects of groundwater pumping
- Providing dataset quality assurance/quality control (QA/QC)

The following planning tools and models are included in Alternative 2:

- A basin-wide water resource planning model (StateMod) that will operate on both a monthly and daily time step and includes 100 percent of the basin's consumptive use.

The existing StateMod model will be enhanced to include river call reporting by node and time step, and will incorporate the updated HydroBase data described previously. This sustainable tool will be available to water users, the CWCB and DWR for planning purposes.

- An enhanced groundwater model for the Denver Basin and Overlying Alluvium Region that operates on a monthly time step and utilizes a one-quarter to one-square mile grid. This model will be the original SB 96-74 groundwater model with the addition of the alluvial aquifers, for a total of seven layers. This enhanced model will facilitate better quantitative understanding of flows between the rivers, alluvial aquifer and the underlying Denver Basin aquifers, and among the Denver Basin aquifers. This enhanced groundwater model will allow unique treatment of each Denver Basin aquifer and the overlying alluvium. Estimates of well pumping will be refined significantly compared to the existing Denver Basin model.
- A groundwater flow model of the Lower South Platte Alluvium Region (from the Stateline upstream to approximately Weldona) that operates on a monthly time step. There is no existing groundwater model for this region. Consequently, water users, the CWCB and DWR will now have access to a tool to help in the planning of water resources development as well as the management of water resources in this region.
- Access to historic priority call data via the Internet and CDs that will help the water users understand how the river was administered to better understand future administration
- Addition of new methodologies for calculating consumptive use, such as adding the Kimberly Penman method to StateCU to make the tool more versatile
- Access to current and historic satellite images and maps of irrigated lands throughout the South Platte River Basin. With the historical irrigated land delineated, water users, the CWCB and DWR can better understand growth trends and water development potential as well as areas of potential conflict.
- Access to a GIS network of surface water hydrology, structures and water distribution systems to aid in planning analyses. This gives the CWCB and DWR the ability to quickly modify or view areas where water resource issues arise.
- Graphical and visual displays of model results. This gives the ability to convey to decision-makers at the CWCB and DWR in a clear and understandable way the results of planning analyses.

User Involvement and Training

User involvement during development of the SPDSS is crucial to the development of a practical decision support system that will be used. User training is also necessary to achieve active and widespread use and is included in each of the three alternatives. However Alternative 2 provides the most cost effective and efficient user involvement and training. User involvement will benefit the CWCB, DWR and water users by insuring more active and consistent use of SPDSS tools and data.

Alternative 2 will provide the following user involvement and training tasks and programs:

- On-line web-based training modules for HydroBase, StateView, CWRAT, StateMod, StateCU and the groundwater model
- Database of contacts for system users together with a point of contact for communication
- Newsletters four times per year which discuss the status of the project and advertise upcoming meetings
- SPDSS advisory committee meetings twice a year
- Technical subcommittee meetings throughout development of the project
- SPDSS core group meetings twice a year
- Four user group meetings per year to provide a mechanism for communication of technical topics

COSTS AND SCHEDULE

Estimated costs for each of the three SPDSS alternatives range from $10.3 to $33.3 million dollars as follows:

- Alternative 1: $10.3 million
- Alternative 2: $15.0 million
- Alternative 3: $33.3 million

Estimated costs to develop and implement the most cost effective and efficient alternative is the recommended SPDSS alternative (Alternative 2) at approximately $15.0 million. This includes $5.65 million (38 percent) for data collection, $6.97 million (46 percent) for development of components and $2.37 million (16 percent) for technical review and project management assistance, consultant coordination, and some aspects of user involvement. The SPDSS will be funded in the same manner as the CRDSS and RGDSS projects, from the CWCB's Construction Fund on a non-reimbursable basis. This is a self-generating funding source that will not result in a tax increase.

Efforts will be made to enter into cooperative agreements with the USGS and other agencies in order to reduce total project costs. Cooperative agreements will focus on data collection activities.

The recommended SPDSS alternative is anticipated to be developed over a six-year period in three phases as follows:

- Phase 1 is expected to require approximately two years and will focus on data collection and water administration tools. Certain data collection activities, such as groundwater levels and streamflow gaging, will continue through and beyond SPDSS implementation.

- Phase 2 is expected to require approximately two years and will focus on water budget modeling, consumptive use modeling, enhancements to the groundwater model for the Denver Basin and Overlying Alluvium Region, and surface water modeling. This phase will begin after completion of Phase 1.
- Phase 3, the final phase, is expected to require approximately three years and will include final surface water modeling and development of a groundwater model for the Lower South Platte Alluvium Region.

As described above, Phase 1 allows basic water resources data to be developed, reviewed and disseminated to the public before any significant modeling occurs. In addition, it allows cost effective water administration activities to be implemented as quickly as possible. Phases 2 and 3 include the addition of various modeling tools that will utilize new and existing data in order to perform the complex water resource analyses identified in the *Needs Assessment* in Chapter 2.

OPERATION AND MAINTENANCE

Operations and maintenance is important for any decision support system to ensure continued use and applicability of the decision support system. Adequate operations and maintenance of the SPDSS will benefit both the State and water users by helping to ensure up-to-date databases and components which are applicable to resolution of future problems. Operation and maintenance costs for the SPDSS have been estimated for the period during SPDSS development and the post-development period. Estimated operation and maintenance costs required during system development are included in the project costs outlined above.

The estimated operation and maintenance costs associated with the recommended Alternative 2 level of SPDSS after implementation is completed include a mixture of contract labor and three full-time employees (FTEs) of the State of Colorado at an approximate cost of $420,000 per year. The required full-time employees include:

- One water resource modeler to maintain and apply the consumptive use, water budget, groundwater and surface water models. In addition this employee will be responsible for conducting annual training sessions on key components of the system.
- One GIS and water resource modeling expert responsible for updating the irrigated acreage data at a five-year frequency and assisting in the maintenance and application of the consumptive use, water budget, groundwater and surface water models.
- One FTE responsible for (1) managing the observation and publication of the new groundwater level monitoring stations, and (2) maintaining the Colorado Water Administration Tool, database, network, personal computers and web site.

The existing operation and maintenance (O&M) programs associated with the Colorado and Rio Grande decision support systems have been requested as a standard line item of the long bill from the general fund. However, a legislative subcommittee has directed the operation and maintenance of the existing DSS programs be paid approximately 50 percent from the general fund and 50 percent from the CWCB construction fund. A request to fund 100 percent of the

SPDSS O&M costs from the general fund is expected to occur after development is complete. How the legislative subcommittee will process that request cannot be predicted at this time.

CHAPTER 1

INTRODUCTION

1.1 PURPOSE

State agencies, water providers and water users are constantly evaluating management of water resources in response to increases in population and demand, droughts, endangered species issues and reductions in Federal water program funding. Water management, for more efficient use of existing supply, is receiving greater attention by State agencies and water providers. 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 (DSS) has been developed for use in the Colorado River and Rio Grande Basins. This DSS provides State of Colorado agencies, water users and managers a better means for organizing, accessing and evaluating a wide range of information and alternative strategies. This, in turn, has helped DSS users make informed decisions regarding major water issues and policy positions.

The Colorado Water Conservation Board (CWCB) and the Colorado Division of Water Resources (DWR) have identified a need for and funded the South Platte Decision Support System (SPDSS) Feasibility Study. The purpose of this study is to determine the feasibility of developing and implementing a DSS with appropriate data and analytical tools for making informed decisions regarding management of the water resources of the South Platte, North Platte and Republican River basins in Colorado. Since the original determination to include the Republican River basin, events have occurred which have resulted in removal of the Republican River basin from further consideration in this Feasibility Study.

The results of the SPDSS Feasibility Study will be used by CWCB, DWR and the State Information Management Committee (IMC) to recommend development of the SPDSS to the Colorado General Assembly. The study area for this Feasibility Study encompasses the drainage areas in Colorado of the South Platte River basin and the North Platte River basin. Funding for the SPDSS Feasibility Study has been provided by the CWCB from its Construction Fund under SB99-173.

The SPDSS is intended to support water management decision making for those concerned with South Platte River basin and North Platte River basin water resource issues. The SPDSS must provide State officials, water providers and water users an effective system with which to develop and manage the water resources of these basins. Consequently, the SPDSS Feasibility Study objectives are to:

- Determine the feasibility of developing a DSS for the study area with similar components to the other Colorado Decision Support Systems (CDSS), the Colorado River Decision Support System (CRDSS) and the Rio Grande Decision Support System (RGDSS)

- Identify the scope, data needs, functions and components of a DSS for the South Platte River basin and the North Platte River basin in Colorado
- Identify the costs and schedule required to develop a DSS for the South Platte River basin and the North Platte River basin in Colorado

The initial vision for the SPDSS is to create a data-centered system that can be incorporated into CDSS and that is capable of:

- Supporting, and integrating with, the existing DWR common database (HydroBase) by providing both historic and real time data required by water users, water managers and State officials
- Providing water budgets for the South Platte River and North Platte River basins in Colorado
- Providing more useful and more efficient tools for the State Engineer's Office to administer water rights in the basin
- Providing more useful and more efficient water planning and accounting tools for water managers and water suppliers to effectively manage their water resources

Accordingly, the SPDSS will need to accomplish the following:

- Provide data required to fulfill the direct data needs of water users, water suppliers, water managers and State officials, as well as provide the appropriate data needed for the required analytical tools. Required data for use in analytical tools will be collected through an initial data collection effort, expected to last two to three years. Analytical tool development will not begin until at least the second year of SPDSS development.
- Provide comprehensive, accurate and user-friendly databases of required data compatible with the HydroBase database
- Provide data and analytic tools to evaluate proposed alternative water resources projects and management plans. These data and analytic tools should (1) facilitate development of projects, plans and strategies that optimize the use of available resources for a range of hydrologic conditions; and (2) provide for development of efficient and effective water projects and management strategies.
- Provide real time data and analytic tools to State officials for efficient administration of water rights according to State water law
- Provide real time data to water managers, suppliers and users for accounting purposes
- Provide a functional, integrated system that can be efficiently maintained and upgraded by the State in the future
- Have the capability to accurately represent current and future Federal and State administrative and operational policies and laws
- Promote information sharing among government agencies and water users

- Respond to the recommendations detailed in the April 1998 Senate Bill 96-74 study, *Denver Basin and South Platte River Basin Technical Study* (Colorado Water Conservation Board and State Engineers Office 1998).
- Have the capacity to be an extension of, and compatible with, the existing CRDSS, and the nearly complete RGDSS
- Respond to those situations and concerns in the study area which differ in some respects from the Rio Grande and Colorado River basins; e.g., multiple groundwater systems, increased urbanization of agricultural lands and the consequent transfer of irrigation water rights to municipalities, increased runoff from impervious areas in rapidly urbanizing portions and lawn irrigation return flows

1.2 BASIN CONDITIONS

1.2.1 South Platte River Basin

The South Platte River basin begins in the South Park area of the Rocky Mountains in central Colorado and flows southeast to near Divide, Colorado (see Figure 1-1). Here the river turns sharply northeast and flows through the Front Range via Waterton Canyon, where it emerges on the plains of the Colorado Piedmont southwest of Denver. Continuing its northeastern course, the South Platte River flows through Denver to near Greeley, Colorado, where it bends eastward to Sterling, Colorado and North Platte, Nebraska. There it joins the North Platte River to form the Platte River after flowing a distance of 442 miles from its source (U.S. Geological Survey 2000). Major tributaries of the South Platte include Tarryall Creek, the North, Middle and South Fork of the South Platte, Plum Creek, Bear Creek, Cherry Creek, Clear Creek, St. Vrain Creek, the Big Thompson and Cache La Poudre Rivers. Major reservoirs on the mainstem of the South Platte River include Antero, Spinney Mountain, Eleven Mile Canyon, Cheeseman and Chatfield. There are no on-channel reservoirs below Chatfield Reservoir, but there are a number of off-channel reservoirs that fill from the South Platte River.

The South Platte River basin has a continental type climate modified by topography in which there are large temperature ranges and irregular seasonal and annual precipitation (U.S. Geological Survey 2000). Mean temperatures increase from west to east and on the plains from north to south. Areas along the Continental Divide average 30 inches or more of precipitation annually which includes snowfall in excess of 300 inches. In contrast, the annual precipitation on the plains east of Denver and in the South Park area in the southwest part of the basin ranges from 7 to 15 inches (U.S. Geological Survey 2000). In general, most of the precipitation falls as rain in the late spring and as snow during late winter, with very dry conditions in between.

The South Platte River basin (see Figure 1-1) within Colorado is located in the northeast section of the State of Colorado and is comprised of 18 counties with a 1999 population of 2,855,181 (Colorado Department of Local Affairs 2001). Of that total, 2,318,178 live in the six-county (Adams, Arapahoe, Boulder, Denver, Douglas and Jefferson) metropolitan area, as compared to 1,854,304 in the six-county area in 1990 (Colorado Department of Local Affairs 2001). This

25 percent population increase in the Colorado Front Range urban corridor illustrates the growth which necessitates better water resources planning.

The economy in the mountainous headwaters area of the South Platte River basin is based on tourism and recreation, while the economy in the urbanized south-central region is related mostly to manufacturing, service and trade industries, and government services. The economy of the basin downstream from Denver is based primarily on agriculture and livestock production.

Agriculture is the predominant water use in the South Platte River basin. Approximately 2.0 million acre-feet per year of surface water are used for irrigation of approximately 1.1 million acres (Colorado Division of Water Resources 1994 and 1998a). Average annual flow of the South Platte River at Julesburg, Colorado is approximately 394,000 acre-feet, thereby indicating that South Platte River water is used and reused several times within Colorado before it leaves the State (Colorado Water Conservation Board 2000).

1.2.2 North Platte River Basin

The North Platte River basin (see Figure 1-1) drains the north-central portion of Colorado and consists of the North Platte River and two tributaries, the Laramie River and Sand Creek, which originate in Colorado and join the North Platte River in Wyoming. The Michigan, Illinois and Canadian Rivers, and Grizzly Creek are tributaries to the North Platte River in Colorado. This basin is comprised of portions of Larimer and Jackson counties with the majority of the population in Jackson County, which had a 1999 population of 1,810 (Colorado Department of Local Affairs 2001).

Water use is controlled by U.S. Supreme Court decrees for the North Platte and Laramie Rivers. The major water use in the North Platte River basin is for irrigation of approximately 120,900 acres of agricultural land (Colorado Division of Water Resources 1998b).

1.2.3 Hydrogeologic Conditions in the South Platte River Basin

The South Platte River basin groundwater system consists of multiple aquifers including the South Platte alluvium, the Denver Basin system and several Designated Groundwater Basins. A "Designated Groundwater Basin" means the area established by the Colorado Groundwater Commission in accordance with Section 37-90-106 of the Colorado Revised Statutes. There are seven Designated Groundwater Basins including Upper Crow Creek, Northern High Plains, Lost Creek, Kiowa-Bijou, Upper Big Sandy, Upper Black Squirrel Creek and Southern High Plains. Recharge for these basins comes from precipitation and seasonally from streams.

The alluvial aquifer along the South Platte River downstream from Denver and its tributaries can vary in width from 1 to 10 miles and from 5 to 200 feet in thickness. An estimated 8.3 million acre-feet of water is contained in the South Platte alluvium (Hurr et al. 1975). This aquifer is recharged through precipitation, irrigation return flows, canal seepage, and seasonally from flows in the South Platte River and its tributaries. The alluvial aquifer is an important source for irrigation supply.

The Denver Basin bedrock aquifers include the Dawson, Denver, Arapahoe, and Laramie-Fox Hills sedimentary rock formations (see Figure 1-2). The Denver Basin aquifer system contains approximately 470 million acre-feet of water (Robson 1988) with 300 million acre-feet of drainable storage. Estimated total pumping of groundwater from the Denver Basin aquifers in 1996 was 56,000 acre-feet (Colorado Water Conservation Board and State Engineers Office 1998). Natural recharge for these deep aquifers is minimal with the majority originating from outcrop areas. The Denver Basin aquifers are important sources of supply for municipal and industrial purposes.

1.3 WATER ADMINISTRATION AND MANAGEMENT ISSUES

Colorado administers water rights according to the prior appropriation doctrine (first in time, first in right). The decreed appropriation and adjudication dates are the basis for determining which users are entitled to river flow during periods when there is insufficient water for all appropriators. The Colorado State Engineer and staff administer water rights to both surface water and groundwater within the State and the South Platte River basin as decreed by the Division One Water Court in Greeley. Administration in the North Platte River basin of Colorado is divided between Division 1 (South Platte River) and Division 6 (Yampa and White Rivers). The Laramie River and Sand Creek are administered as part of Division One and the North Platte River is administered as part of Division 6.

Water management and administration in the study area have become more challenging in the past few years, due to several factors:

- Increased demand for municipal and industrial water supply along the Front Range has emphasized the need for efficient and effective management and administration
- Difficulty and expense of developing new reservoir storage given today’s environmental regulations
- Transfers of water from agriculture to municipal uses. These and other water rights transfers are becoming increasingly complex in order to fulfill the demand of growing urban areas and industry. Augmentation plans, water exchanges and substitutions have added to the complexity of administration.
- Recent years of seasonal low flow in the South Platte River (e.g., summer 2000) have increased the competition for water supplies for both direct use and for augmentation purposes

The increasing complexity of water administration requires efficient access to real-time diversion and streamflow data together with effective analysis tools.

1.3.1 South Platte River Compact of 1923

This Compact establishes Colorado and Nebraska's rights to use water from the South Platte River. Colorado has the right to fully use water from the South Platte River between October 15th and April 1st every year. During the rest of the year, if the mean daily flow of the South Platte River at Julesburg, Colorado drops below 120 cubic feet per second (cfs) and water is needed for beneficial use in Nebraska, diversion by water rights in Colorado between the western boundary of Washington County and the State line (the "Lower Section") with priorities junior to June 14, 1897 shall be curtailed (Colorado Revised Statutes 1990).

1.3.2 North Platte River Basin Decrees

The decree in Nebraska v. Wyoming [325 U.S. 665 (1945) and 345 U.S. 981 (1953)] equitably apportion water in the North Platte River among Colorado, Nebraska, and Wyoming. In Colorado, these decrees limit:

1. Total irrigation in Jackson County to 145,000 acres
2. Storage for irrigation during any one irrigation season to 17,000 acre-feet
3. Total water exports from the North Platte River in Colorado to no more than 60,000 acre-feet per year on average during any 10-year period

The 1957 Substitute Decree in Wyoming v. Colorado [353 U.S. 953 (1957)] permits Colorado to divert from the Laramie River and its tributaries 49,375 acre-feet per year. The decree does not prejudice the right of either State to exercise the use of the waters of Sand Creek. This decree was a major departure from the original 1922 decree, and stipulated the following provisions:

1. No more than 19,875 acre-feet per year may be diverted by Colorado for use outside the Laramie River basin
2. No more than 29,500 acre-feet per year may be diverted by Colorado for use within the basin, of which not more than 1,800 acre-feet can be diverted after July 31st of each year
3. Any portion of the 19,875 acre-feet per year not diverted by Colorado for use outside the basin can be added to the 29,500 acre-feet per year permitted for use within the basin
4. All waters diverted by Colorado for use within the basin are restricted to irrigation use on lands designated by the court at the time of the decree

1.3.3 Endangered Species Issues

One of the goals of the Endangered Species Act of 1973 is to conserve the ecosystems upon which endangered and threatened species depend. The presence of threatened and endangered species in the North and South Platte River basins has impacted water resources management and development, because water related activities can affect the habitats that the species use.

The Preble's meadow jumping mouse is Federally listed as a Threatened Species, which is affecting development in the South Platte River basin. This species' habitat is not directly related to water flow in the South Platte River, but its occupation of riparian lands adjacent to the South Platte River basin has affected land development, ditch maintenance and water infrastructure development, thus indirectly affecting water resource management and administration.

Four threatened or endangered species in central Nebraska are affecting development and management of the South Platte River in Colorado. Three bird species, the interior least tern, whooping crane and piping plover, use migratory habitat in the Platte River valley between Lexington and Chapman, Nebraska. A fourth species, the pallid sturgeon, is a fish that occupies the lower Platte River below its confluence with the Elkhorn River in Nebraska. The U.S. Fish and Wildlife Service has concluded that habitat for these species has been reduced by water diversions and land use changes, including flow alteration, as a result of upstream water development (Platte River Endangered Species Partnership 2000).

1.3.3.1 Three States Agreement. In 1994, the U.S. Secretary of the Interior and the Governors of Colorado, Nebraska and Wyoming entered into a Platte River Memorandum of Agreement (MOA). An outgrowth of this effort was the development and signing of a Cooperative Agreement (CA) in 1997. Under the CA, the three States and the Federal government agreed to

develop a program to implement certain aspects of the United States Fish and Wildlife Service's (Service) recovery plans for the whooping crane, interior least tern, piping plover, and pallid sturgeon. Specifically, the program would seek to secure defined benefits for the subject species and to serve as a reasonable and prudent alternative to offset the effects of existing and new water related activities within the Platte River basin. The program would also try to help prevent the need to list, under the Endangered Species Act, any additional Platte River basin associated species.

Pursuant to the CA, a Governance Committee with members from the three States, water users, environmental groups, and two Federal agencies has been established to implement the CA. The CA provides a general framework for the development of a program to improve and maintain habitat for these species. The CWCB has worked as a member of the three-state partnership to develop the specific details of the program. The program specifies both water measures in Colorado, Wyoming and Nebraska and land/habitat measures in Nebraska that will be implemented to improve and maintain habitat. One significant benefit of a basin wide program is that it would allow existing and new water uses in the Platte River basin to proceed without additional requirements (beyond the program) under the Endangered Species Act (Governance Committee of the Cooperative Agreement for Platte River Research 2000).

A Water Action Plan has been developed to improve the occurrence of Platte River flows. The Service has developed species target flows and the Water Action Plan is focused on reducing shortages to the target flows by an average of 130,000 to 150,000 acre-feet per year. The first 70,000 acre-feet of water will be provided in part by (1) restoring the storage capacity of Pathfinder Reservoir in Wyoming, (2) establishing an environmental water account in Nebraska's

Lake McConaughy, and (3) utilizing a groundwater recharge and river re-regulation project on the Tamarack State Wildlife Area in Colorado. The plan identifies other water conservation or water supply means for further enhancing flow conditions by an additional 60,000 to 80,000 acre-feet per year from water conservation or new water supply sources within the three States (Governance Committee of the Cooperative Agreement for Platte River Research 2000).

Colorado's portion of the Water Action Plan is known as the Tamarack Plan. The Tamarack Plan includes a variety of activities (both on and off the state wildlife area) aimed at re-timing water from periods when flows are in excess of target flows to periods when there are shortages. For example, at the state wildlife area groundwater can be pumped from the South Platte alluvium up to ponds and recharge areas to re-regulate flows that are in excess of legal rights and physical demands for water in Colorado. The ponds and recharge areas provide instate environmental benefits for Colorado species of concern and other wildlife. A secondary benefit of the groundwater recharge that results from the Tamarack Plan is an estimated increase in flows at the Julesburg gage by an average of approximately 27,000 acre-feet over the flows that would otherwise occur during that period. Water rights for the operation of the components of the Tamarack Plan will be obtained and exercised under Colorado law for beneficial uses in Colorado (Platte River Endangered Species Partnership 2000).

An Environmental Impact Statement (EIS) is currently being prepared for the Platte River program, as well as a range of alternatives as required under the National Environmental Policy Act. Following completion of the EIS, the Federal government and States may agree to participate in a 15-year implementation program.

1.4 DECISION SUPPORT SYSTEMS

The term DSS has become a common phrase used to describe multiple software products and systems that are linked together. A DSS is typically a group of databases and tools that help users make decisions, not by telling them what to do, but by providing data displays, analytical results, and model output that summarize the information that the decision maker needs in order to make a decision. A DSS does not have to be large or complex, but it should provide a timely and relatively complete view of a problem such that it can be addressed efficiently and comprehensively.

1.4.1 DSS Classes

DSS use can be divided into three main classes.

1. Planning DSS
2. Administration DSS
3. Integrated planning and administration DSS

A planning DSS is typically used where water resources development, management and protection are the central issues. Such studies involve reviewing long periods of historical data in order to validate a decision based on the long-term hydrologic characteristics of a basin. Studies may address issues such as ensuring minimum streamflows for fish or ensuring adequate reservoir storage to meet agricultural demands for irrigation water.

A DSS devoted for administration tasks is typically used by state water officials for administering water rights. The administrative component of a DSS relies on real-time data and information to help make daily decisions involving water rights administration. An administration tool must deal with the cumulative hydrometeorological and operational forces that affect a river basin. The increasing complexity of water administration requires access to real-time diversion and streamflow data together with effective analysis tools. The increased complexity of water accounting required for augmentation plans and water rights transfers also requires efficient access by water managers and suppliers to the same real-time data.

An integrated planning and administration DSS provides tools for planning studies and water rights administration. For example, an administrative tool may rely on displays of historical data and the planning model results to indicate the reasonable bounds of a real-time decision. The SPDSS is envisioned to be this type of DSS.

1.4.2 The "What If" Decision Process

Most DSSs are implemented because there is a primary need to answer "what if" questions. The need for this capability may be driven by a number of reasons but is often related to management, environmental and legal issues (e.g., minimum flows for fish, interstate compact issues and water rights adjudication).

In order to implement a decision support process for problem resolution, the problem and the objectives in solving the problem must first be clearly defined. Next, a procedure needs to be defined to analyze or solve the problem. If this cannot be done, then the problem may have to be redefined or broken into smaller components. The final output from the process is one or more tangible products. Quite often, in terms of water resources modeling, these are hydrographs or basin yield reports.

1.4.3 User-Friendly Interfaces for Decision Makers

DSSs are typically developed around a series of databases. The databases can be accessed directly, or through graphical user interfaces (GUI) and analysis tools that are components of a DSS and that provide information to decision makers. This system structure and integration distinguishes a DSS by providing a framework with easy access to databases through user-friendly interfaces. CDSS utilizes this type of data-centered system (see Figure 1-3).

These systems enable users to simply review the data, or run complex analysis software without having extensive knowledge of input and output data structures. DSS linkages to the database allow users to display input and output data via a GUI and to perform data analyses with the visualization tools that are typically an integral part of the interface. The key element of a DSS is the integration of the data-centered system of models, databases, and interfaces to help the user analyze different scenarios. These combinations of data, model output, and data visualization were not previously possible without current computer capabilities. This integration of the DSS components into a logical and easy-to-use framework is the core of the decision making process. Given the complexity of water availability and use in the South Platte basin, the need for a DSS becomes increasingly apparent.

1.4.4 The Colorado River and Rio Grande Decision Support Systems

1.4.4.1 General. As part of the SPDSS Feasibility Study, the consultant team reviewed the CRDSS and the RGDSS to determine the applicability of their components to the SPDSS. This review was conducted to:

- Facilitate the development of compatible databases among the DSSs in order to minimize future maintenance costs and maximize use of existing tools
- Ensure that the tools developed for CRDSS and RGDSS are used to the greatest extent possible in SPDSS in order to improve the cost-effectiveness of SPDSS tool development and future CDSS maintenance

CRDSS and RGDSS are data-centered systems that integrate analysis tools, relational databases and models to help water users and water managers make decisions. The relational database holds structure and station information, including time series, water rights, and geographic data. Key components of CRDSS and RGDSS are listed below:

- A centralized relational database
- Associated spatial databases
- Infrastructure (e.g., a database server, a Web server)
- An intra-network to link the DWR's server in Denver with field offices throughout the basin and the CWCB
- The State of Colorado consumptive use model (StateCU)
- The State of Colorado water resources planning model (StateMod)
- The State of Colorado water rights administration tool (CWRAT)
- The State of Colorado Water Budget tool (StateWB)
- The State of Colorado Groundwater Preprocessor (StateGWP) which includes a spatial and temporal preprocessor and a MODFLOW input preprocessor
- Several data management interfaces (DMIs) to view and analyze data in the relational database
- Satellite connections to support real-time data

- A visual data browser to display GIS coverages
- A web-based database interface to allow Internet users access to the DSS database

The main components are supported by DMIs that take data from the database and reformat it for models and specific data products, such as GIS coverages and river network diagrams. The entire systems for the CRDSS and the RGDSS are documented and are accessible via the Internet.

1.4.4.2 Modifications May be Required for the SPDSS. As indicated above, an objective of this Feasibility Study is to ensure that the tools developed for CRDSS and RGDSS are used to the extent possible in SPDSS in order to improve the cost-effectiveness of SPDSS tool development and future CDSS maintenance. This should be possible in large measure because the CRDSS and the RGDSS were developed as data-centered decision support systems and, consequently, it should be possible with few or minimal changes to utilize many of the components of the CRDSS, and the more recent RGDSS, in development of the SPDSS.

There are, however, important differences between the South Platte River, Colorado River, and the Rio Grande basins that will require modification of some of the components from the CRDSS and RGDSS before application in the SPDSS. Paramount among these differences is the much larger population in the South Platte River basin. Population data for 1999 indicate the counties composing the Rio Grande basin have a population of 48,173, while the counties composing the South Platte River basin have 2,855,181 (Colorado Department of Local Affairs 2001). This difference in population provides indication of the greater competition for municipal and industrial water supply from both groundwater and surface water sources in the South Platte River basin.

1.5 LIST OF KEY REPORTS AND INDIVIDUALS INTERVIEWED

Throughout the Feasibility Study, efforts were made to maximize the use of previous reports and existing data to help define the SPDSS needs. A literature search was performed for publications and databases relevant to the study, including those available from the State of Colorado, Northern Colorado Water Conservancy District, Denver Water, Groundwater Appropriators for the South Platte, Colorado State University and the United States Geological Survey. The most relevant publications were obtained and reviewed. A list of publications reviewed is presented in references sections within each chapter.

Personal and telephone interviews were held from September 2000 to February 2001 with key South Platte River basin water users and managers in order to gather information about the water user needs for a DSS in the South Platte River basin. This process resulted in 35 entities (72 individuals) being interviewed for the Feasibility Study. These meetings and contacts are listed in Table A-1 of Appendix A. In addition, three SPDSS Advisory Committee meetings were held in Loveland, Fort Morgan, and Denver, Colorado. SPDSS Advisory Committee members are listed in Table A-2 of Appendix A. The results of these meetings and interviews are discussed further in *Chapter 2, Needs Assessment*.

1.6 FEASIBILITY STUDY ORGANIZATION

The State of Colorado, through the CWCB, contracted with Brown and Caldwell for project management of the Feasibility Study. Brown and Caldwell, in turn, subcontracted with Riverside Technology, Inc. (RTi); Leonard Rice Water Consulting Engineers; Camp, Dresser and McKee (CDM); and Helton and Williamsen to assist in completing this Feasibility Study. The firms' respective responsibilities are:

- Brown and Caldwell–Project management and technical review
- RTI–Spatial and relational database design issues, system integration
- Leonard Rice–Consumptive use and water budget data, tools and modeling
- Helton and Williamsen–Surface water data assessment for preparation of Data Collection Report (prior to January 1, 2001)
- CDM–Surface water data assessment, tools and modeling for preparation of Feasibility Study (after January 1, 2001)
- CDM–Groundwater data assessment, tools and modeling

In order to achieve the objectives of this study, this team addressed the following tasks:

- Introduction–reviewed available publications and provided an introduction to the Feasibility Study and the study area in sufficient detail to allow the report to be a stand-alone document
- Needs Assessment–met with water users, water providers, and State officials, either independently or in groups, and identified needs to be met by SPDSS
- Data Assessment–assessed the availability and quality of existing data and determined what new data were necessary or desirable to develop an SPDSS that accurately and effectively addresses the needs identified in the previous task. Prioritized new data collection based upon cost-effectiveness in meeting those needs. Identified new data that must be obtained to fill gaps or increase SPDSS accuracy. This information was used to formulate the specifications of the proposed system.
- DSS Components–Reviewed the existing CRDSS and RGDSS systems and identified components that can be used in SPDSS. Identified the components required to develop an SPDSS that addresses the needs identified in the previous tasks in a cost-effective manner. Described the functionality of each component and the data, hardware, and software requirements, as appropriate.
- Alternative Analysis–Developed three SPDSS component alternatives considering needs, data availability, costs, and other appropriate factors. Fully evaluated one proposed SPDSS alternative in consultation with the State and the SPDSS Advisory Committee.

Figure 1-1. North Platte and South Platte River Basins in Colorado

Figure 1-2. Arial Extent of the Denver Basin Aquifers

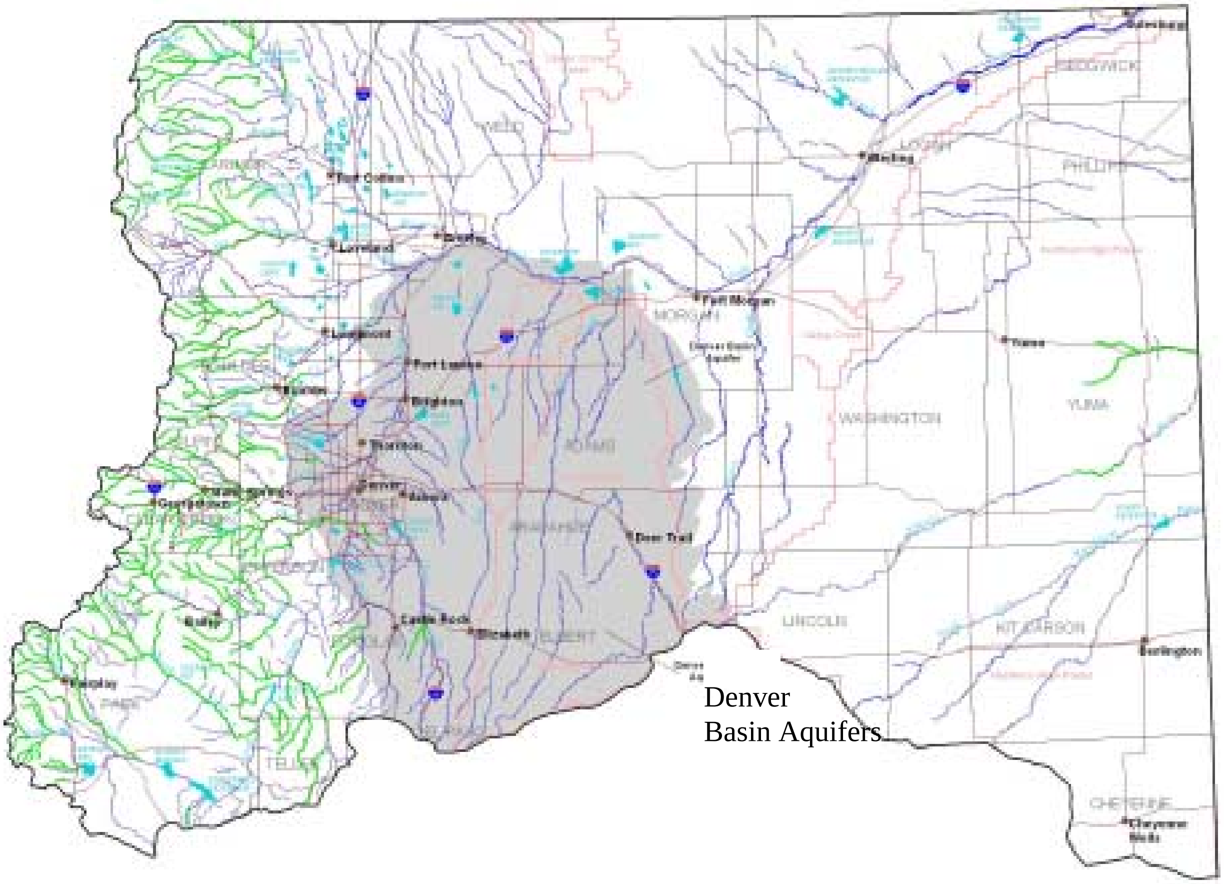
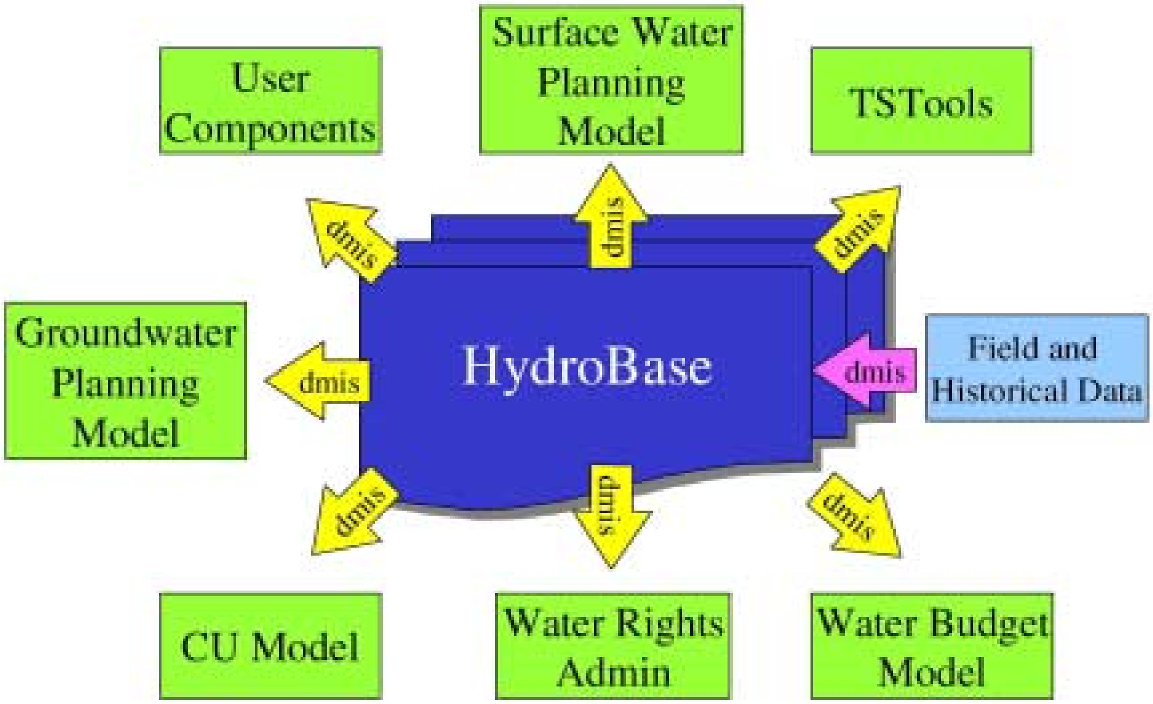


Figure 1-3. CDSS Data-Centered System Integration



CHAPTER 2

NEEDS ASSESSMENT

2.1 INTRODUCTION

To develop a decision support system (DSS), the needs of potential system users must first be identified. Information for assessing these needs was collected through interviews with State officials, water users, water managers and water suppliers in the basin. The consultant team interviewed 35 entities (72 individuals) through meetings and telephone calls, in order to assess their needs for the SPDSS (see Appendix A for list of interviewees). Comments concerning SPDSS needs were also collected at Advisory Committee meetings and at the October 2000 South Platte Forum using a comment sheet developed in coordination with the State. Experience gained from the design, construction and use of the Colorado River Decision Support System (CRDSS) and the Rio Grande Decision Support System (RGDSS) was also drawn upon during the needs assessment process. In addition, explicit needs identified in the April 1998 SB 96-74 study are included.

The interview process identified three types of needs: system needs, application needs and data needs. System needs and application needs are discussed below. Data needs that were expressly identified by users are included in the application category. Other data needs for DSS components and analyses that were identified by the users and consultants are included in Chapter 3.

The needs presented in this section have been paraphrased and categorized but otherwise are presented as they were received in the original interviews. Therefore, some of the needs presented identify a system or application that is already in place. For completeness, these identified needs remain in this section even though their development costs, which are further discussed in Chapter 5, are insignificant.

Several of the expressed needs have been identified as being within the scope of activities associated with other State or Federal agencies or replicating other existing tools. Needs so identified are discussed in Section 2.11 and have been excluded from further consideration for the SPDSS.

2.1.1 System Needs

System needs are those identified needs that are common to a number of users and categories, including surface water planning, water rights administration and accounting, groundwater planning and water budgets. In addition they include standards developed during the development of DSS systems for the Colorado River and Rio Grande. These system needs indicate that the SPDSS should:

- Be a data centered system based on quality data
- Characterize water supplies in the study area

- Characterize water uses in the study area
- Analyze water supply plans in various hydrologic settings
- Support development of creative solutions to water resources management issues
- Support analysis of Compact, instream flow and endangered species issues
- Be fully accessible to both the State and water users
- Provide enhanced visualization of data, analysis and model results
- Provide complete documentation
- Provide training and public information dissemination
- Expand user base to include more classes of users
- Provide easy to use interfaces
- Provide a maintenance/updating program including upgrades to current system technology
- Be based on proven and accepted concepts
- Make maximum use of existing data
- Make maximum use of existing tools
- Have an open architecture that promotes expandability and versatility
- Use state-of-the-art technology
- Conform to existing hardware and software standards adopted by the State
- Not duplicate efforts or products of other State and Federal agencies

2.1.2 Application Needs

Application needs are those that can be fulfilled by a specific application or function of the SPDSS. Application needs of potential SPDSS users as expressed in the series of interviews were allocated to specific categories. These categories were created to facilitate translation of these needs into components and functionality of the SPDSS. These categories of application needs include:

- Visualization, presentation and common data needs
- Surface water planning needs
- Water rights administration and accounting needs
- Groundwater planning needs
- Consumptive use needs
- Water budget needs
- Irrigated acreage assessment needs
- Interstate needs
- Water quality needs

2.2 VISUALIZATION, PRESENTATION AND COMMON DATA NEEDS

One of the primary objectives of the SPDSS is to facilitate ease of use and greater understanding by the users. Based on the interviews and other available information, the following visualization, presentation and common data needs were identified:

- Need for easy access to documentation, data, and products on the CDSS web site, while adhering to the State's web site standards
- Need visualization tools for all components, including data, maps and graphs
- Need a comprehensive, easy to use GIS database for use in most elements of the SPDSS
- Need spatial data and DSS products that are in an easily understood map form. Basic spatial data that are needed include boundaries, land resources, river network, gages, diversion structures, etc., in consistent and commonly used projections and formats
- Need improved user access to spatial data and DSS results through the Internet. These results should be available from the user's desktop using standard viewing tools (e.g., web browser) and without having to transfer large data sets.

2.3 SURFACE WATER PLANNING NEEDS

Surface water planning is a primary function of the SPDSS. The following expressed needs provide guidance for the data and tool development required by entities involved in surface water planning, including water users, water managers and State officials:

- Need to assess effects of historic and future growth scenarios on water use and water supply sufficiency
- Need to assess influence of drought on historic water use and water supply
- Need to investigate opportunities for, and value of, water management strategies including:
  - interruptible supply programs
  - re-operation of existing storage
  - water banking
  - recharge plans
  - instream flow appropriations
  - augmentation and exchange plans
  - water availability for junior priority water rights
  - changed water rights,
  - conjunctive use plans
- Need to assess effects of historic and proposed water management strategies to satisfy Compact obligations in an environment of changing water use
- Need to investigate opportunities for new storage reservoirs

- Need to accurately define historical flow and water use conditions in the South Platte basin, including the flow conditions prior to the introduction of transmountain diversions
- Need to assess effects of irrigation practices (e.g., center pivot sprinkler development) on water use over time
- Need to verify effects of historic and future development of tributary groundwater on surface water users to assure depletions are adequately augmented
- Need to track transmountain water from the sources to the beneficial use, including successive re-uses, and evaluate effects of changes and/or increases in transmountain imports and associated uses on water supplies
- Need to evaluate effects of changes and/or increases in lawn irrigation return flows and urban runoff on water supply
- Need to assess effects of existing or potential instream flow requirements on water use and supply
- Need to investigate effects of proposed water rights changes on instream flows
- Need to assess water management strategies for Section 7 consultations, including aquatic species that may be listed as Threatened or Endangered
- Need of a tool that could help users to assess water management strategies for the Cooperative (Three States) Agreement. (This expressed need does not mean that the SPDSS will evaluate Colorado's response to the Agreement, only that others could use the tools developed for surface water planning for this purpose.)
- Need to assess the effect of proposed reserved rights claims on water uses
- Need to assess and enhance the quality of historic records of diversions, storage, and water rights
- Need to provide historic call records, which have been interpreted to an attainable common standard
- Need of additional data and analysis on historic river losses to assist (1) the Colorado State Engineer in water rights administration, and (2) water users in developing water management alternatives
- Need of additional data and analysis on point flows to assist (1) the Colorado State Engineer in water rights administration and (2) water users in developing water management alternatives
- Need to address the Senate Bill SB-74 recommendation to conduct biannual stream gain-loss measurements in support of Denver Basin groundwater modeling efforts
- Need for renovation and/or addition of 11 stream gages, including 3 new rated control sections in the lower South Platte River
- Need of additional satellite monitoring systems on existing diversion gages for 12 key structures

- Need to utilize data and mapping available from the CWCB Flood Protection Section and share appropriate SPDSS data and mapping with this group

2.4 WATER RIGHTS ADMINISTRATION AND ACCOUNTING NEEDS

Water rights administration is the responsibility of the Colorado State Engineer. Water accounting is performed by water users and holders of water rights to demonstrate compliance with water right requirements. Because the same data are used in many cases for water rights administration and water accounting, these needs are discussed together.

The State Engineer's staff performs daily water rights administration, involving evaluation of past and current flow conditions, data communications, data entry, data storage, and visualization of results. Specific needs of the State Engineer and his staff to facilitate daily administration include:

- Access by State and Division 1 staff to current records of water rights, diversions, reservoir storage, priority calls and other data entered by the State Engineer's staff
- Access to real-time streamflow, snow, and climate data, and related information about historic statistics (return period, percent of average, etc.)
- Ability to enter administrative data only one time in order to account for a number of parameters, including:
    - diversions
    - reservoir storage and releases
    - exchanges
    - transmountain diversions
    - augmentation plans
    - instream flows
    - conjunctive use
    - municipal and industrial (M&I) and agricultural return flows
- Ability to account for the South Platte River Compact and Three States Agreement
- Ability to view more than one day's administration information at a time, including recent and historic administration data
- Ability to export administration information as provisional data for distribution
- Ability to perform water right curtailment analysis
- Ability to notify a list of people via e-mail or other automated method when a priority call is placed
- Ability to check administration data against decrees and augmentation plans
- Ability to enter diversion water type (e.g., native or transmountain) and user
- Ability to account for stream losses and improved estimates of losses
- Ability to create updated straight line diagrams listing structures and water rights

- Improved snowmelt forecasts and local precipitation and streamflow forecasts to assist in water rights administration
- Ability to easily incorporate user supplied data

The following additional needs have been identified to help water users and managers perform water accounting (items from above are not repeated below):

- Access to scanned images of Water Commissioner field books
- Access to CWCB instream flow tabulation
- Accounting for various types of water (e.g., transmountain, storage, direct)
- Access to provisional data (e.g., real-time data before it becomes an official record)
- Access to historic call records in a digital format
- Improved snowmelt forecasts and local precipitation and streamflow forecasts to assist in reservoir operations and water management
- Access to observed and calculated point flows for monitoring instream flow requirements
- Access to permit/water rights data for wells
- Ability to share data among various accounting/management tools used by the State and others

2.5 GROUNDWATER PLANNING NEEDS

Groundwater planning needs have been segregated into two categories (1) those general needs that apply to all groundwater within the South Platte River basin, and (2) those needs that apply only to the Denver Basin aquifer system and overlying alluvium.

2.5.1 General Groundwater Needs

Identified general groundwater needs include:

- Need to develop better estimates of historic and current well pumping
- Need to assess the effect and timing of stream depletions from alluvial well pumping
- Need to quantify water leaving Colorado in aquifers as underflow
- Need to better quantify the effect of recharge and augmentation plans on stream accretions in terms of both timing and location
- Need to evaluate the effect of conjunctive use on streamflow
- Need to extend procedures for quantifying stream-aquifer interaction (e.g., stream depletion factors or SDFs) into areas where they do not currently exist (e.g., SDFs into the Beaver Creek alluvium)
- Need to evaluate the effects on surface water appropriators of additional groundwater development to assure out-of-priority depletions are replaced

- Need to assess effects of land use changes (e.g., urbanization, contour terracing, stock ponds) on groundwater recharge and surface runoff
- Need to evaluate the effect of changes in irrigation practices (e.g., flood to center pivot) on groundwater recharge
- Need to determine whether or not current methods used to estimate stream accretions and depletions (e.g., SDFs) are conservative
- Need to evaluate effect of phreatophytes on groundwater recharge and surface runoff

2.5.2 Denver Basin and Overlying Alluvium System Needs

Needs specific to the Denver Basin and Overlying Alluvium include:

- Need to assess the feasible yields of the Denver Basin aquifers
- Need to address the Senate Bill SB-74 recommendations which include:
  - obtaining more reliable estimates of streambed conductance
  - conducting biannual stream gain-loss measurements
  - improving stream-aquifer simulation procedures
  - collecting and interpreting more accurate well pumping data
  - collecting and analyzing aquifer test data and core samples
  - expanding the groundwater level measurement program
- Need to assess impacts to the tributary aquifers from well pumping in the underlying Denver Basin aquifers
- Need to assess the effects of well pumping in each Denver Basin aquifer on flow in adjacent aquifers
- Need to better characterize well pumping from each of the Denver Basin aquifers

2.6 CONSUMPTIVE USE NEEDS

Consumptive use analysis has been included in prior CDSS efforts in order to quantify basin water uses and losses. This will continue to be an important analysis in order to better quantify and characterize water use in the South Platte River basin. Consumptive use needs include:

- Need to quantify basin crop consumptive use for historic and current time periods to understand how agricultural consumptive use has changed over time
- Need to quantify non-crop consumptive uses and losses due to human influence municipal use, industrial use, livestock use, wildlife use, reservoir evaporation for historic and current time periods to understand how growth has affected water use in the basin
- Need to estimate water use for the following types of water uses:
  - native vegetation
  - creation and maintenance of wildlife areas

- municipal lawn irrigation

- Need to investigate the relationship between crop water use and crop yields
- Need of localized crop coefficients for consumptive use methods
- Need to include the following functionality in crop consumptive use calculations:
  - high altitude crop coefficients or altitude adjustment
  - method for determining application depth
  - Kimberly-Penman method
  - specific CU features currently being used by basin water users
- Need for better understanding for specific ditch systems of how crop demands are satisfied during dry, average, and wet years
- Need for better understanding of water use efficiencies to assist in understanding how irrigation practices affect consumptive use and available return flows
- Need a tool interface for consumptive use analysis that:
  - is GIS-based
  - is easy to use
  - has easy to understand file management
  - includes access to Penman-Monteith calculation method
- Need of a tool for estimation of lake evaporation
- Need to include in consumptive use tool a consumptive use based procedure for estimating groundwater pumping to provide a comparison with other methods currently used by basin water users for estimating groundwater pumping
- Need to access extent of sub-irrigation for ditch systems

2.7 WATER BUDGET NEEDS

Water budget analysis was included in the RGDSS in order to better understand the interactions of various water uses and the hydrologic cycle, as well as to serve as a "reality check" on intermediate modeling results during the DSS implementation. These same functions will be useful to the SPDSS. Specific needs for development of a water budget analysis in the South Platte River basin include a need to provide historic basin-wide and sub-basin water budgets to understand the interactions among various water uses and sources and how these interactions have changed over time. The water budget should include:

- Gaged and estimated surface and estimated groundwater inflows (including precipitation and basin imports)
- Gaged and estimated surface and estimated groundwater outflows
- Changes in surface and groundwater storage
- Crop consumptive use
- Other non-crop consumptive uses (e.g., municipal) and reservoir losses

2.8 IRRIGATED ACREAGE ASSESSMENT NEEDS

There have been major changes in land use and irrigation practices in the South Platte River basin. An assessment of current irrigation water use, and changes in irrigation water use over the past 50 years, is needed by water users and water providers for water management purposes and for water rights administration by the State engineer. Such an assessment would address the following needs:

- Need of reliable mapping of current and historic land use and irrigated acreage by crop type
- Need to link irrigated areas with their sources of water supply. This will require mapping of ditch systems and well locations with their respective service areas.
- Need an assessment of major changes in land use and irrigation practices (i.e., changes in irrigated areas, transition to center pivot irrigation methods, and conversion of irrigation to municipal and industrial water use)
- Need of a system for mapping and analysis that is dynamic and efficient, fully documented, easily maintained and updated
- Need mapping of native vegetation category

2.9 INTERSTATE NEEDS

Interviews with State officials and water users identified several needs associated with interstate matters:

- Need for data and tools to assist the Colorado State Engineer in administering Colorado's obligations under the South Platte River Compact
- Need the ability to evaluate (1) the effects of water management strategies for Cooperative (Three States) Agreement, and (2) the effects of other future downstream water uses on Compact and Colorado water users
- Need for connection between SPDSS and OpStudy model of downstream Platte River in Nebraska and/or North Platte River in Wyoming
- Need for interaction of SPDSS with Nebraska DSS

2.10 WATER QUALITY NEEDS

Although not currently existing in CDSS, the recognition that water quality and quantity are closely linked has prompted water users to communicate needs related to water quality. These needs primarily include data needs such as the following:

- Need to include a comprehensive database of all existing water quality data in order to aid in water quality investigations, Total Maximum Daily Load (TMDL) modeling efforts and possibly to help resolve quality/quantity issues

- Need for additional flow data along the South Platte River and major tributaries to assist in water quality investigations

2.11 NEEDS IDENTIFIED BUT PROVIDED BY OTHERS

A few of the needs expressed by water users are within the services and products typically provided by other State or Federal agencies. These needs, indicated below, are left to those agencies and are not considered further in the SPDSS Feasibility Study.

- Streamflow forecasts are provided cooperatively by the National Weather Service and the Natural Resources Conservation Service. The needs that have been expressed by water users for forecast information can be addressed through a combination of coordination with responsible agencies and through tools provided in the SPDSS to efficiently access forecast information provided by these agencies. It is not anticipated that a component that performs streamflow forecasting will be included in the SPDSS.

- Water quality issues are handled by the Water Quality Control Division (WQCD) in the Colorado Department of Public Health and Environment. Although the WQCD does not maintain a comprehensive database of water quality data (a need expressed by water users), large quantities of these data are stored and maintained in EPA's STORET database. Most public entities that want to share their data make it available through STORET. Therefore, water quality will not be further pursued as a potential component in the SPDSS.

- As part of ongoing investigations related to endangered species in Nebraska, a number of tools have been developed or refined by State and Federal agencies. In order to not replicate these efforts, SPDSS linkage to out-of-state components (e.g., the OpStudy model or a Nebraska DSS) will not be considered further in the SPDSS. However, the development of the SPDSS will not preclude the integration or linkage of components to external systems or models such as the Nebraska DSS or downstream OpStudy models of the Platte River or the North Platte River.

2.12 SUMMARY

Water users and State officials who will utilize the data and tools of the SPDSS communicated each of the needs outlined in the above sections. These needs require that the SPDSS have both data and analysis components. The data required to fulfill both the direct data needs of the users, as well as the data required for analytical tools, are discussed in Chapter 3. The components required to interface with the user, display data, perform analyses and present results are presented in Chapter 4. Three alternative DSS systems, each incorporating different combinations of data and components, are presented in Chapter 5.

Table 2-1 indicates the locations of responses in Chapter 3 (Data Assessment) and Chapter 4 (DSS Components) to the expressed needs detailed in this chapter.

Table 2-1. Needs Summary and Relation to Data and Components

Needs Category	Data and Component(s)	Appropriate Section of Discussion
Visualization, Presentation and Common Data Needs	GIS Data Collection	3.16
	System Integration Components	4.7
Surface Water Planning Needs	Surface Water Data Collection	3.2–3.5, 3.14
	Surface Water Resources Planning Components	4.2
Water Rights Administration and Accounting Needs	Water Rights Data Collection	3.6
	Water Rights Administration and Accounting Components	4.3
Groundwater Planning Needs	Groundwater Data Collection	3.7–3.10
	Groundwater Resources Planning Components	4.4
Consumptive Use Needs	Consumptive Use Data Collection	3.11, 3.13
	Consumptive Use Analysis Components	4.5
Water Budget Needs	Water Budget Data Collection	3.12
	Water Budget Analysis Components	4.6
Irrigated Acreage Assessment Needs	Land Use and Irrigation Service Areas Data Collection	3.15
	System Integration Components	4.7
Interstate Needs[1]	Water Rights Administration and Accounting Components	4.3
	Surface Water Resources Planning Components	4.2

[1]Needs dealing with interstate issues will be addressed through data and tools associated with surface water planning and water rights administration.

CHAPTER 3

DATA ASSESSMENT

3.1 INTRODUCTION

A major component of the SPDSS is the ability to provide observed water resource data in a readily accessible and easy to use format; e.g., provide data for data sake. In addition, the filling of data gaps, quality control reviews and the digitizing of selected hard copy information is required in order to allow the SPDSS to provide the types of modeling capabilities identified in *Chapter 2, Needs Assessment*. The purpose of this chapter is to:

- Inventory data sets that pertain to the groundwater and surface water resources of the South Platte and North Platte River basins in Colorado
- Assess the adequacy of these data sets with respect to their spatial coverage, period of record, completeness and reliability
- Determine what additional data need to be obtained for development of the necessary SPDSS data sets and the estimated cost and time required for obtaining these additional data

This inventory, analysis and determination of additional required data is accomplished for the following categories of data:

- Streamflow
- Surface water diversions
- Transbasin diversions
- Reservoirs (physical data and use)
- Surface water rights
- Wells (location and physical data)
- Groundwater pumping
- Geologic structure and aquifer properties
- Groundwater levels
- Consumptive use
- Water budget
- Climate
- Snow survey
- Landuse and irrigation service access (including agricultural statistics)
- Geographic information system

3.2 STREAMFLOW

Streamflow data are important as a basic water resource need and for the water rights administration and modeling requirements. Streamflows throughout Division 1 and Water District 47 (in Division 6) vary due to:

- Source (e.g., rainfall, snowmelt, springs and seeps)
- Interaction with groundwater as reaches gain or lose water
- Direct diversions removing water from the system

- Return flows to the system from irrigation, municipal use and other non-consumptive uses of water

Given the relatively large size of the South Platte River basin, time of travel also represents a significant factor in the variation of streamflows throughout the basin.

Historical streamflow data are a very important component of understanding and modeling of surface and groundwater resources. Historical records are used to (1) establish the baseline hydrology of the basin, (2) define the available surface water supply under a range of hydrological conditions and flood/drought cycles, (3) provide boundary conditions for groundwater modeling, and (4) calibrate water resources models.

Real-time streamflow data are used by the Division Engineers to quantify the flows throughout the basin at any given time. DWR also maintains and operates a number of real-time satellite-monitoring gages on major diversions in the South Platte basin. These diversion gages are used in conjunction with the streamflow gages to more accurately administer water rights. Based on both the flows and the priority of diverting rights, the Division Engineer administers the water rights by identifying those rights that are junior in priority that must be curtailed in order to satisfy rights more senior. Understanding the relationships between flows at various locations along the river and the effect of curtailing water rights diversions on downstream water rights enters into the administration decision making process.

The greater the coverage of streamflow data available, both in terms of spatial coverage and period of record, the greater the understanding of the hydrologic system and the ability to effectively administer water rights and model the operation of the surface water and groundwater systems for purposes of managing South Platte water resources.

3.2.1 Description and Inventory of Available Data

HydroBase is a database that includes streamflow, diversion, reservoir and water rights records that is available through the Division of Water Resources' (DWR) Colorado Decision Support Systems (CDSS). Diversion, reservoir, water rights, and climate data also contained in HydroBase are discussed in subsequent sections of this chapter. HydroBase currently includes records through 2000, and is updated annually by DWR. Table B-1 in Appendix B presents a summary of information for stream gages in the South Platte and North Platte (including the Laramie) River basins. The gages are summarized first by Water District and second by station name. The streamflow data in HydroBase are available on a daily basis.

3.2.2 Data Assessment

The streamflow data assembled in HydroBase are obtained from the U.S. Geological Survey (USGS) and the DWR. Inspection of Table B-1 shows that some of the gages include surface water diversions, return flows, transbasin diversions, storage facilities, or precipitation gages, due to the querying processes used to extract streamflow data from HydroBase. The available streamflow records were reviewed for spatial coverage throughout Division 1 and Water District 47, period of available records, completeness of available records, and data reliability.

3.2.2.1 Spatial Coverage. There are 302 gaging stations in the South Platte and North Platte River basins; 267 in the South Platte and 35 in the North Platte River basin (including six gaging stations in the Laramie River Basin). Stations are located on river mainstems and tributaries throughout Division 1 and Water District 47 and this spatial coverage is adequate for water resources planning purposes. However, the Division 1 Engineer has indicated the spatial coverage is less than ideal for water rights administration needs on the lower South Platte River, the Cache la Poudre River, and Boulder Creek.

3.2.2.2 Period of Records. At least 85 streamflow gages in the South Platte River basin have records extending to 2000, indicating the gages are currently active. Only four streamflow gages in the North Platte River basin (including two in the Laramie River basin) are currently active. Many of the gages have relatively short periods of records and are located on small tributaries to the mainstem rivers in the basin. Out of the total of 302 gages in both the South Platte and North Platte River basins, 29 gages do not have any records after 1949.

3.2.2.3 Completeness of Records. For the period of record at each gage, Table B-1 lists the percentage of daily data that are missing. Of the 302 gages, about 45 are streamflow gages with less than 10 percent missing records for 1950-2000. Approximately 65 streamflow gages have less than 30 percent missing records. Assuming a study period of 1950 to the present, missing daily and monthly data would need to be estimated to provide complete data sets.

3.2.2.4 Reliability of Records. The measurement procedures and preparation of the records are established and accepted in the water community. The records published by the USGS indicate the accuracy of the record by “poor,” “fair,” “good,” and “excellent.” Each qualitative description relates to a statistical degree of accuracy. Reliability is generally considered adequate for modeling purposes; however, the Division 1 Engineer has indicated that three administrative gages on the lower South Platte mainstem (located at Julesburg, Balzac, and Kersey) are not hydraulically stable and require extensive care to improve reliability.

3.2.3 Additional Data Required

As with any water resource study, additional streamflow information is always useful. A complete record of monthly and daily streamflows covering the study period of record and adequately defining the flows over the study basin would be needed for an accurate water resources modeling effort. Evaluation of additional data to support water resources investigations should consider both the cost of additional data collection and the accuracy improvement from the additional data. Potential streamflow-related data collection activities for the SPDSS are discussed below and summarized in Table 3-1 at the end of this chapter.

3.2.3.1 Fill Missing Records for Key Streamflow Gages. Based on the review of data in Table B-1 and interviews with water users, it has been determined that the available spatial coverage of streamflow gages is adequate for development of models of the surface and groundwater resources of the South Platte River basin. The data collection effort for the streamflow data should therefore concentrate on identifying the key streamflow gages in the basin and determining missing streamflow records at these key gages. Missing streamflow records could be filled using the same techniques utilized in the CRDSS and RGDSS.

3.2.3.2 Real-Time Streamflow and Diversion Gages. Real-time streamflow and diversion data are integral to administration of South Platte River water rights. Interviews of the Division 1 Engineer and water users indicate that there is need for eight new streamflow gages to assist in administration of the basin, as well as satellite-monitoring systems on twelve key ditches in the basin. These ditches have continuous recording capabilities but are not currently on the State's satellite-monitoring network. These ditch monitoring systems are needed to provide better information to water users, assist in administering Water District 64 and provide more accurate and timely data from remote transbasin diversions. Table 3-1 at the end of this chapter summarizes the additional real-time stations required to meet the needs identified in Chapter 2.

Real-time streamflow and diversion data are expected to be accessible through an administration tool as part of the SPDSS. This tool could either take a form similar to the Colorado River Water Rights Administration Tool (CWRAT) or the South Platte Water Rights Management System, or simply be an enhancement of these existing tools. Other than the additional streamflow stations indicated in this chapter and real time diversion and call information indicated in subsequent chapters, the administration tool will not require additional streamflow data collection during the Phase I data collection period.

3.2.3.3 Rated Control Section Streamflow Gages. The Division 1 Engineer has also expressed the need, if cost effective, for three rated control sections on the mainstem of the South Platte River to replace the existing gages near Kersey, Balzac and Julesburg in support of the administrative and surface water models. These rated control sections are included in Table 3-1. Streamflow gages are currently operated at these sites; however, extensive care is needed at all three locations to maintain reliability, thereby resulting in significant operation and maintenance costs. For water administration, existing gaging stations have been typically located at Water District boundaries. Unfortunately, many of these locations in Division 1 were not hydraulically stable and "shifts" in the rating curves occur every time the stream rises or falls. This instability is especially problematic because the three gages mentioned above are located below bridges, which constrict the flow and aggravate scour/fill processes. The instability also limits the usefulness of these gages to monitor flood flows because flow at a specific flood stage can vary widely from event to event. Flow data during high water will often show discontinuities because of shifts in the rating curve.

If implemented, the existing gages would be moved away from the unstable cross-sections below bridges, but there would still be the general instability of gaging a sand channel. Establishing a stable rating curve over a full range of low and high flow conditions in a sand channel can be difficult. Discussions with the USGS have indicated a permanent stable rating curve over a full range of low and high flow conditions may not be achievable at a reasonable cost. However the ability to develop an improved rating curve, particularly at the low flows required for Compact water rights administration are realistic. For this feasibility study, potential alternatives to improve measurement accuracy and lower maintenance have been considered, including:

- Grouted rock grade control structure
- Sheet-pile structure
- Dual sheet-pile design
- Flow measuring structure in the primary low flow channel with improvements upstream to direct low flows towards that channel
- Low flow diversion channel to redirect and accurately measure compact deliveries
- Chemical tracer methods
- Radar or sonar measurement methods

Wyoming has had some success with sheet-pile weirs in similar channels on the North Platte River. Also, the DWR is currently working with the Urban Drainage and Flood Control District (UDFCD) to install a rock control on the South Platte River below Henderson. Other methods, including the last two listed above, are currently being investigated by the USGS as possible solutions for difficult gaging locations.

An appropriate solution for establishing a stable rating control is dependent on local site conditions and the application of available technologies to the site. A Conceptual Design Investigation (CDI) could be performed to fully evaluate alternative solutions. Given the importance of the Julesburg gage in administering the Compact, the CDI would focus on that site, though recommendations will be developed for solutions at all three gaging locations. The CDI would include the following tasks:

- Identify and evaluate historic channel and floodplain migration to characterize channel stability using available satellite or topographic mapping, aerial photo analysis, and field reconnaissance surveys of the Julesburg location
- Define extent of current and historic channel morphology
- Identify gaging technologies that are currently available or are under development
- Investigate opportunities for utilizing (and modifying as necessary) existing diversion structures to continuously monitor streamflow
- Evaluate potential effect of gaging technologies on hydraulic characteristics of the existing flow regime (e.g., forcing alluvial flow to the surface by impeding groundwater flow)
- Develop cost estimates for implementing existing candidate technologies
- Evaluate institutional issues (location of site potentially in NE, water rights implications, etc.)
- Develop a technically feasible and legally and financially implementable solution

CDI recommendations could range from building a grouted rock control structure across the entire channel at one, two, or all three gage locations, to modifications of existing diversion structures for streamflow monitoring, to recommending that the State continue on with the existing system until ongoing investigations by the USGS and others are further advanced.

3.2.3.4 Maintenance of New Gages. DWR staff are responsible for the general maintenance and operation of many of the existing streamflow gages and diversion satellite monitoring systems in Division 1. This responsibility would continue with the twelve new diversion satellite monitoring systems and the replacement streamflow gages at the three candidate rated controlled sections. At current staffing levels, up to two additional standard streamflow gages can be maintained by Division 1. Beyond the two gages, however, the additional new standard streamflow gages would be rated, operated and maintained under the SPDSS for the duration of the SPDSS implementation program. After SPDSS implementation, responsibility for the gages would be turned over to the State.

3.2.3.5 Point Flow Stream Gaging. A point flow module or gain/loss module would be an integral part of the surface water planning tool. Additional stream gaging required for the gain/loss studies recommended in the SB 96-74 report is included in Table 3-1. The SB 96-74 recommendations include the measurement of gains and losses in stream base flow in valleys with thin alluvium overlying the Denver Basin aquifer, with measurements done twice per year over a two-year period. This information can be used in coordination with the groundwater modeling component of the SPDSS to evaluate the accuracy and validity of the Denver Basin and Overlying Alluvium Region groundwater model. Approximately 25 gaging sites will be selected in coordination with the groundwater modeling team. Information to be collected from the field and available topographic mapping will include flow, streambed slope, and channel width.

Point flow gaging on the mainstem of the lower South Platte River is also needed by the Division 1 Engineer to better understand gains and losses of deliveries of water down the South Platte River. Four reaches of the river where a gain/loss study is warranted are as follows:

- Jay Thomas Ditch (located upstream of the St. Vrain River) to the gage at Kersey
- Kersey gage to Weldona gage
- Weldona gage to Balzac gage
- Balzac gage to Julesburg gage (state line)

Within each reach, flows would be measured at the endpoints on the South Platte and at all direct inflows to and diversions from the river. Two to four intermediate flows in the river will also be measured for each reach depending on reach length. Overall, there are 15 tributaries which flow to the South Platte River (three of which are presently gaged) and 56 diversions or outfalls associated with diversions and reservoirs. Where gaged records are available, the point flow monitoring program will utilize that data; otherwise, field measurements of flow will be taken. A total of four measurement events will be conducted for the four reaches of the river. The program will take place over two years, with gaging performed during the following distinct periods: late fall (October-Nov) of year one, early spring (March-April) of year two, and late summer of both years 1 and 2 (August).

For both point flow monitoring programs, technical memoranda will be prepare summarizing the data results of the programs and including an analysis of the gains and losses in the tributaries and reaches investigated.

3.2.3.6 Flow Routing Data. To meet expressed needs detailed in Chapter 2, the daily time step operations in the planning model may be enhanced to include flow routing to reflect the time of travel through the system. Additional data collection activities would be required to implement daily flow routing including (1) channel characteristics to establish reach lengths and channel geometry, (2) roughness factors, and (3) slopes along the South Platte River mainstem and major tributaries.

3.3 SURFACE WATER DIVERSIONS

Historical diversion records are important as a basic water resource data need and for use in water rights administration and modeling. Historical diversion records for existing water rights in Division 1 and Water District 47 will be used in water resources planning models for two primary purposes: (1) to estimate baseflows (pre-development streamflows) and (2) to define water demands under future condition or planning scenarios. A complete and reliable source of historical diversion records available to the State and all water users was a need expressed during the interview process.

3.3.1 Description and Inventory of Available Data

HydroBase includes daily diversion records (in cfs) for structures diverting in Division 1 and Water District 47. Table B-2 in Appendix B provides an estimate of the number of direct surface water diversions, categorized by average annual diversion volumes, in each Water District. The reported values in Table B-2 are based on estimates developed from the current HydroBase database for Division 1 and Water District 47. A thorough review of appropriate available records in HydroBase should be conducted during the SPDSS development to verify these summary values in Table B-2 and substantiate if the data represent diversions in Division 1 and Water District 47.

3.3.2 Data Assessment

The available diversion records were reviewed for spatial coverage throughout Division 1 and Water District 47, period of available records, completeness of available records, and overall reliability of the data. Table 3-2 is a general summary of the diversion records adequacy by Water District. Table 3-2 is based on discussions with the staff of the Division 1 Engineer's office and from observation and use of the diversion records. It should be noted that assessment of diversion records for any given structure in a water district could vary significantly from the general assessment presented in Table 3-2 and the discussion below, which analyzes the diversion records for a Water District and summarizes the quality of these records for the entire district.

3.3.2.1 Spatial Coverage. As shown in Table B-2, HydroBase includes records for 7,121 surface water diversion structures in the South Platte River basin and 931 structures in the North Platte River basin (including 135 structures in the Laramie River basin), thereby providing good coverage for basins in Division 1 and Water District 47.

3.3.2.2 Period of Records. Record lengths vary as shown in Table 3-2, with the period of digital records available generally dating back to 1950 and continuing through the present. This period of record should be adequate for water resources planning purposes. As shown in Table 3-2, however, some Water Districts do not include data for significant portions of the 1950-present period of record.

3.3.2.3 Completeness of Records. About 76 percent of the structures in Division 1 and Water District 47 show infrequent records and only 530 structures show recorded diversions exceeding 1,000 acre-feet annually. This 1,000 acre-feet limit was used to provide an indication of the number of larger structures. Of the 7,121 structures in Division 1 and Water District 47, approximately 319 structures have annual diversions of 2,000 acre-feet or greater, representing about 85 percent of the total average annual diversion in Division 1. Approximately 210 structures have annual diversions exceeding 5,000 acre-feet, representing about 75 percent of annual diversions in the Division.

Many of the smaller ditches in the Water Districts have infrequent measurements, especially prior to the 1980s. As shown in Table 3-2, many of the incomplete diversion records exist in the upper South Platte and North Platte River basins.

3.3.2.4 Reliability of Records. Most of the diversion structures are currently equipped with reliable measuring devices such as Parshall flumes. Many of the ditches with diversions in excess of 2,000 acre-feet in the basin have been equipped with continuous recording devices since the early 1960s. In recent years, Division 1 has made an intense effort to require reliable measuring devices on diversion structures. The accuracy of most permanently installed measurement devices is considered good. The accuracy of the records for structures without recording equipment is dependent on the number and timing of spot observations by the Water Commissioner for that District.

For those structures without continuous recorders, the DWR's policy is to record changes in flow only. For example if a diversion of 5 cfs was recorded on June 10th and the next reading was 3 cfs on June 20th, the DWR enter data on June 10th and June 20th. To determine the diversion for the period June 11th through June 19th, the June 10th value of 5 cfs is carried forward. This procedure of carrying data forward is an efficient database practice that has been accepted in numerous Water Court transfers. It is generally acknowledged in the water community as being a reasonable procedure for developing a complete diversion record.

It is assumed that the diversion records have undergone the normal quality control review by the DWR during the process of transcribing records from Water Commissioner field books to the electronic database and are considered sufficiently accurate for water resources planning purposes. On the basis of this review, data for the total water diverted through a given structure are considered reliable. Data for water use are also reasonably reliable. The primary exception is releases from off-stream storage for municipal or irrigation purposes. Data for diversions to storage are usually available because they are administered as part of the river. Measurements of off-channel reservoir releases are typically an owner's decision that are not administered and therefore often go unrecorded. Therefore, the total water supply for a given structure may not be known because the diversion records do not reflect the water supplied by an off-channel reservoir. In addition, coding of the types of water diverted by a given structure, such as reservoir water or water taken by exchange, has not been consistent over the years. Finally, there also exist situations that are so complex that they cannot be described adequately with existing diversion coding.

3.3.3 Additional Data Required

For water resources planning, a complete record of diversions for the study period of record is needed for major structures in Division 1 and Water District 47. The explicit modeling of the major structures comprising 75 to 85 percent of the total diversion in the basin and aggregating minor diversions spatially has been adequate for modeling 100 percent of a basin's consumptive use in the Colorado and Rio Grande River basin DSS models. Because of the relatively greater competition for water from some of the tributaries to the South Platte River (e.g., Clear Creek and South Boulder Creek), it may be necessary to explicitly model more than 75 to 85 percent of total diversions in these tributaries. However, explicitly modeling 75 to 85 percent overall in the South Platte basin will be adequate for SPDSS purposes.

Major diversion structures with average diversions greater than 2,000 acre-feet/year representing approximately 85 percent of the diversions in the basin as calculated from the data shown in Table B-2, will be explicitly modeled. It is anticipated that the remaining diversion structures with average annual diversions between 0 and 2,000 acre-feet per year, including structures reporting infrequent diversion data, will not be explicitly incorporated into the surface water planning tool. Rather, these structures will be combined into "aggregate" structures for modeling purposes. Therefore, it is not necessary to estimate the missing diversions at these smaller diversion structures.

The data collection effort for the diversion data should concentrate on identifying the major diversion structures in the basin with missing data and developing estimates for the missing records at these key structures. Table B-2 shows 319 diversion with average annual diversions greater than 2,000 acre-feet/year. Approximately 25 percent of these diversion structures have some missing diversion records based on the information in Table B-2, spot inspection of the diversion records, experience from working in the South Platte River basin and past experience from the CRDSS and RGDSS. Diversion records will therefore need to be filled for approximately 80 major diversion structures with average annual diversions greater than 2,000 acre-feet/year (see Table 3-1).

3.4 TRANSBASIN DIVERSIONS

Transbasin diversion records are important as a basic water resource data need and for use in water rights administration and modeling. Transbasin diversions represent a major inflow component of the South Platte River. As with surface water diversion records, transbasin diversion records will be used in the development of baseflows and will also be used to define inflows to the basin for future conditions modeling. Transbasin diversion records are maintained by DWR and also independently by owners/operators of the diversions. The need for a complete and reliable source of historical diversion records available to the State and water users also applies to transbasin diversion records.

3.4.1 Description and Inventory of Available Data

There are a total of 19 transbasin diversions in the study area for the SPDSS. Table B-3 in Appendix B summarizes the available records from HydroBase for transbasin imports.

3.4.2 Data Assessment

The available transbasin diversion records were reviewed for spatial coverage throughout Division 1 and Water District 47, period of available records, completeness of available records and overall reliability of the data.

3.4.2.1 Spatial Coverage. The transbasin diversions import water into the South Platte River basin from the Colorado, Arkansas and North Platte (including the Laramie) River basins. Diversion records for the 19 transbasin diversions are included in HydroBase.

3.4.2.2 Period of Records. The periods of record shown in Table B-3 are somewhat misleading in some cases because some of the structures have operated for several more years than the data indicate. For example, Roberts Tunnel began delivering water to the North Fork of the South Platte River in 1964 but the HydroBase records begin in 1974. It will be necessary to rely upon the owners' records for such periods.

3.4.2.3 Completeness of Records. From inspection of Table B-3, the period of record and the data contained in the DWR files, records are not complete for many of the structures. Table B-3 shows the percentage of missing records within the period of record.

3.4.2.4 Reliability of Records. The major transbasin diversions are currently equipped with Parshall flumes or similar devices that accurately measure the flow. The available records identify the point where the imports reach the stream but in many cases do not identify the end user or the delivery point. Many of the smaller transbasin imports have changed ownership and end user. Overall, the quality of the transbasin diversion data will only be adequate after the missing data have been filled or estimated.

3.4.3 Additional Data Required

For water resources planning, a complete record of diversions for the study period of record is needed for transbasin diversion structures in the Division. The HydroBase records should, therefore, be supplemented with historical data available from (1) owners of transbasin diversions, (2) DWR hard copies of transbasin data, and (3) USGS records. Missing records (such as Roberts Tunnel deliveries from 1964-1974) will be filled from the owners' records and from USGS records. If these sources are incomplete, the missing record will be estimated.

Another effort for this task will involve resolving conflicting records. For example, diversions through Roberts Tunnel are measured at the inlet and outlet of the tunnel and the differences are most likely due to seepage and to measurement inaccuracies. Accurate and complete records of the transbasin diversions are important because the deliveries represent foreign water, which in most cases can be fully consumed by first or secondary uses. The information shown in Table B-3 indicates that the 19 transbasin structures have some periods with incomplete records. These missing data need to be filled and daily records need to be obtained if available. Table 3-1 summarizes the additional transbasin diversion data required.

3.5 RESERVOIRS

Historical reservoir records are important as a basic water resource data need and for use in water rights administration and modeling. Reservoirs regulate streamflows and are important components of river systems. Reliable reservoir physical and operational data (e.g., storage, stage and releases) are required to accurately develop baseflows and conduct realistic simulations of the historic and future operations of the facilities and their effect on streamflows in the basin.

3.5.1 Description and Inventory of Available Data

Table B-4 in Appendix B summarizes reservoir storage information that was taken from HydroBase. As with surface water diversions (Section 3.3), the reported values in Table B-4 are based on estimates developed from the current HydroBase database for Division 1 and Water District 47.

3.5.2 Data Assessment

The available reservoir records were reviewed for spatial coverage throughout Division 1 and Water District 47, the period of record available, the completeness of available records, and the overall reliability of the data.

3.5.2.1 Spatial Coverage. In Table B-4 in Appendix B, 2,885 reservoirs are identified in the South Platte River basin and 262 reservoirs in the North Platte River basin, (including the 25 reservoirs in the Laramie River basin). This covers the river basins in Division 1 and Water District 47.

3.5.2.2 Period of Records. From inspection of the data in HydroBase, the majority of the reservoirs have very limited historical storage records available.

3.5.2.3 Completeness of Records. Table B-4 breaks down the number of reservoirs by size and identifies peak storage volumes for the period of record. Only 235 reservoirs show storage volumes that exceed 1,000 acre-feet. There are 50 reservoirs with storage volumes exceeding 10,000 acre-feet and 23 exceeding 50,000 acre-feet, representing 85 percent and 65 percent, respectively, of the total annual storage in Division 1 and Water District 47.

For the South Platte River basin HydroBase does not include elevation-area-capacity information, operating rules for the facilities or identify the end user. Storage deliveries to specific users in many cases are coded in the diversion records only if the storage releases are conveyed to the user via a stream. Of the data sources required for the surface water component of the SPDSS, the reservoir data are the most incomplete.

3.5.2.4 Reliability of Records. The reservoir data in HydroBase are inadequate for SPDSS purposes. HydroBase has very limited information concerning historical storage records, reservoir inflows, reservoir releases, maximum storage capacity, dead storage and stage area-capacity information. No information is available to identify the ownership of the various accounts in a reservoir. Currently, the operating principles of each reservoir are not available in HydroBase. In addition, HydroBase only keeps track of one source for a reservoir, even if there are multiple sources with the same priority.

3.5.3 Additional Data Required

For water resources planning, a complete record of physical and operational data for the study period of record is needed for major storage facilities in Division 1 and Water District 47.

The data collection effort would next concentrate on identifying major reservoir structures (defined as those approximately greater than 10,000 acre-feet) in the basin. Then, DWR personnel and the owners of the selected key reservoirs would be interviewed to collect available hydrologic data, document use of the reservoirs and develop operating rules. The hydrologic data collected through these efforts would be digitized and incorporated into HydroBase and missing historical storage records estimated.

It is anticipated that the surface water modeling effort would be divided into several phases. In the first phase, the major reservoir structures in the basin would be simulated and the smaller reservoir structures would be incorporated into subsequent phases. As shown in Table B-4, there are 50 reservoirs with reported annual storage greater than 10,000 acre-feet. The data for these structures would be gathered. Based on previous modeling experience in the South Platte River basin, several of the reservoirs with capacities less than 10,000 acre-feet have significant impacts on basin operations. Data for these reservoirs would also be collected during SPDSS implementation. It is reasonable to estimate that data would be collected for up to nine of these smaller reservoirs. Table 3-1 summarizes the additional reservoir data required.

3.6 SURFACE WATER RIGHTS

Water Rights records are important as a basic water resource data need and for use in water rights administration and modeling. For the purposes of the SPDSS, this category of data includes (1) the State's water rights tabulation, (2) CWCB instream flow appropriations, and (3) call records maintained by the State. Water rights data form the basis for identifying the key physical and legal attributes of each decreed water right in Division 1 and Water District 47, and this information provides the operational information necessary to both administer water rights and simulate the operation of the rights under historic and future conditions. Water rights administration is one of the more important needs to address in developing and implementing the SPDSS.

3.6.1 Description and Inventory of Available Data

The water rights tabulation is a database maintained in HydroBase by the DWR that contains pertinent aspects of the decreed water rights in Colorado. Table B-5 in Appendix B is a summary of the net water rights in the South Platte and North Platte River basins. The net water rights are the water rights remaining at a given structure after accounting for all transfers to and from the structure. As with the other information extracted from HydroBase, the reported information on net water rights are based on the current water rights database for Division 1 and Water District 47.

The Colorado Water Conservation Board (CWCB) is responsible for the appropriation, acquisition and protection of instream flow and natural lake level water rights to preserve the natural environment to a reasonable degree. Since the creation of the State's Instream Flow Program in 1973, the CWCB has appropriated instream flow water rights and natural lake levels on more than 8,000 miles of streams and 486 natural lakes in the state. Within the South Platte River basin, the CWCB has appropriated 234 instream flow water rights (Colorado Water Conservation Board 1996) on both the mainstem and tributaries throughout the basin. The CWCB maintains its own database for these water rights that should be incorporated into HydroBase during SPDSS implementation.

River call records maintained by Division 1 and Water District 47 indicate for a given time period the most senior water right in a given river reach whose demand is not satisfied. Call records provide an indication of administration of water rights on a river system and are valuable for understanding both historic and future water right settings. In addition, consideration should be given to recording dry stream reaches since these can result in futile call conditions. These data are not currently included in HydroBase.

3.6.2 Data Assessment

The available water rights records were reviewed for spatial coverage throughout Division 1 and Water District 47, the period of record available, the completeness of available records, and the overall reliability of the data.

3.6.2.1 Spatial Coverage. The HydroBase water rights tabulation for Division 1 and Water District 47 contains records for decreed water rights in the South Platte and North Platte River basins, providing sufficient coverage for SPDSS purposes. However it does not include instream flow and natural lake level water rights information.

3.6.2.2 Period of Records. The electronic water rights tabulation includes water rights decreed since the first adjudications in the individual water districts within Division 1 and Water District 47. Call records typically exist for the mainstem of the South Platte River in both hard copy and electronic format since approximately 1930, but only in hard copy format for the South Platte tributaries.

3.6.2.3 Completeness of Records. Information in HydroBase indicates what water rights at a given structure have been transferred to other uses but does not provide sufficient detail to describe the terms and conditions of these transfers. For example, many of the water rights in the South Park area of the Upper South Platte River basin were originally decreed for irrigation, but were transferred to municipal purposes in the 1980s and 1990s. HydroBase indicates that these water rights have been transferred to municipal uses but the database does not describe the terms and conditions associated with these transfers. Similarly, the current structure of HydroBase is not designed to include details of augmentation plans and substitute supply plans. CWCB instream flow appropriations are inventoried in the HydroBase database, but are included in the "other" category of water rights listed and are not uniquely identified. Priority call records in paper form are maintained by Division 1 and Water District 47 for the mainstem of the South Platte, but few records are available for the tributary watersheds.

3.6.2.4 Reliability of Records. Water rights data in HydroBase provide an accurate summary of the water rights originally decreed for a given structure. It is assumed that the water rights tabulation has undergone quality control review by the DWR and is considered sufficiently accurate for the purposes of the SPDSS. The reliability of information on water rights transfers, augmentation plans and substitute supply plans will be dependent on information filed with the court, digitized by DWR personnel and reviewed by owners. The CWCB maintains an accurate and reliable tabulation of instream flow rights. Call records have been maintained by Division 1 and Water District 47 for the mainstem of the South Platte; however, procedures for recording calls and dry river conditions were inconsistent in the early records. Also, the availability of call records for tributary watersheds is inadequate.

3.6.3 Additional Data Required

A complete record of the physical and legal attributes of major operating water rights in Division 1 and Water District 47 would be necessary for developing a complete and accurate water resources model. Although the water rights tabulation in HydroBase accurately defines original water rights, it needs to be supplemented with additional transfer decree, augmentation plan, substitute supply plan, CWCB instream flow and priority call data. Additional water rights data required to meet the needs detailed in Chapter 2 are presented in Table 3-1.

Data collection and assessment of terms and conditions for water rights transfers, augmentation plans and substitute supply plans could be a relatively expensive effort. The level of effort for this task is dependent upon the level of detail that would be incorporated into the surface water model. For purposes of this feasibility study, it is assumed that detailed information would be collected and summarized for 10 to 40 of the largest water rights transfers and augmentation plans (in terms of annual diversions) in Division 1 and Water District 47.

The CWCB tabulation of instream flows should be incorporated into HydroBase, either directly or through linkages to the CWCB's database with querying tools to obtain all information currently in the CWCB database.

Priority call data would be valuable to an understanding of historic and existing water rights administration. Existing call records for the mainstem of the South Platte River, interpreted and digitized by the Division 1 Engineer's Office, would be reviewed and validated prior to placement in HydroBase. Other existing call records would be interpreted and digitized. As part of this effort, various issues concerning the quality of the call records would have to be addressed. This effort does not address the development of call records where none exist.

3.7 WELLS

Well data are important as a basic water resource data need and for use in water rights administration and modeling. In the SPDSS, well data are required to identify the location and determine the capacity and ownership of wells in the basin. In addition, the well data could be used to establish a tie to the water rights. There are well completion and driller's well logs available for most well permit records.

3.7.1 Description and Inventory of Available Data

Publicly recorded well information for the South Platte River basin is available primarily from the State Engineer's Office (SEO) and the Colorado Oil and Gas Conservation Commission. These data vary greatly in content and quality. Much of this information is administrative in nature.

The well data available from the SEO are contained primarily in three databases. The first is the water rights tables in Hydrobase, which includes information on well owner, location, use and adjudication information, including decreed pumping rate and priority date. Over 25,000 well records consisting of absolute rights and conditional rights are maintained in the water rights tabulation for Division 1 and Water District 47. Information from wells located in the Designated Basins is listed in Hydrobase under Water Division 8.

The second database, the well permit database for Division 1 and Water District 47, is larger and includes information on (1) wells that may or may not be listed in the water rights database, (2) wells that are for non-production (e.g., monitoring) purposes, (3) wells that have been abandoned, and (4) wells that have yet to be installed. This database also contains information on owner, location and use. Many of the well permits contain geologic information from the well driller, including a log of geologic materials encountered during drilling, initial water levels, well yield and well completion information such as well depth, well construction and screened or open borehole intervals. There may be some wells listed in one database and not the other, so it will be necessary to combine the databases during SPDSS implementation to obtain a more comprehensive State listing of wells.

The third database is of geophysical well logs. This database is maintained by the SEO Geotechnical Services Branch. It includes information on well permit number, location and owner, formation boundaries, sand thickness, water level and types of logs available. This database contains approximately 4,000 logs for the Denver Basin and Overlying Alluvium Region.

Additional records are maintained by (1) water user groups within Water Division 1 and Water District 47 including, but not limited to, agricultural user groups such as Groundwater Appropriators of the South Platte (GASP), the Central Colorado Water Conservancy District (CCWCD) and the Lower South Platte Water Conservancy District (LSPWCD), and (2) municipal user groups such as Centennial Water District and Willows Water District.

Data available from the Colorado Oil and Gas Conservation Commission are primarily on oil and gas test wells that were drilled during limited development efforts in the basin. Data collected on these wells include geophysical logs, drillstem tests and geologic descriptions of formations encountered.

3.7.2 Data Assessment

The available data are reviewed in terms of spatial coverage, length or period of record, completeness and reliability. The assessment of the available well data are discussed below:

3.7.2.1 Spatial Coverage. Well data are available for all of Division 1 and Water District 47 from the State in its well permits, water rights and geophysical log databases. The databases cover all of the study area.

3.7.2.2 Period of Record. Well data is not a time series, so the period of record does not directly apply. However, permit records are present in the State's permit database that documents beneficial use dating back to 1858.

3.7.2.3 Completeness and Reliability. Well data vary greatly in content and quality. The location information associated with the SEO well permit and water right databases are the primary sources of information for well locations. Experience with the RGDSS has shown that interpretation of this information and association of the well with the land irrigated by the well can be difficult. The difficulties lie in the fact that original well locations are approximate and many wells have been moved or replaced. Also, these records have been collected over a long period where recording procedures have changed. A well permit may contain coarse geologic and hydrologic information in the form of driller's descriptions of formations encountered, casing program, well depth, completion interval, water level and well yield. Not all permits contain this additional information and the permits are not cross-referenced. While the geologic and hydrologic information associated with an individual permit may be acceptable, the consistency of these other data in the permit records is poor.

3.7.3 Additional Data Required

The SPDSS would benefit from a program to verify locations of wells. Such programs are underway both through the SEO Division 1 and Water District 47 office and through GASP. The improved well location data will be populated in the well permit database. The SEO program may take as long as ten years to complete at the current funding rate. Therefore it is recommended additional funding be provided by the SPDSS so that the program could be completed in one to three years.

It would be beneficial to link the well permits database to the water rights database. A procedure and utility program to produce this link were developed as part of the RGDSS effort. The same procedure would be adequate for use on the SPDSS. This process is discussed further in *Chapter 4, DSS Components*.

3.8 GROUNDWATER PUMPING

This section discusses existing information and data needs relating to groundwater pumping from wells. Pumping data can be used to (1) characterize historical water usage, (2) evaluate the location and timing of stream depletions, and (3) assess future water supply options. Pumping information will be used in the groundwater modeling efforts to quantify changes in aquifer water levels, stream depletions and aquifer yields.

3.8.1 Description and Inventory of Available Data

Information on existing well data is discussed in Section 3.7. It is assumed that essentially all higher capacity wells have permits and/or water rights and, therefore, are included in the SEO databases.

A summary of wells by Water District and pumping rates for wells with absolute and conditional water rights obtained from the SEO water rights database is presented in Table B-6 in Appendix B. As shown in this table, wells with rights to pump over 500 gallons per minute (gpm) represent less than 23 percent of the total number of wells but these same wells have the rights to over 88 percent of the water. For greater efficiency it is expected that groundwater modeling and evaluations in the SPDSS will focus on wells with pumping rates greater than 50 gpm. Table B-6 shows that wells with water rights of less than 50 gpm constitute less than 2 percent of groundwater pumping in Division 1 and Water District 47.

There are several State and USGS reports that include estimated historical pumping in (1) the Denver Basin and Overlying Alluvium Region, (2) some of the Designated Groundwater Basins, and (3) portions of the Lower South Platte Alluvium Region; these include Robson (1987), Duke and Longenbaugh (1966), McConaghy et al. (1964) and Schneider (1962). Many of these estimates will be used to cross-check analyses and data collection performed during completion of the SPDSS, however they will not supplant the need to gather existing historic pumping data.

Other sources of well pumping information include GASP, which maintains annual records of approximately 3,000 wells located within the alluvial aquifer tributary to the lower South Platte River from near Denver to the State line. CCWCD estimates pumping from approximately 1,000 irrigation wells. The Bijou augmentation plan involves pumping of approximately 180 wells and the Fort Morgan augmentation plan involves approximately 100 wells. The Cache la Poudre Water Users Association maintains records of approximately 750 wells associated with their augmentation plan on the Cache la Poudre River. LSPWCD maintains records of approximately 60 wells located in the South Platte alluvial aquifer primarily in Logan and Sedgwick Counties. Additional information on wells is maintained by various municipalities, public water suppliers, irrigation and ditch companies, and various water organizations throughout the basin. It is not known at this time, however, how many of these records will be available for use in the SPDSS project.

3.8.2 Data Assessment

The available data are reviewed in terms of spatial coverage, length or period of record, completeness and reliability. The aquifer systems within Division 1 and Water District 47 encompass a wide range of aquifer types, usage and water rights administration.

To facilitate evaluation of the data, where appropriate, the aquifer systems have been subdivided into four geographical regions as follows:

- Denver Basin and Overlying Alluvium Region. Consists of the Denver Basin bedrock aquifers (Laramie-Fox Hills, Arapahoe, Denver and Dawson aquifers) and overlying unconsolidated rock aquifers (alluvium and Designated Groundwater Basins including Lost Creek, Kiowa-Bijou, Upper Black Squirrel, and Upper Big Sandy).
- Lower South Platte Alluvium Region. Consists of the alluvial aquifer of the lower South Platte River.
- Other Designated Groundwater Basins which do not overlie the Denver Basin aquifers (Upper Crow Creek and Camp Creek)
- North Park and South Park Regions

The location and distribution of these aquifer systems is shown on Figure 3-1. Note that not all data assessment discussions required use of the four geographic regions. The four geographic regions were only used in those circumstances where data quality differed between regions. Also note that the mountainous groundwater regions were not included in this assessment. This is because the USGS is currently involved in a program to characterize these mountainous groundwater regions and a duplication of their efforts is not desired at this time.

The assessment of available wells and pumping data is summarized in Table 3-3, using the four evaluation criteria for each geographic area, and discussed in detail below.

3.8.2.1 Spatial Coverage. Virtually all wells pumping significant quantities of water are expected to have well permits on file in the SEO. The spatial coverage of well records is expected to be good in all geographic areas, therefore this portion of the discussion of the data will not require segregation by geographic area. Based on experience in the basin, however, many small capacity wells are not permitted and consequently, the absolute number and location of these wells are unknown. The locations of wells in the SEO database are generally presented by township, range, section and quarter section, with some records provided to the quarter-quarter section or by longitude/latitude coordinates. The SEO is undertaking a program to identify the location of wells that have capacities greater than 50 gpm using GPS technology, so the location information will improve in the future. It is likely that the locations of some wells will be checked when correlating them to individual farms or other points of use.

The coverage of pumping records is limited because the SEO does not collect and/or maintain well pumping data. GASP, CCWCD, municipalities and other water user groups maintain records of pumping but it is unknown if these records will be available for the SPDSS. In addition, the accuracy of the pumping records maintained by these groups varies because some wells are measured directly but most pumping records are estimated based on a variety of techniques. The limitations regarding pumping data are discussed in the following paragraphs.

3.8.2.2 Period of Record. Well records on file at the SEO, which are consistent between geographic regions, extend back to a well's permit or adjudication date. Therefore, well records are good with respect to temporal coverage. Pumping data, where available, range from daily to average annual rates and extend back for periods of varying length. Accordingly, the condition of the temporal pumping record is fair to poor.

3.8.2.3 Completeness and Reliability. Well pumping records within Division 1 and Water District 47 generally are incomplete and of poor quality. For most wells the only available pumping information is contained in either the well permit or water rights databases with very few records available of actual pumping rates. Pumping of municipal and industrial wells within the Denver Basin bedrock aquifers was estimated in 1996 by the SEO as part of the SB 96-74 groundwater modeling effort. Pumping information from that time period would be considered fair for the Denver Basin bedrock aquifers, but poor for the overlying alluvial and Designated Groundwater Basin aquifers. Data for other time periods is considered poor as well.

Pumping records for some wells in the Lower South Platte Alluvium Region are more complete and reliable as a result of the 1969 Water Rights Determination Act. For example, GASP has been reporting their members' groundwater withdrawals on an annual basis since 1982. Other groundwater user groups and ditch and irrigation companies in this area also may have records of groundwater pumping over time. Therefore, groundwater pumping information in this geographic area is fair.

Pumping data from the Other Designated Groundwater Basins and the North Park and South Park Region are almost nonexistent and are, therefore, considered poor. The total number of users and permitted wells in these two areas, however, are limited because of the small populations in each location and the short agricultural season on these high plateaus.

3.8.3 Additional Data Required

Based on interviews with the SEO and water users, the SB 96-74 recommendations and the data review provided herein, a data collection effort is needed to quantify groundwater pumping rates for at least the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions. Pumping evaluations will be needed throughout Division 1 and Water District 47 if models are created for the Other Designated Basins and the North and South Park Regions. These data are needed to (1) determine overall groundwater use within the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions, (2) better quantify deep percolation recharge to the aquifer systems, (3) assess groundwater return flows to nearby streams, (4) estimate aquifer yields, and (5) assist in determining irrigation water supply when both surface and groundwater sources are used for agricultural lands.

It is likely that sufficient pumping data for municipal wells can be obtained directly from the municipalities or can be estimated based on population and demand estimates.

Pumping records are not available for most irrigation wells. This situation exists because many agricultural well users do not maintain pumping records and/or do not have metered wells or pumping data are considered by individual users to be private and are not easily obtained. Accordingly, data collection efforts for the SPDSS should combine methods to estimate pumping data with methods to collect actual historic pumping records. The principal alternative methods for estimating irrigation and agricultural pumping include:

- Use of consumptive use (CU) estimates for crops combined with irrigation efficiency and available irrigation water supply from surface water to estimate historic groundwater pumping for irrigation
- Use of electric power records combined with rating curves for different types and ages of production wells

The approach for the well pumping data collection effort consists of six possible tasks that are described below. These tasks are considered to be part of the future data collection effort, and will be used to evaluate the feasibility of using pumping data versus pumping estimation techniques to support the SPDSS. Costs for performing these six tasks, as presented in Chapter 5, relate to different levels of effort (depending on the alternative) to collect historic data, since historic pumping data records are variable in quality and are not readily available for acquisition and review. The final selection of the groundwater pumping estimation method will not be made until the feasibility investigation (Task 1) is performed during the first year of SPDSS implementation.

3.8.3.1 Task 1–Perform Feasibility Investigation to Select Method for Estimating Historical Irrigation and Agricultural Pumping. A feasibility investigation is recommended during the first year of SPDSS implementation to determine how historical pumping for irrigation and agricultural purposes can best be estimated. This feasibility investigation would be used to evaluate the reliability and completeness of available historical groundwater pumping records and compare these historical data to pumping data estimated by alternative techniques.

3.8.3.2 Task 2–Collect Historical Groundwater Pumping Data. This task would involve interviewing selected groundwater users and compiling, interpreting and analyzing the historical pumping data collected through the interview process. Interviewees would include agricultural, municipal and industrial users. Specific entities that have been identified for interviews include (but are not limited to):

- Agricultural–Groundwater Appropriators of the South Platte, Central Colorado Water Conservancy District, Lower South Platte User Group, Bijou Ditch Company, Morgan Ditch Company, Cache le Poudre River Water Users Association, Riverside Irrigation District, North Sterling and Pruitt Irrigation District, and Julesburg Irrigation District.
- Municipal–Centennial Water District, Willows Water District, Brighton, Thornton, Westminster, Julesburg, Sterling, Ft. Morgan, Ft. Lupton, Watkins, Bennett, Deer Creek, Agate, Brush, Hudson, Roggen, Byers and Larkspur, and South Adams County Water and Sanitation District.
- Industrial–Kodak, Budweiser, Coors, Conoco, Hewlett-Packard, and Cargill

The SEO (in Greeley and Denver) would also be interviewed for purposes of data collection.

3.8.3.3 Task 3–Collect and Analyze Existing Power Records. If the power record based method for estimating historic agricultural and irrigation pumping is selected, based on the Task 1 feasibility investigation, it would be necessary to collect power record data. These data, when coupled with pump rating curves, would be utilized to estimate groundwater pumping both on an annual and seasonal basis.

Given that there are an estimated 15,000 wells with capacities greater than 50 gallons per minute (gpm) and approximately 5,700 wells with capacities greater than 500 gpm in Division 1 and Water District 47, this is expected to be a time consuming and complex effort.

3.8.3.4 Task 4–Obtain Well Rating Curves. For power records to be used to estimate pumping, it would be necessary to have acceptable estimates of the “wire to water” efficiency for various types of wells/pumps in the study area. Considerable information is available on these efficiencies for wells in the Arkansas River Basin, as a result of the *Kansas v. Colorado* litigation. This information would be obtained, if available, and used in this task. It would probably be necessary to test sample wells in the South Platte River Basin and determine wire to water efficiencies in order to confidently extrapolate the Arkansas River Basin well data to the South Platte River Basin.

These tests would also provide data on pumping water levels that occur in the South Platte River basin. Only a portion of the production wells needs to be tested. This is due to inherent similarities between wells producing from similar aquifers in similar locations. The number of wells to be tested for purposes of estimating wire to water efficiencies would be determined in the feasibility study. However, water to wire efficiencies could be greatly affected by the piping design of individual well systems, making accurate determination of rating curves a difficult task.

Obtaining well rating curves would involve (1) mapping of wells using the data provided from the GIS consultant, (2) identifying those wells that have accessible power records, (3) identifying those wells to be tested in order to determine wire to water efficiency, and (4) running the necessary tests.

Up to approximately 150 wells out of the estimated 5,700 wells with greater than 500 gpm capacities would be tested. Using a subset of wells would provide information to allow extrapolation of the Arkansas River Basin wire to water efficiency data to wells in the South Platte River basin. This would allow testing of wells to determine well/pump efficiencies for wells in all geographic regions, including the Lower South Platte Alluvium Region, Denver Basin and Overlying Alluvium Region, North Park and South Park Region, and the Other Designated Groundwater Basins.

3.8.3.5 Task 5–Calculate Pumping from Consumptive Use Estimates. Under this task, the groundwater contractor would work closely with the consumptive use contractor to obtain crop irrigation requirement data, irrigation surface water supply data, irrigation efficiency data and other necessary data needed for the consumptive-use based calculations to estimate groundwater pumping.

3.8.3.6 Task 6–Develop Pumping Estimates from Collected Data. Under this task, estimates of well pumping would be made based on the collected data. These estimated values would then be compared to historical well pumping where possible for calibration purposes.

3.9 GEOLOGIC STRUCTURE AND AQUIFER PROPERTIES

Figure 3-1 at the end of this chapter shows the aquifers in the South Platte River basin. Geologic structure (aquifer extent and thickness) of all aquifers in the basin will be used to identify the horizontal and vertical extent of the various aquifers in the study area. Aquifer properties describe the groundwater flow rate and yield and include parameters such as hydraulic conductivity, storage coefficient, transmissivity, streambed conductance (used to simulate stream-aquifer interactions) and saturated thickness. The geologic structure and aquifer property information are necessary inputs in groundwater models. These models will be used to estimate drawdown due to pumping, groundwater levels, flow within and between aquifer layers, aquifer yield and stream-aquifer relationships.

3.9.1 Description and Inventory of Available Data

Descriptions of aquifer structure and aquifer properties are available for most of the groundwater systems within Division 1 and Water District 47 in the form of investigation reports and maps. The following is a list of the key sources of information on geologic structure and aquifer properties:

- United States Geological Survey (USGS)
- State Engineer's Office (SEO)
- Colorado Water Conservation Board (CWCB)
- Colorado State University (CSU)

Most of the available information is in the form of oversize maps. These maps show aquifer extent and the top and bottom elevations, and in some cases aquifer saturated thickness and properties. Much of the aquifer property information is descriptive in nature. A limited number of aquifer test results have been compiled into summary maps and tables within some of the reports. A summary of published reports containing information on geologic structure and aquifer properties relevant to the SPDSS is presented in Table B-7 in Appendix B.

Another potential source of aquifer property data exists in the Stream Depletion Factors (SDF) that Division 1 and Water District 47 rely on to specify the timing of stream depletions due to pumping (and accretions due to augmentation). SDFs which take into account the transmissivity of the alluvial aquifer were developed by the USGS in 1972-73 for the South Platte River downstream of Denver and are presented in a series of USGS Open File reports as maps.

3.9.2 Data Assessment

Available data were evaluated for each geographical region of interest (described in Section 3.8 and shown on Figure 3-1) based on four criteria: spatial coverage, length of records, completeness of records, and reliability of records. Table 3-4 gives a summary of the data assessment for each basin by each criterion. Two rankings are given for each geographical region and criteria; the first ranking is the assessment for geologic structure data and the second ranking is for the aquifer property data. The following text expands on the summary presented in Table 3-4 and explains the overall category rating for each region.

The data assessment for geologic structure and aquifer properties is discussed in the following subsections by aquifer region. It is convenient to present the information by geography because of differences in uses and needs in each region with respect to the SPDSS.

3.9.2.1 Denver Basin and Overlying Alluvium Region. This region consists of four bedrock aquifers (Dawson, Denver, Arapahoe and Laramie-Fox Hills Formations), the alluvial aquifer of the South Platte River extending North to approximately Weldona and alluvial aquifers of several Designated Groundwater Basins (Lost Creek, Kiowa-Bijou, Upper Big Sandy and Upper Black Squirrel) that overlie the Denver Basin aquifers.

The majority of the geologic structure information available for the Denver Basin bedrock aquifers is summarized in Van Slyke et al. (1988a-d), Robson (1987), Banta (1989) and in the SB 96-74 and SB 85-5 groundwater models and their supporting reports (Robson 1983; Robson and Romero 1981a and 1981b; Robson, Romero and Zawistowski 1981; Robson et al. 1981), and in the SEO database of geophysical logs. The SB 96-74 and SB 85-5 groundwater models also include calibrated results for the aquifer properties (porosity, specific yield, etc.) with raw data available primarily from USGS reports. Robson 1983 includes aquifer property data from approximately 300 pumping tests and 100 laboratory tests and Wilson (1965) presents aquifer test results for 15 tests from the bedrock aquifers and approximately 100 tests in the alluvial aquifer located in the Denver Basin and Overlying Alluvium Region. More recent maps have been prepared for the alluvial aquifer in the Denver Metro area (Robson 1996), and the Fort Lupton-Gilcrest area (Robson et al. 2000), and for the bedrock aquifers along the western margin of the Denver Basin (Robson et al. 1998). Finally, additional detailed geophysical and aquifer test data for the bedrock aquifers are available from a borehole drilled at Castle Pines (Robson and Banta 1993).

Collectively, the geologic structure and aquifer property information within the individual aquifers for the Denver Basin bedrock aquifers is considered good. However, data representative of the hydrogeologic properties of the aquitards, the predominantly shale or clay layers that inhibit water movement between the various aquifers, are generally lacking, as are data on streambed conductance.

Overlying the bedrock aquifers within the Denver Basin are four Designated Groundwater Basins (Lost Creek, Kiowa Bijou, Upper Black Squirrel, and Upper Big Sandy) and the alluvium of the South Platte River and its tributaries (such as Cherry Creek, Clear Creek, Beebe Draw and Box Elder Creek). The overall aquifer structural data for these water bearing units is considered good given the number of reports available that detail their extent and thickness [including Duke and Longenbaugh (1966); Hillier et al. (1983a,b); Hurr et al. (1972a-c); Nelson, Haley, Patterson and Quirk, Inc. (1967a,b); Robson (1996); Robson et al. (2000); Schneider (1962); Smith et al. (1964)]. Information on aquifer properties in the Designated Groundwater Basins is limited, although some pumping test and laboratory data are available, and specific capacity data may exist in the well permits and construction logs.

Hydrogeologic data on aquifer structure (especially thickness) and properties may be available on a limited basis in environmental studies conducted by or on record with the Colorado Department of Public Health and Environment.

Aquifer property data that can be used to access river-aquifer interactions exists principally in the form of SDFs for the South Platte River downstream of Denver. SDFs are not available for most portions of the Designated Groundwater Basins or for the alluvial aquifers on tributary streams within this region. Also missing for the shallow alluvium are data for determining streambed conductance, which are aquifer property data used to characterize river-aquifer interactions.

3.9.2.1.1 Spatial Coverage. There are extensive database records defining the location and vertical extent of the bedrock aquifers in the Denver Basin and, therefore, the coverage of these records is good. A significant source of Denver Basin bedrock aquifer information (Van Slyke et al (1988a-d); Robson 1987) also includes saturated thickness, transmissivity, available storage, geologic cross sections, and pump test information. However, there is very limited information on the hydrogeologic properties of the lower permeability deposits that separate the bedrock aquifers. The aquifer property data for the alluvial aquifers overlying the Denver Basin and Overlying Alluvium Region are limited with most reports instead discussing the underlying bedrock.

3.9.2.1.2 Period of Record. The geologic structure of the aquifers and information on aquifer properties are independent of time, so this evaluation criteria does not apply to the Denver Basin and Overlying Alluvium region, or other groundwater regions in this study.

3.9.2.1.3 Completeness of Record. The amount of data for the Denver Basin and Overlying Alluvium Region is considered to be good for the geologic structure and fair overall for aquifer property data. There is little information regarding the Designated Groundwater Basins overlying the Denver Basin aquifers but a good amount for the bedrock aquifers. The data are poor on the hydrogeologic properties of the aquitards within the Denver Basin.

3.9.2.1.4 Reliability of Records. The reliability of the extent and thickness data for the aquifers and aquitards in the Denver Basin and Overlying Alluvium Region is considered to be good for the bedrock units and fair for the overlying alluvium and Designated Groundwater Basins. Data reliability of the aquifer properties is considered fair since many of the data were obtained through laboratory analyses, and for the aquifer tests little information is available for the bedrock aquifers.

3.9.2.2 Lower South Platte Alluvium Region. This region includes the alluvial aquifer along the mainstem of the South Platte River, from approximately Weldona to the State line and alluvial aquifers along with tributary streams draining this reach including Badger and Beaver Creeks.

Generally, the data available to characterize aquifer structure and aquifer properties of the Lower South Platte Alluvium Region is less than that available for the Denver Basin bedrock aquifers. Various investigations have been conducted in the Lower South Platte Alluvium Region with the most extensive sources (e.g., Hurr et al. 1972a, 1972b, 1972c, 1972d, 1972e, 1972f) focusing on maps of aquifer structure. The SDF maps included in these will also be a valuable source of aquifer property data.

3.9.2.2.1 Spatial Coverage. The data available to delineate the extent and thickness of the aquifer for the Lower South Platte River alluvium are extensive based on thousands of borehole logs contained in well permit and mapping of the aquifer as reported in several USGS and CWCB reports. A key set of data for aquifer properties for this region is contained in the USGS Open File reports (Hurr et al. 1972a, 1972b, 1972c, 1972d, 1972e, 1972f), that includes information on elevation of the aquifer base and SDFs. The number and location of test sites upon which aquifer property and SDF data have been collected on the mainstem of the river are considered fair. There is very limited published information, however, on streambed conductance or other properties needed to undertake more detailed modeling of river-aquifer interactions. Information on aquifer properties is limited for the alluvial system, especially off of the mainstem of the South Platte River, although some specific capacity data may exist on the well permits and construction logs.

3.9.2.2.2 Completeness of Record. The data includes maps of saturated thickness of the valley-fill aquifer, and bedrock configuration below the valley-fill aquifer from Hurr et al. (1972a, 1972b, 1972c, 1972d, 1972e, 1972f). The aquifer structure data are therefore considered good. The data on aquifer properties are far more limited but are considered to be fair for the purposes of this study.

3.9.2.2.3 Reliability of Records. The reliability of the geologic structure data is considered to be good while the reliability of the aquifer property information is rated as fair due to the relatively limited spatial coverage of the available data and lumped-parameter nature of the SDF values available. This means that the majority of the aquifer property data needed for the SPDSS can not be directly estimated from the information available through the SDF sources.

3.9.2.3 Other Designated Groundwater Basins. The two Other Designated Groundwater Basins within Division 1 and Water District 47, Upper Crow Creek and Camp Creek, are not part of the Denver Basin and Overlying Alluvium Region as discussed above. They both lie in relatively unpopulated areas and are not under significant development pressure.

3.9.2.3.1 Spatial Coverage. The spatial coverage of data in these basins is fair for geologic structure and poor for aquifer properties since very few wells have been tested for aquifer properties in these geographic regions. The data for the Upper Crow Creek Basin were completed during a 1986 study (Kirkhan and Rold 1986). The data for the Camp Creek Basin were obtained during a 1967 study (Nelson et al. 1967).

3.9.2.3.2 Completeness of Record. The available data for Upper Crow Creek include alluvial information and specific yield. There is little information regarding the aquifer properties and, therefore, this data record is considered poor. The Camp Creek Basin Study has data for bedrock locations, aquifer storage quantities and aquifer thickness. As with the Upper Crow Creek, aquifer property data are limited and are considered to be poor. Specific capacity data are expected to exist within well permits and construction logs and will likely suffice in the development of aquifer properties.

3.9.2.3.3 Reliability of Records. Due to the limited amount of information that exists in these basins, the geologic structure and aquifer property data are considered to be fair.

3.9.2.4 North Park and South Park Regions. The North Park and South Park groundwater Regions are located in sparsely populated portions of the state. Although South Park is undergoing development pressure related to the transfer of agricultural water rights to municipal water rights, little change is expected with respect to water use in these regions over the short and long-term.

Currently there are very little groundwater data available for the North Park and South Park Regions. These areas have experienced relatively little groundwater use historically and most water demand has been supplied from surface water. There may be data that can be obtained from the City of Aurora associated with their efforts to undertake a conjunctive use project in the South Park area. These data, however, have not been obtained for this feasibility study because of the on-going litigation; consequently their adequacy cannot be assessed at this time. However, it is estimated that the aquifer structure and aquifer property data for the South Park Region will have poor spatial coverage, poor length of record, fair to poor completeness, and fair reliability. Collection of existing data from the South Park Region and its analysis for the SPDSS is warranted.

There is a relatively recent USGS geohydrology report for the North Park area that focuses on groundwater levels, well usage and recharge-discharge relationships (Robson and Graham 1996). Data on extent of the alluvial and bedrock aquifers in North Park are fair but data available on aquifer properties is considered poor for spatial coverage, period of record, completeness and reliability.

3.9.3 Additional Data Required

A substantial data collection effort is warranted to characterize the aquifer structure and aquifer properties of the Division 1 and Water District 47 groundwater aquifers, based on interviews with the SEO and water users, the recommendations of SB 96-74 and the data review provided herein. Data collection is needed to map the aquifer extents, both horizontally and vertically, and to characterize the aquifer properties, especially with respect to the streambed conductance of the South Platte and its key tributaries. The following data collection activities for the Denver Basin and Overlying Alluvium Region and the Lower South Platte Alluvium Region would be needed to meet the user needs identified in Chapter 2. Additional data collection efforts may also be warranted in the Other Designated Basins and the North and South Park Regions, depending on which alternative is selected.

Overall, the field work related to the five tasks discussed below would be necessary for the following reasons:

- To allow for the characterization of aquifer hydraulic properties and aquifer boundaries (both vertically and horizontally) in the Denver Basin and Overlying Alluvium Region and Lower South Platte Alluvium Region groundwater flow systems.
- To allow for substantially more characterization of streambed conductance including the interaction of the shallow bedrock aquifers of the Denver Basin with the overlying alluvium in accordance with the recommendations of SB 96-74
- To allow for characterization of vertical flow in the Denver Basin from one bedrock aquifer to the other, especially in areas connected to the overlying alluvium, in accordance with the recommendations of SB 96-74
- To create water level monitoring points in the bedrock and overlying alluvium of the Denver Basin in critical groundwater production areas in response to the SB 96-74 recommendations

- To characterize alluvial underflow from tributaries to the main stem drainage and across the State line

3.9.3.1 Task 1–Review and Summarize Historical Data on the Structure of the Alluvial and Bedrock Aquifers. A significant amount of work has been completed by previous investigators regarding the structure of the bedrock and alluvial aquifers in Division 1. Most of the documents available in the literature are not in a format conducive to analysis and modeling, and much of the data used to develop the interpretations reported in the literature have not been provided by the authors. Therefore, this task would involve performing three activities: (1) locating the historical data reports, (2) reviewing the mappings for accuracy and applicability, (3) digitizing mapped data and (4) developing new or updated maps of the aquifer layers. A portion of this task would be used to satisfy the needs recommended in SB 96-74 as well as the needs of the Lower South Platte Alluvium Region.

3.9.3.2 Task 2–Review and Summarize Historical Data on Aquifer Properties. Historical data on aquifer properties exist in reports and within the well permit records on file with the SEO. This task focuses on acquiring the available data on aquifer properties, converting the non-digital data into an electronic format and developing maps for purposes of data analysis. Data analysis efforts would concentrate on identifying whether or not adequate data exists to configure, calibrate and use the requisite groundwater models. The SB 96-74 recommendations indicated a lack of data to characterize the South Platte alluvium, especially with respect to streambed conductance. This task would address these SB 96-74 issues for the Denver Basin and Overlying Alluvium Region.

3.9.3.3 Task 3–Prepare Workplan for Field Activities. This task will involve developing a detailed plan for execution of all of the groundwater-related field activities. This plan will provide a description of field procedures that will be followed by the contractor's staff and all subcontractors. Detailed plans are needed to develop accurate cost proposals from subcontractors and to ensure that appropriate field procedures are followed. It will include information on site access, control and rehabilitation, drilling and well construction procedures, proposed drilling locations and target completion depths, soil and water sampling methods, aquifer test procedures, surveying, health and safety requirements, field QA/QC protocols and field documentation requirements.

3.9.3.4 Task 4– Perform Field Studies to Characterize Streambed Conductance. Stream-aquifer interactions are one of the most important technical issues in the South Platte River basin. Quantifying these interactions was identified by many water users in the basin as a key need (see Section 2.5), and is a central aspect of most of the SB 96-74 recommendations. A better understanding of surface water-groundwater interactions will be gained by undertaking five activities during the implementation phase of the SPDSS. These activities represent the range of proven and cost-effective methods and all warrant consideration given the importance of stream-aquifer interactions in this watershed. One of these is a program to measure stream gain-loss through point-flow measurements on selected stream within Division 1 and is described in Section 3.2.3.5.

The four other activities focus on the permeability of the bottom sediments of a stream, also called the streambed conductance. This is an important hydraulic parameter that, when combined with the stream and underlying alluvial aquifer water levels, controls the flow between the stream and aquifer. Three of the four streambed conductance activities are field-related and are described below, while the fourth remaining activity is model calibration-related and is discussed briefly in Section 5.3.2.3.

The field data will provide initial values and reasonable ranges for the streambed conductance parameter used in the Denver Basin and Overlying Alluvium Region and Lower South Platte Alluvium Region groundwater flow models. The field-related streambed conductance activities include:

- Collecting and characterizing samples of streambed materials – Streambed sediments would be collected by hand auger at representative sites of different streambed morphology (braided, meandering, pool and riffle, scour). Sediments would be described in the field and undergo geotechnical analyses for grain size distribution. The lithologic descriptions and grain size distribution would be translated into hydraulic conductivity via tables of literature values, the Hazen Equation, and related methods.

- Performing percolation tests – Percolation tests would be undertaken at representative stream channel locations, at least some of which would correspond to the streambed sediment sampling locations, by driving a drive point into channel sediments and conducting a constant-head infiltration test. This would indicate the actual flow through the sediments from which streambed conductance could be calculated using Darcy's Law.

- Evaluating changes in stream and groundwater levels. Stream and groundwater level changes would be measured by drilling and constructing paired staff gages and nearby shallow monitoring wells. Existing gages and monitoring wells would be used to the extent possible. The stream gages and monitoring wells would be equipped with continuous water level recording devices for one growing season. Changes in stream stage would be compared to changes in groundwater levels in the nearby well to assess streambed infiltration.

Up to approximately 80 sites would be selected for streambed sediment sampling and percolation testing while up to approximately ten sites would be selected for stream stage-groundwater level measurement. For all three field-related streambed conductance activities, specific locations would be selected after completion of Tasks 1 and 2 described in Sections 3.9.3.1 and 3.9.3.2 above.

3.9.3.5 Task 5–Drill and Install Monitoring Wells in the Alluvium to Characterize Aquifer Properties. This task would involve installation of monitoring wells and fieldwork to collect data on aquifer properties from the alluvial aquifers in the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions. This type of data collection was identified by the Technical Support Committee (TSC) for the SB 96-74 groundwater modeling effort. The wells would also be used to monitor water levels in the alluvial aquifer, as described in Section 3.10.

Each borehole would be logged to identify soil types present. Selected core samples would be retained for later geotechnical analysis, as recommended by the TSC for SB 96-74. Once installed, each of these monitoring wells would undergo short-term pumping and recovery tests to estimate aquifer hydraulic conductivity. The monitoring wells would be equipped with continuous water level recording devices to allow for the continuous collection of water level data through one spring runoff cycle and late summer dry season. This data would provide important information for groundwater management and modeling efforts (such as model calibration) by observing aquifer stresses due to seasonal rainfall, runoff and irrigation cycles.

In addition, core samples would be retained during the drilling and throughout monitoring well installation for inspection and description by a qualified geologist to characterize aquifer properties. One of the core samples collected from each the screened intervals of the monitoring wells would be sent to the laboratory for testing of hydraulic conductivity. This effort, which was recommended by the TSC for SB 96-74, benefits the characterization of aquifer properties in an area (shallow alluvium and bedrock) where little information exists.

Up to 220 wells would be installed in the alluvium along the mainstem South Platte River and its tributaries, including up to 100 wells within the Denver Basin and Overlying Alluvium Region, and up to 70 wells within the Lower South Platte Alluvium Region. Up to 50 alluvial wells would be installed in the North and South Park and Other Designated Basins Regions. Specific locations for these wells will be determined after the initial data collection activities (described under Tasks 1 and 2, above) have been evaluated.

3.9.3.6 Task 6–Drill and Install Monitoring Wells in the Denver Basin Bedrock to Characterize Aquifer Properties. A recommendation from the SB 96-74 study was for improved information on flow within and between the bedrock aquifers and between the bedrock and overlying alluvial aquifers. This need was identified as especially important in areas where the bedrock and alluvial systems interact. To meet this need, bedrock monitoring wells will be installed at locations adjacent to the shallow monitoring wells discussed in the previous task. These bedrock monitoring wells would be installed to depths that may range from 200 to 1000 feet and average about 400 feet. The wells would target the uppermost bedrock aquifer at a given location. As recommended by the SB 96-74 TSC, these boreholes would undergo geophysical logging and would have core samples collected from representative strata to undergo laboratory testing for hydraulic conductivity, porosity and storativity. All well screened intervals would be selected based on the results of borehole logging.

All bedrock wells will be instrumented with continuous water level recording devices to allow for the continuous collection of water level data through one spring runoff cycle and late summer dry season, providing information on seasonal variations with municipal, industrial and agricultural pumping. This data would provide important information for groundwater management and modeling efforts.

Wells completed at these locations would be used to estimate vertical flow between aquifer systems based on water level data collected in conjunction with the shallow monitoring wells and with deeper municipal wells, since the proposed locations are in areas with extensive ongoing groundwater pumping. Short-term pumping and recovery testing would be performed on each installed bedrock monitoring well to estimate aquifer hydraulic conductivity. Core samples would be retained during the drilling exercises throughout monitoring well installation for inspection by a qualified geologist to further characterize aquifer properties.

Up to 25 bedrock monitoring wells would be installed under this task. Locations will be determined after completion of Tasks 1 and 2, described above, and will be installed at locations to reduce existing data gaps.

3.9.3.7 Task 7–Conduct Aquifer Pumping Tests. This task involves conducting extended pumping tests on selected existing high-capacity municipal, irrigation or other wells. Small diameter observation wells would be installed near the selected pumping wells, if existing wells do not already exist, and outfitted with continuous water level recording devices to monitor changes in groundwater levels during pumping. Pumping would continue at a constant rate for a sufficient length of time to be clearly detected in the observation wells, with up to a week of pumping estimated to be sufficient. Water levels would be recorded prior to and for several days after pumping stops to collect information important for analyzing the pumping results. Analyses would be undertaken using standard aquifer test analysis methods to obtain estimates of relevant aquifer properties, including leakage from nearby confining units if present. Up to ten pumping tests would be conducted in bedrock aquifers in the Denver Basin and Overlying Alluvium Region, up to two tests in the alluvial aquifers within both the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions, and up to two additional tests in the North Park, South Park and Other Designated Basins Regions. The Denver Basin and Overlying Alluvium Region tests would address the SB 96-74 recommendations regarding aquifer pumping tests.

3.10 GROUNDWATER LEVEL DATA

Measuring groundwater levels is relevant to many aspects of the SPDSS. These include (1) understanding the changes in bedrock aquifer water levels due to pumping, (2) quantifying the amount, timing and location of stream depletions resulting from groundwater pumping, (3) determining the timing and rate of streamflow replenishment by recharge projects providing water for augmentation purposes, and (4) forecasting when and where critical water use scenarios are developing. In Douglas County, for example, appropriately placed monitoring wells could be used to signal decreasing aquifer levels in areas of significant usage such that water resources management remedies could be initiated. The need for better understanding of stream-aquifer interactions and for expanded monitoring in the Denver Basin and Overlying Alluvium where groundwater levels are declining are recommendations from the SB 96-74 Technical Study. This study also recommended a doubling of the existing network of wells and more frequent collection of water level measurements.

A review of existing records indicates there is a significant lack of spatial and temporal water level data in most of Division 1 and Water District 47. Given the importance of this information in groundwater–related aspects of the SPDSS, collecting adequate water level data likely will require a substantial effort to establish a more detailed monitoring well network and to develop a sustained water level data collection effort throughout the development and implementation of the SPDSS.

This section discusses the adequacy and reliability of the water level data for each of the four groundwater geographic regions defined for this report:

- Denver Basin and Overlying Alluvium Region (includes the Denver Basin bedrock aquifers and overlying alluvium and the Lost Creek, Kiowa-Bijou, Upper Big Sandy and Upper Black Squirrel Designated Basins)
- Lower South Platte Alluvium Region (includes the alluvial aquifer of the lower South Platte River)
- Other Designated Groundwater Basins (includes the Camp Creek and Upper Crow Creek groundwater basins)
- North Park and South Park Regions

See Figure 3-1 at the end of this chapter for locations of these groundwater regions.

3.10.1 Description and Inventory of Available Data

Historically, many agencies have collected and assembled groundwater data in several specific areas of the South Platte Basin. Water level measurements have been collected from over 1,000 monitoring points located throughout Division 1 and Water District 47. The following is a list of sources for water level data currently available for use in the SPDSS:

- Colorado State Engineers Office (SEO)
- United States Geological Survey (USGS)
- Central Colorado Water Conservancy District (CCWCD)
- Colorado Department of Public Health and the Environment (CDPHE)
- US Bureau of Reclamation
- US EPA Region 8

Additional water level data may be available from water user organizations such as GASP and from municipalities. Table B-8 in Appendix B includes a summary of the number of wells and period of record of available water level data collected by the SEO on an annual basis, by geographic region.

3.10.2 Data Assessment

As with the other groundwater data (see Sections 3.8 and 3.9), water level data were evaluated for each geographical region. Table 3-5 gives a summary of the initial data assessment for each region by each criterion. The following text expands on this table and explains the overall rating for each category of evaluation.

3.10.2.1 Denver Basin and Overlying Alluvium Region. The data assessment for the available water level data in the Denver Basin and Overlying Alluvium Region is described below.

3.10.2.1.1 Spatial Coverage. Spatial coverage of water level data for the Denver Basin and Overlying Alluvium Region is considered fair overall. Approximately 216 active monitoring locations are found in the SEO database throughout the different Denver Basin bedrock aquifers including 37 wells located in the Upper and Lower Dawson aquifers, 41 in the Denver Aquifer, 86 in Arapahoe aquifer and 52 in the Laramie-Fox Hills aquifer. Of these there are only 16 groups of monitoring wells from which information on vertical flow in the aquifers might be available. More importantly, there is only one non-pumping well included in the monitoring well network. Measurements are made in the spring before the irrigation season begins, but many of the sampling points are part of municipal wellfields so the measurements may be biased by nearby pumping. The spatial coverage of wells not affected by pumping in the Denver Basin bedrock aquifers is considered poor. Figure 3-1 shows the location of the wells within each of the aquifers in the Denver Basin and Overlying Alluvium Region.

In addition, there are approximately 130 wells in the SEO monitoring network located in the four Designated Groundwater Basin aquifers and alluvial deposits of the South Platte River that overlie the Denver Basin (Figure 3-1). Twenty-one of these wells are located within the Lost Creek Basin, 32 in the Kiowa-Bijou, 30 in Upper Big Sandy, 20 in the Upper Black Squirrel Creek and 30 in the South Platte alluvium. Measurements in these areas generally are from irrigation wells with readings collected in the spring. Because the irrigation wells have been inactive for several months prior to measurement, the spatial coverage for unbiased water level measurements is considered fair to good. The CCWCD reportedly monitors approximately 200 wells in the Box Elder and Beebe Seep tributaries to evaluate stream depletions and augmentation requirements as part of their Substitute Supply Plan. If CCWCD's data become available for use in the SPDSS the spatial coverage in this aquifer would be enhanced greatly.

3.10.2.1.2 Period of Record. The length of record for the water level data within most areas of the Denver Basin and Overlying Alluvium Region is typically from the 1960s through 2000. The length of record for the overlying Designated Basin alluvial aquifer is typically for the 1980s and 1990s. This length of record is good with respect to evaluating water level changes over time. The length of record appears to be uniform for all the wells, allowing for comparisons and links to be made between the records within each region of the Denver Basin and Overlying Alluvium.

Additional water level data are available from the USGS, EPA and CDPHE. The USGS has collected water level data and prepared maps of groundwater levels for the Denver Basin bedrock aquifers based on mid-1970s measurements (Robson 1987) and for the alluvial aquifer in the Denver Metro area based on 1990s measurements (Robson 1996).

Water level measurements collected are also available on a limited basis as part of environmental site investigations conducted by or reported to USEPA and CDPHE. These data are generally of limited spatial and temporal extent and are only for the alluvial aquifer system. Overall, the length of record given the period of groundwater use in the Denver Basin and Overlying Alluvium is good.

3.10.2.1.3 Completeness of Record. Water levels are typically recorded annually in the spring for the majority of the wells within the Denver Basin and Overlying Alluvium Region. Given this limited temporal frequency over a year, the completeness is considered poor for the purposes of evaluating seasonal changes in water levels over time. Additionally, the data within the database are considered to be inadequate for determining the timing or quantity of groundwater pumping impacts. Adequate water level data do not exist to assess the firm yield of the Denver Basin bedrock aquifers, which is consistent with the findings of the SB 96-74 Technical Study.

3.10.2.1.4 Reliability of Records. The period of record and source of the data are considered to be fairly reliable as an indication of overall aquifer water level trends. However, because the water level data may be collected from active pumping wells or from wells in active wellfields it is not expected that the data accurately depict aquifer water levels. As a result, the ranking of reliability is poor. A more reliable data set would include water level measurements taken from wells used strictly for observation purposes.

3.10.2.2 Lower South Platte Alluvium Region. The following assessment is for groundwater level data for the Lower South Platte alluvial aquifer.

3.10.2.2.1 Spatial Coverage. There are approximately 35 wells contained in the SEO databases as shown on Figure 3-1 at the end of this chapter. Spatial coverage varies but in general is poor, with as much as 20 miles between wells in the Fort Morgan-Sterling area. In most locations only a single well exists; consequently, the shape of the water table across the three- to five-mile wide river valley is generally unknown. The CCWCD reportedly measures water levels in almost 200 wells in the alluvial aquifer. If these data become available the spatial coverage would improve to a fair to good rating, depending on the location of wells.

3.10.2.2.2 Period of Record. The length of record for the wells is mainly from 1988 through 1999. This length of record is considered to be poor for evaluating water level changes over time, given that pumping of groundwater for agricultural purposes extends back for several decades. The length of record appears to be uniform for the wells.

3.10.2.2.3 Completeness of Record. Water levels are typically measured twice per year in this region, which provides a more complete database for aquifer trends over the last dozen years than in the Denver Basin and Overlying Alluvium Region. Seasonal fluctuations in the water table may not be captured with biannual water level measurements. Overall, the completeness of the water level data set for this geographic area is considered fair.

3.10.2.2.4 Reliability of Records. As with the other water level measurements in the South Platte Basin, the water level data recorded for the Region are recorded from pumping wells and the reliability of the data is considered to be poor. A more reliable data set would be water level measurements taken from wells used strictly for observation purposes.

3.10.2.3 Other Designated Groundwater Basins. The Other Designated Groundwater Basins assessment for water level data includes the Upper Crow Creek and Camp Creek Basins.

3.10.2.3.1 Spatial Coverage. There are approximately 10 wells located within the Camp Creek Basin and no known wells for monitoring purposes located within the Upper Crow Creek Basin. All of the wells known to exist in the Camp Creek Basin are located in Townships 2 and 3 North, Range 54 West, which is only a portion of this basin area. The spatial coverage is considered to be poor for these basins.

3.10.2.3.2 Period of Record. The length of record for the wells located within the Camp Creek Basin is typically from 1993 through 2000. There are no known records for the Upper Crow Creek Basin. This period of record is considered poor.

3.10.2.3.3 Completeness of Record. The data for the Camp Creek Basin are recorded annually by the SEO for the entire period of record and include the change in water level from earlier measurements. No water level data are available from the Upper Crow Creek Basin. The completeness is considered poor for both Designated Basins.

3.10.2.3.4 Reliability of Record. The water level measurements from the Camp Creek Basin were taken from pumping wells, so reliability is considered to be poor. No water level data are available from the Upper Crow Creek Basin.

3.10.2.4 North Park and South Park Regions. Currently there are very little water level data available for the North and South Park Regions. A recent USGS study on the North Park Basin (Robson and Graham 1996) includes general information on groundwater levels. The USGS currently is collecting water levels from approximately 15 wells in the South Park area, from the shallow alluvial aquifer and from the upper 400 feet of the bedrock aquifer. There potentially are additional data that can be obtained for the South Park area from the City of Aurora in relation to their conjunctive use project. It is estimated that, in general, the data from these areas will have poor spatial coverage, poor length of record, and fair to poor completeness and reliability. More analysis of these data are needed, however, to better define the data needs in these two regions.

3.10.3 Additional Data Required

A relatively large effort to collect water level information from selected aquifer regions within Division 1 and Water District 47 would be necessary to meet the needs detailed in Chapter 2. This data collection effort would focus on the Denver Basin and Overlying Alluvium and the Lower South Platte Alluvium groundwater Regions. The data collection effort would be used to (1) better manage groundwater use in Division 1 and Water District 47, (2) satisfy the SB 96-74 recommendations, and (3) better characterize aquifer yield and streamflow depletions caused by groundwater pumping in the South Platte alluvium.

The key reasons for collecting water level data are as follows:

- Provide basic data required for groundwater management
- Determine the direction of groundwater flow, which is especially important in and around surface water features (indicating gaining and/or losing groundwater conditions) and across bedrock aquitards
- Help quantify streambed leakage and characterize streambed conductance which support the characterization of aquifer properties
- When combined with aquifer properties, water level data can be used to estimate aquifer underflow at specific, and often critical, locations that may be used to help determine stream accretions and depletions in aquifer alluvium, and water flow out of the State.
- Provide information for the development and calibration of groundwater flow models (in part as indicated in the recommendations of SB 96-74) including estimation of (1) large-scale aquifer properties, (2) impacts of irrigation recharge, (3) location of lithologic heterogeneity, and (4) impacts of aquifer pumping for the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions.

There are many locations throughout Division 1 and Water District 47 where water level data have been, and will continue to be, collected under SEO data collection programs. However, most of these data are collected once per year and thus do not provide information on seasonal trends, nor do they adequately quantify impacts from pumping wells or sufficiently characterize stream-aquifer interactions. Therefore, the existing data do not meet the needs of the SPDSS as indicated in Chapter 2. Consequently, the following data collection activities would be necessary to meet identified needs.

3.10.3.1 Task 1–Collect and Interpret Historical Water Level Data. This task involves collecting water level data from various Division 1 and Water District 47 entities such as the SEO, Centennial Water District, Douglas County, CCWCD, GASP, and NCWCD, and where appropriate, converting the data to electronic format for mapping, analysis of trends and selection of model calibration targets. The goal of the effort would be to develop a better understanding of groundwater elevations and interactions within the basin and to provide calibration targets for the various groundwater models.

Between one and three time periods of water level data would be collected and analyzed using data from the 1950s, 1970s and/or 1990s. Information from the SEO and the USGS will be relied on together with available data from additional State, municipal and private sources. This effort would be used to develop a broad spatial database of water levels.

3.10.3.2 Task 2–Collect and Interpret New Water Level Data from Existing Wells. The SB 96-74 study recommended that the 250 wells currently monitored by the SEO each spring in the Denver Basin and Overlying Alluvium Region is monitored on a semi-annual basis. This recommendation originated from the concern that seasonal data are not currently available from the historical record. Since the same concern holds true for the Lower South Platte Alluvium Region, the Other Designated Groundwater Basins and North Park and South Park groundwater Regions, this task provides for the collection of water level data from selected monitoring locations in all four geographic regions, where access is available, during the fall season after agricultural pumping has ceased. As new wells and monitoring wells are accessed and/or installed, the level of effort for this task increases since more monitoring will be required to collect data from the new monitoring points.

Up to 270 existing wells, 240 new wells and 20 converted wells would be utilized for water level monitoring in the fall of the year for four years of data gathering. Water level data would be added to existing electronic databases and be used for mapping aquifer potentiometric surfaces and spatial and temporal trends. Wells in the Lower South Platte Alluvium Region and the Denver Basin and Overlying Alluvium Region would be the highest priority, and up to 40 wells would be used for monitoring in the North Park and South Park Region, and Other Designated Groundwater Basin regions.

3.10.3.3 Task 3–Identify Candidate Monitoring Wells for Conversion. The SB 96-74 study recommended that approximately 250 new wells be added to the SEO list of regularly sampled Denver Basin wells, in order to double the current number of wells monitored. One technique recommended by the SB 96-74 Technical Support Committee (TSC) for increasing the number of wells to be monitored was to convert existing wells scheduled for abandonment into monitoring wells. Since the time of the SB 96-74 recommendations (January 1999), the SEO has tightened its regulations associated with well abandonment. The new regulations provide a six-month window for owners abandoning their wells to pressure-grout and seal the annular space of the hole. This short time frame will require vigilance to stay current with the abandonment applications and quickly mobilize to field inspect and test candidate wells for conversion. Nonetheless, wells which are scheduled for abandonment will be evaluated in a timely fashion to determine whether or not they can be converted to monitoring wells. This effort will require coordination with the well owner, such that permission for the conversion can be obtained.

3.11 CONSUMPTIVE USE

Consumptive use data are important as a basic water resource data need and for use in water rights administration and modeling. The consumptive use (CU) component of the SPDSS will be an important part of an integrated system of models and databases. Some of the key data required by the consumptive use component will be the responsibility of other contractors (e.g., diversion record filling). Data and modeling results from the consumptive use component will flow to contractors responsible for other portions of the integrated system (e.g., irrigation water requirement to groundwater contractor to estimate pumping).

Development of a consumptive use component for the SPDSS will include the following consumptive uses and losses:

- Agricultural (crop) consumptive use
- Municipal and domestic consumptive use
- Wildlife area consumptive use
- Native vegetation consumptive use

- Other consumptive use (industrial, livestock, reservoir and stockpond evaporation)

The historic crop consumptive use analysis, which will estimate an irrigation water requirement and compare to water supply, requires a variety of information based on user interviews, historic experience, previous reports and professional judgement. This information will be combined with historic time series data, typically obtained from, or estimated from, historic records. The consumptive use analysis will rely on historical information because the processes themselves are time variable. Short term data collection efforts do not typically enhance the consumptive use and water budget assessments and tools since it is difficult to characterize time varying factors through short term (less than one year) monitoring. Required input data for consumptive use analysis and the relationship to other components are shown in Table 3-6.

3.11.1 Description and Inventory of Available Data

3.11.1.1 Agricultural Consumptive Use Data. Some of the information required to estimate and verify historic agricultural consumptive use and return flows will come from user interviews and published reports, including lysimeter studies, high altitude consumptive use estimates, crop yields, ditch conveyance losses, and application losses. Other data requirements, including historic irrigated acreage tied to surface and groundwater sources and irrigation methods by ditch over time are discussed in Section 3.15. Climate data required to estimate potential consumptive use are discussed in Section 3.13. Historic surface water supply data are discussed in Section 3.3 and historic groundwater pumping estimates are discussed in Section 3.8.

3.11.1.2 Municipal and Domestic Consumptive Use Data. Population data will be necessary to estimate historic municipal and domestic consumptive use. Municipal supply and use data are available for many of the larger municipalities in Division 1 and Water District 47 for recent years but may not be available in past years or for all cities. Rural water supply in Division 1 and Water District 47 is generally from domestic wells that are not measured. Therefore, population data will likely be used to estimate some municipal and most domestic consumptive use. In addition, per capita withdrawal and use rates will need to be determined to estimate consumptive use based on population data. The following data types will be useful in determining municipal and domestic consumptive use:

- Population Data: County and municipal population estimates are available from the Colorado Census Bureau web site for 1985 through 2000 and are available digitally from 1950 through 1985.
- Indoor Municipal and Domestic Per Capita Supply and Use Rates: User interviews and review of municipal withdrawal and treatment plant records during the winter months will help to provide actual municipal indoor consumptive use estimates and associated amount, timing and location of return flows. These use estimates can be used to determine a per capita consumptive use factor that can be applied to municipal areas where data on per capita use and consumption are not available. These data can also be used to estimate domestic consumptive use factors.

- Outdoor Municipal and Domestic Water Use Rates: User interviews and review of municipal withdrawal and treatment plant records during the lawn irrigation months will help to estimate actual municipal outdoor consumptive use estimates. In addition, many of the larger cities in the South Platte River Basin have begun, or have completed lawn irrigation return flow studies to determine outdoor water use and return flow factors. The results of these investigations could be used to determine per capita consumptive use factors for application to municipal areas that lack necessary data. These data can also be used to estimate domestic outdoor consumptive use and return flows.
- Published Studies: Existing published reports and data regarding municipal use will be collected and reviewed.

3.11.1.3 Wildlife Area Consumptive Use Data. Published reports and estimates of water use associated with the creation and maintenance of wildlife and wetland areas in the basin will be collected and reviewed. User interviews will be held with managers of wildlife areas to understand water application methods and water use practices over time.

3.11.1.4 Native Vegetation Consumptive Use Data. Although native vegetation consumptive use estimates are envisioned to be outputs of the water budget process, published reports and estimates will be collected and summarized to provide verification of the water budget results. In addition, published reports and studies will be reviewed to estimate the amount of groundwater use by native vegetation as a function of depth to groundwater and will be prepared for use in groundwater area budget analyses.

3.11.1.5 Other Consumptive Use Data. Livestock counts published as part of annual county agricultural statistics will collected to estimate livestock water use. Per capita livestock water use estimated by the U.S. Bureau of Reclamation, will be used. Reservoir and stockpond evaporation losses will be based on reservoir end-of-month contents, discussed in Section 3.5, and evaporation data, discussed in Section 3.13. Industrial water use estimates will be based on user-supplied information gathered through interviews.

3.11.2 Data Assessment

3.11.2.1 Agricultural Consumptive Use Data. Information obtained through user interviews and published reports are difficult to assess but are considered the best available. Information required for agricultural consumptive use estimates, such as climate data, historic crop acreage and associated irrigation water source and historic irrigation methods, are discussed in other sections of this chapter.

3.11.2.2 Municipal and Domestic Consumptive Use Data. As with other historic data, population census data need to be assessed to determine if they are adequate for estimating municipal consumptive use. The data can be assessed based on spatial coverage, length of records, completeness of records, and reliability of records. Information obtained through user interviews, published reports, and municipal withdrawal and discharge records are difficult to assess but are considered the best available data.

3.11.2.2.1 Spatial Coverage. Colorado census data are collected or estimated for every county and most towns (generally over a few hundred residents) in Colorado. Larger municipalities along the Front Range of Colorado generally have withdrawal and discharge records for their public water systems. Therefore, spatial coverage is believed to be good for use in estimating municipal consumptive use.

3.11.2.2.2 Period of Records. Colorado census data are available for over 50 years. Therefore, the length of available records is believed to be adequate for use in estimating municipal consumptive use, even if a long record of withdrawal and discharge information is not available.

3.11.2.2.3 Completeness of Records. County census data are estimated yearly. City and town census data are compiled every five years. It is believed that city growth can be estimated using simple linear interpolation between census data. Therefore, census data are adequate for use in estimating municipal and domestic consumptive use.

3.11.2.2.4 Reliability of Records. Population census data are generally believed to be reliable for use in estimating municipal and domestic consumptive use. The use of municipal withdrawal and discharge records will likely provide a more accurate estimate of municipal consumptive use and are considered to be the best available data. Lawn irrigation return flow studies are reliable for providing a basis for estimating outdoor consumptive use.

3.11.2.3 Wildlife Area Consumptive Use Data. Information obtained through user interviews and published reports are difficult to assess but are considered the best available.

3.11.2.4 Native Vegetation Consumptive Use Data. Information obtained through user interviews and published reports are difficult to assess but are considered the best available.

3.11.2.5 Other Consumptive Use Data. Livestock count data is published by year, by county. Data can be obtained in non-digital form back to the early 1900s. Livestock count data is believed to be reliable for estimating livestock water use. The data required to estimate reservoir and stockpond evaporation is assessed in Section 3.5 and 3.13. Industrial water use information obtained through user interviews is difficult to assess but is considered the best available data.

3.11.3 Additional Data Required

3.11.3.1 Agricultural Consumptive Use Data. No additional data beyond that discussed in other sections of this chapter are expected to be required for the agricultural consumptive use analysis. Additional data required, as discussed in other sections, includes historic irrigated acreage estimates, surface and groundwater sources tied to historic acreage, and irrigation methods tied to historic acreage (sprinkler versus flood irrigation).

3.11.3.2 Municipal and Domestic Consumptive Use Data. The amount and quality of municipal and domestic use data in the South Platte River basin generally exceed that which was available in the Colorado River and Rio Grande River basins. Because the municipal and domestic use data were found to be adequate for development of decision support systems in those basins, no additional municipal and domestic data are expected to be required for SPDSS.

3.11.3.3 Wildlife Area Consumptive Use Data. No additional data are required to estimate wildlife area consumptive use.

3.11.3.4 Native Vegetation Consumptive Use Data. No additional data beyond that discussed in other sections of the chapter are expected to be required to estimate native vegetation consumptive use.

3.11.3.5 Other Consumptive Use Data. No additional data are required to estimate other consumptive uses.

3.12 WATER BUDGET

Water budget information is important as a basic water resource data need and for use in water rights administration and modeling. The water budget component of the SPDSS will be an important part of an integrated system of models and databases. The water budget model will tie inputs and outputs from data collection and modeling efforts to complete the overall basin water balance. Final inputs to the water budget component will primarily be developed by other component contractors according to their emphasis (consumptive use, surface water, or groundwater) and are covered in those sub-sections. These inputs include such components as basin consumptive uses, basin surface water inflows, basin imports, change in basin surface water storage, change in basin groundwater storage, surface water leaving the basin, and groundwater discharging from the basin.

It is envisioned that initial water budget analyses will be completed for the entire South Platte, North Platte, and Laramie River basins to provide guidance for contractors responsible for the final estimates of consumptive use, surface water flows and groundwater flows that will be used in the water budget. Initial estimates will be developed based on existing reports and published documentation on previous water budgets, consumptive use analyses, surface water analyses, and groundwater analyses. During the SPDSS, these initial estimates will be regularly updated with inputs provided by the component contractors thereby providing an accounting tool of current information. Final water budget analyses will likely include sub-basin water budgets corresponding to groundwater model areas.

One of the inflow, outflow, or change in storage terms in the water budget can be designated as the closure term, or residual. Because native vegetation consumptive use is more difficult to estimate than other terms that are either more easily measured or have been studied more extensively, it is envisioned to be the closure term. Published information regarding native vegetation consumptive use will be collected, reviewed, and compared to the water budget estimate.

3.12.1 Description and Inventory of Available Data

Published reports and estimates of previous water budgets, consumptive use analyses, surface water analyses, and groundwater analyses will be used for initial water budget analyses. Final data requirements, including basin consumptive uses, basin surface water inflows, basin imports, change in basin surface water storage, change in basin groundwater storage, surface water leaving the basin, and groundwater discharging from the basin, will be developed by other component contractors during the SPDSS.

3.12.2 Data Assessment

Data obtained for the water budget analysis through published reports are difficult to assess, but are considered the best available data. Although previous reports have not been extensively reviewed for this assessment, it is believed that enough information is available to prepare estimates of average annual inflows, outflows, and changes in storage for the initial water budget analyses.

3.12.3 Additional Data Required

No additional data, beyond that discussed in other sections of this chapter, are expected to be required for the water budget analysis.

3.13 CLIMATE

Climate records are important as a basic water resource data need and for use in water rights administration and modeling. Climate data will be used to estimate historic crop consumptive use in Division 1 and Water District 47. The Blaney-Criddle evapotranspiration method, which is the current method used for consumptive use analysis in the CDSS, requires monthly temperature and precipitation data. Other monthly or daily methods, such as the Kimberly Penman method, may be added to the SPDSS and require climate information such as wind speed, solar radiation, and vapor pressure. Evaporation data will be used to determine reservoir evaporation for both the water budget and the surface water modeling efforts.

3.13.1 Description and Inventory of Available Data

There are climate measurements recorded for almost 200 locations in the South Platte and North Platte River Basins in Colorado (Division 1 and Water District 47). Most of the stations (153) are operated by the National Weather Service (NWS) within the National Oceanic and Atmospheric Administration (NOAA) and archived by the National Climate Data Center (NCDC). These stations generally have records for minimum, maximum and average daily and monthly temperatures, daily and monthly total precipitation, and daily snow depths. Seven NCDC stations also report evaporation. NCDC climate data was collected directly from NOAA and placed in HydroBase during previous HydroBase population phases. Table B-9 in Appendix B lists the NCDC climate stations in Division 1 and Water District 47, location information including latitude, longitude, elevation, and water district, data available, and period of record.

Colorado State University collects climate information from 18 CoAgMet stations in Division 1 and Water District 47. CoAgMet stations collect daily temperature, precipitation, relative humidity (vapor pressure), wind speed, solar radiation, and soil temperature data. CoAgMet climate data can be accessed through the Colorado Climate Center. Table B-10 lists the CoAgMet stations in Division 1 and Water District 47.

Northern Colorado Water Conservancy District (NCWCD) also maintains climate stations within the District boundaries in Division 1 and Water District 47. These 17 stations collect daily temperature, precipitation, relative humidity (vapor pressure), wind speed, solar radiation, and soil temperature data. This climate data can be obtained from NCWCD. Table B-11 lists the NCWCD climate stations in Division 1 and Water District 47.

NOAA, in conjunction with the Forest Management Fire Center, also provides hourly weather updates including wind speed, temperature, and vapor pressure. There are several RAWS and METAR stations located in Division 1 and Water District 47. Information regarding station locations and periods of record was not available for this report.

In addition to the NWS stations with evaporation data, shown in Table B-9, evaporation data are available at six reservoirs throughout the South Platte River drainage. Table B-12 presents these data which are available from the Denver Water Board and the Army Corp of Engineers.

3.13.2 Data Assessment

Historic climate data were reviewed to determine if these data are adequate for estimating basin crop consumptive use by assessing the spatial coverage, length of records, completeness of records and reliability of records. In addition, it is recognized that the location and elevation of climate stations needs to be reviewed to determine the applicability of data from a specific station for use in crop consumptive use estimates during SPDSS implementation.

3.13.2.1 Spatial Coverage. The NCDC provides climate information for 153 stations. Figure 3-2 at the end of this chapter shows the spatial extent of the NCDC climate stations, as well as the CoAgMet and NCWCD climate stations. There appears to be adequate coverage to represent the historic temperature and precipitation throughout the South Platte River basin, and specifically in agricultural areas. The North Platte River drainage in Jackson County has only one known climate station in Walden. The Walden climate station, with a period of record from 1948 through 2000, is near the center of agricultural production in North Park and is believed to be acceptable for use in historic crop consumptive use estimates.

Twenty-four NCDC stations over 8,000 feet in elevation have relatively long periods of record. These stations are generally located near the high altitude agricultural areas. The coverage is adequate to represent the historic temperatures and precipitation for the areas of higher elevation in Division 1 and Water District 47.

The CoAgMet and NCWCD climate stations also have relatively good spatial coverage for the South Platte River basin. They are generally located in areas of high agricultural use. These stations, however, do not generally represent the high altitude areas of the South Platte River basin, and none of the CoAgMet or NCWCD stations are located in the North Platte River basin.

Existing evaporation stations are located in lower elevation areas of the South Platte River basin. Evaporation data for the upper South Platte River mainstem, the North Platte River basin, and the upper reaches of the Cache la Poudre have not been identified. Existing evaporation station data, however, are believed to be adequate for estimating evaporation throughout Division 1 and Water District 47.

3.13.2.2 Period of Records. There are over 50 NCDC stations that have continuous temperature and precipitation records beginning prior to 1950 and continuing through 2000. These stations, highlighted in Table B-9, are scattered throughout Division 1 and Water District 47 with at least one station in each Water District. Five long-term stations have records prior to 1947. If the historic crop consumptive use analysis were to start in 1950, there is sufficient long-term climate data to represent historic climate throughout the basin. There are, however, insufficient data for an analysis period beginning prior to 1950 in many parts of the basin.

Other climate data from CoAgMet and NCWCD, including wind speed, solar radiation, and vapor pressure, have a relatively short length of record, generally 10-years or less. The use of these data to estimate crop requirements for a long historic period may be limited. These data could be extremely useful, however, for comparing Blaney-Criddle results to those using a different evapotranspiration calculation method for the purposes of calibrating local Blaney-Criddle crop parameters.

3.13.2.3 Completeness of Records. The percent completeness of records for the NCDC climate stations for the period of record is indicated in Table B-9. These percentages are based on the data stored in HydroBase. In some cases, temperature data are available through NCDC, but these data are not in HydroBase. An "na" has been placed in Table B-9 to indicate that temperature data likely exists; however, a percentage completion for these records could not be assessed at this time. The amount of missing data for the long-term stations is relatively low. Precipitation data are more than 90 percent complete for most stations. The percent complete for temperature data is also high in many cases. The long-term NCDC stations generally have few missing data. It is believed that the data from these stations can be used to estimate missing data at other stations.

The low percent complete for evaporation stations represents the fact that most of the stations do not record evaporation during the winter months. Because most of the evaporation in the basin occurs during the warmer months, the percent complete is misleading. Generally the evaporation data percent complete for the non-winter months is closer to 90 percent at the listed stations. Therefore, there are adequate evaporation data for use in the SPDSS project. A complete assessment of the additional reservoir evaporation stations shown in Table B-12 has not been completed. The evaporation data presented in Table B-12, however, appear to be relatively complete during the non-winter months and could be used to supplement the NCDC stations.

The CoAgMet data for the entire period of record have not been obtained. Based on records reviewed, however, the percent complete for the CoAgMet climate stations is likely as high as 90 percent for the period of record. No analysis has been made of the percent complete of records from the NCWCD stations.

3.13.2.4 Reliability of Records. NCDC, CoAgMet, and NCWCD climate stations are generally considered to be of good quality. The extent of records and excellent spatial coverage will allow sufficient climate data to be used to estimate crop consumptive requirements throughout the basin. As part of the process of determining crop consumptive demands, a more detailed assessment should be made for the appropriate use of each climate station.

3.13.3 Additional Data Required

Given the length of record and spatial distribution of climate stations, additional climate data stations would not improve historic consumptive use estimates in the South Platte River or North Platte River (including the Laramie River) basins. Existing climate stations provide adequate coverage for precipitation and temperature.

The South Platte River basin is sufficiently covered for recent measurements (last ten years) of wind speed, vapor pressure, and solar radiation. These data should provide an adequate basis for possible use in a consumptive use analysis, especially for calibration purposes. Stations measuring these factors are near the major agricultural areas in both basins. Although a climate station in the North Platte River basin equipped with measurement devices for wind speed, solar radiation and vapor pressure could be useful for future consumptive use estimates, it is not recommended as part of the SPDSS. Adequate information is believed available from other climate stations to develop consumptive use relationships for the North Platte River basin.

3.14 SNOW SURVEY

Snow survey records are important as a basic water resource data need and for use in water rights administration and modeling. Historic snow course data can be used to develop and evaluate the accuracy of forecasting spring runoff quantities and patterns. Real-time snow course data can be used to assist with water management if an accurate forecast method is available. This information is often used by reservoir owners to determine their releasing and filling operations for the year.

3.14.1 Description and Inventory of Available Data

Both the NWS and the National Resource Conservation Service (NRCS) provide snow measurement information in Division 1 and Water District 47. Data collection includes automated SNOTEL and manual snow course measurement. Available data include:

- Percent average of snow pack depth
- Daily SNOTEL data
- Comparison against previous years
- 30-year average snow water equivalent and percent of average
- Monthly snow course and SNOTEL averages
- Basin-wide summaries

Table B-13 in Appendix B lists the seventeen SNOTEL sites that collect information on snow water equivalent.

3.14.2 Data Assessment

Snow data was reviewed to determine if it is adequate for use in forecasting runoff quantities and patterns and as a tool for estimating historic reservoir operations by assessing the spatial coverage, length of records, completeness of records, and reliability of records.

3.14.2.1 Spatial Coverage. The snow survey sites are all located in the upper areas of the basin and have good coverage for the mainstem South Platte River and its major tributaries. Table B-13 provides the major tributary location of each SNOTEL site.

3.14.2.2 Period of Records. Most SNOTEL sites have been in place since the early 1980s, providing nearly 20 years of records. The length of records is adequate to use for forecasting.

3.14.2.3 Completeness of Records. Based on information provided from the Western Regional Climate Center, the SNOTEL sites are continuously recorded and relatively complete. It is believed that the SNOTEL stations are adequate to use for forecasting and historic analyses.

3.14.2.4 Reliability of Records. SNOTEL data are believed to be reliable for use in spring runoff forecasting and historic estimation of reservoir operations.

3.14.3 Additional Data Required

Given the amount of historic snow survey data available, its spatial distribution and its reliability, no additional snow survey data sites are recommended for use in the SPDSS.

3.15 LAND USE AND IRRIGATION SERVICE AREAS

Land use and irrigation service are important as a basic water resource data need and for use in water rights administration and modeling. Mapping of land use and land cover are essential for understanding current water use, estimating historic water use, analysis of trends and other planning functions. In the SPDSS, current land use/cover maps will be a key component for serving other elements of the SPDSS including surface water, groundwater, and especially the consumptive use/water budget component. Historic data on land use will enable the quantification of changes in water use including, for example, extension of irrigated areas by surface or groundwater (especially center pivot), changes from agriculture to municipal use, or conversion of lands from flood irrigation to more efficient sprinkler irrigation. Locating and mapping irrigation service areas will provide essential spatial data for linking consumptive use and water delivery and allocation systems for both surface water and groundwater.

Data collection for land use and irrigation service area data consists of three main activities:

- Classification and mapping of current land use/land cover with emphasis on irrigated lands
- Classification of historic land use and change analysis
- Identification of the source of irrigation water and mapping of service areas for both ground and surface water

The information flow used in these three activities is presented on Figure 3-3 at the end of this chapter. The process relies on an information foundation of both attribute and spatial (GIS) data. The attribute, or tabular, data includes agricultural statistics, diversion locations, etc. Some of these data are presently available in Hydrobase and others will be collected or generated by other SPDSS activities (i.e., consumptive use, surface water, groundwater). The spatial data, such as digital elevation models, hydrography, soils, etc. also will be assimilated under SPDSS and are described in Section 3.16. The base information will be used to create three main intermediate products--historic land use, current land use and source of irrigation water—which will be used to derive the main results of this activity. Those results are historic land use, current land use and irrigation service areas for both groundwater and surface water. Users within the State will include the Division Engineer, Water Commissioners and managers and planners. Other users will include water districts, ditch companies, municipalities and the public. As shown on Figure 3-3, these results will also be input for SPDSS models, including consumptive use, groundwater and surface water models.

Agricultural statistics will be collected for use in estimating historic irrigated acreage and corresponding crop types for periods when a more detailed irrigated acreage assessment is not practical or not cost-effective. In addition, agricultural statistics provide information on crop yields that may be useful in determining variations in crop water use over time.

The activities described in this section focus on the derivation of information. The approach is to utilize existing information as much as possible and then augment with information to be derived or created under this project. This section first examines the available data and assesses its utility, then describes the need for additional information. For organization, each section is structured according to the main products: historic land use, current land use, irrigation service areas, and agricultural statistics.

3.15.1 Description and Inventory of Available Data

A listing of data applicable for land use classification and for delineating irrigation service areas is provided in Table B-14 in Appendix B. Included in this table are the main sources of data that are known to exist or that are currently under development. Some of these data have already been acquired for use in the SPDSS and others have yet to be acquired pending formal requests or payment of nominal fees. In addition, some of the data are being developed and will be available to SPDSS during 2001.

3.15.1.1 Current Land Use. As shown in Table B-14, the data applicable for mapping current land use includes maps of irrigated lands developed by NCWCD using satellite images from 1997 and irrigated land coverages in South Platte Mapping and Analysis Program (SPMAP), derived from satellite imagery processed in 1996. The satellite images used in these studies are from Landsat Thematic Mapper (TM), with a nominal ground resolution of 30m by 30m. A regional water demand study by NCWCD utilized these same data, coupled with 1990s land use maps acquired from various municipalities and counties. The other potential source for current land use is the National Land Cover Data by the USGS. These land cover data also will be derived from Landsat satellite imagery, for the year 2000, but the data will not be available for several years.

Another source of data for both current and historic land use mapping is the Farm Service Agency (FSA, formerly ASCS). Crops are reported to the FSA at the field level by individual producers, and mapped on NHAP aerial photographs, typically at a scale of about 1:8,000. Within the South Platte River basin, most of the aerial photographs currently in use were acquired during the late 1980s and the early 1990s.

3.15.1.2 Historic Land Use. In addition to statistics and FSA data described in the above section, there are other historic land use data that could be useful, as listed in Table B-14. The first is a land use and land cover classification developed under the interagency, national-level, Multi-Resolution Land Characterization (MRLC) initiative that involves three divisions of USGS, EPA, NOAA and the USFS. Data for the entire state of Colorado were completed in draft in August 2000. For the South Platte River basin, the main data source is Landsat TM imagery acquired during the period 1988 to 1994. Other ancillary data used included elevation, census data and wetlands inventory. There are 21 classes used for the study area; irrigated lands are not explicit categories but they can be inferred somewhat from the map units and legend.

Other historic land use data include a late 1970s Land Use and Land Cover map at 1:250,000 scale derived from aerial photography, USGS quadrangles and other data. These data are available in vector format and include 9 classes for the South Platte River basin. Irrigated lands are not discriminated from other agriculture land uses. Another set of land use maps is being developed by the Front Range Infrastructure Project of the USGS, covering the Front Range from Fort Collins to Denver. This project has gathered historic aerial photographs and other sources of historical data including the USDA, USGS, county governments and the University of Colorado. The maps generated for these dates are being referenced to ground features, such as streams, canals and roads, to enable use of the data in a GIS for comparing to current imagery and digital maps. The results of this project are not yet available, but should be completed during 2001.

3.15.1.3 Irrigation Source and Service Areas. There are some existing data available, or being developed, that could be used to depict irrigation canals and ditches and their service areas. One source is the National Hydrography Data (NHD) being prepared by the Colorado Division of Wildlife under contract to the USGS. These digital maps are being created from the 1:24,000 scale 7.5 minute topographic quadrangles of the USGS. All the hydrographic features depicted on the USGS quads are being digitized, including rivers, streams, canals, major ditches and drains. The South Platte River basin is about 40 percent complete and it is expected to be fully complete by the end of 2001.

In addition to the NHD maps, other data that should be useful in constructing the irrigation sources and service area maps include the State's database on diversion structures which will at least give the point of diversion and ditch names to facilitate the mapping process. Another data set is being developed by the Cache La Poudre Water Users Association that includes maps of main ditches and easements. The main impetus for this project is to inform developers and real estate buyers of the system of existing ditches and easements. The completion date for this project is not known, but assumed to be during 2001. In addition, many irrigation ditch companies have maps of some type describing their irrigation delivery systems. These maps are in a variety of formats and degrees of completeness.

Locating wells and mapping their associated irrigation service areas will depend largely on location data obtained from the State and from groundwater users in the basin. Division 1 and Water District 47 personnel have developed a database for most wells where the water rights are tied to the permits with associated well location data. The total number of wells with capacity greater than 50 gpm is about 12,000. More detail on these data is presented in Section 3.7. Also, Division 1 and Water District 47 has additional well data known as the "tag number" file, which includes well locations that have been field verified and located with a GPS. These data exist for between 15 percent and 20 percent of the wells, as part of an ongoing Division 1 program to identify the location of all non-exempt alluvial groundwater wells. This well location program involves doing background research of decrees, well permits and augmentation; locating and tagging wells using GPS; entering GPS and other data into a database; and finally notifying and following up with well owners who have problems associated with their. The database from this effort is scheduled for completion about 2009 with current funding levels, but may be accelerated to aid with SPDSS development.

In addition, there are data being developed by water users using various techniques. For example, GASP is currently gathering detailed information on well locations, using GPS, and associated irrigation service areas. Data for about 240 of the 3000 well records have been completed by GASP. There are similar data being stored in SPMAP for some wells, with an emphasis on augmentation plans.

3.15.1.4 Agricultural Statistics Data. Colorado Agricultural Statistics (CAS) report producer-provided annual acreage and yield by crop. National Agricultural Statistics Surveys report acreage and yield by crop every five-years. Both Colorado and National statistics are available for each County in Colorado from prior to 1950 to the present. Recent irrigated acreage reports are available through the Internet. Historical data can be ordered. It is likely that early years may not be available digitally, but would need to be hand-entered to be useful.

3.15.2 Data Assessment

The base spatial data described in Section 3.16 will be used extensively in land use classification and in mapping irrigation service areas. In addition, there are a number of sources of data applicable for developing the required information. However, none of the existing data are immediately applicable for the purposes of this study. This is due to a variety of reasons, for example the spatial coverage may be limited, the information is dated or there are inconsistencies in interpretation, etc. The main uses and limitations and an overall utility for existing data are provided in Table B-14.

3.15.2.1 Current Land Use. The following is an assessment of available current land use data.

3.15.2.1.1 Spatial Coverage. Irrigated lands maps, shown in Table B-14 and available in SPMAP, cover the NCWCD within the South Platte basin. The National Land Cover Data (NLCD) of the USGS also will cover the entire state. The Farm Service Agency (FSA) data cover about one-half of the high value crops within the South Platte Basin.

3.15.2.1.2 Period of Record. SPMAP data are derived from 1997 satellite images. NLCD data will be derived from 2000 satellite images, but the mapping will not be completed and available for several years. FSA data cover portions of the irrigated lands since the 1950s.

3.15.2.1.3 Completeness of Record. This is described by the Spatial Coverage and Period of Record sections above.

3.15.2.1.4 Reliability of Record. Maps in SPMAP are fairly accurate for irrigated lands and they will be very useful as input to the SPDSS. One limitation is that most agriculture is assumed to be irrigated, for example non-irrigated pasture could be classified as “irrigated land.” Other limitations of the SPMAP coverages are that they are derived for 1997, they only cover the NCWCD and there is no delineation of crop types. The NLCD classes do not include irrigation, which would be a subset of “agricultural land” and they will not be available until about 2005. The FSA data will be useful in providing ground information as “training” for computer classification of satellite images, and for verifying the image processing results. These same data also will be useful for historic land use mapping, especially considering that this may be the only source of reasonably reliable historic ground data. The main limitation with FSA data are that they are inconsistent or not available for lower value agriculture, for example, irrigated pasture. Also, reports to FSA are voluntary and, thus, only represent a portion of agriculture in the South Platte River basin.

3.15.2.2 Historic Land Use. The following is an assessment of available historic land use data.

3.15.2.2.1 Spatial Coverage. The Multi-Resolution Land Characterization (MRLC) data and the Land Use and Land Cover (LULC) data cover the entire state. The Front Range Infrastructure Project (FRIP) data extend from Fort Collins to Denver and east of I-25 by a few miles.

3.15.2.2.2 Period of Record. The MRLC is derived from satellite imagery acquired during the period 1988 to 1994. The LULC data is from the 1970s and the FRIP included maps as early as 1937 to the 1990s. FRIP interpretations of land use are being made for the 1930s, 1950s, 1970s and 1990s.

3.15.2.2.3 Completeness of Record. This is described in the Spatial Coverage and Period of Record sections above.

3.15.2.2.4 Reliability. The MRLC data will have some utility for historic land use mapping; the main limitation is that irrigated lands are not segregated from other agricultural uses. The MRLC will also be useful for mapping land cover for consumptive use estimates of non-irrigated lands. The historic land use mapping of the Front Range (FRIP) is not yet available, but is expected to be a unique source of information for land use prior to 1970, particularly for documenting the conversion from agriculture to other uses in the most impacted area of the basin. The utility of these maps will be enhanced if they are in digital format, and geo-referenced, as anticipated. The LULC data will have some utility for mapping land use in the 1970s.

3.15.2.3 Irrigation Source and Service Areas. There are only a few data currently available on irrigation source and service areas in the South Platte basin. These include information on the location and attributes of diversion structures and headgates, location and attributes of wells, alignment of canals and main ditches and their associated service area and lands served by irrigation. The assessment below addresses the state of existing data that will be used for deriving the required irrigation service area maps.

3.15.2.3.1 Spatial Coverage. The National Hydrography Data (NHD) of the USGS, when complete, will cover the entire state and will be useful for mapping irrigation canals, main ditches and their service areas. The maps being created by the Cache La Poudre Water Users Association (CLPWUA) will cover only the main canal systems within the Poudre basin. The State database on wells and diversion structure locations covers the entire Division 1 and Water District 47. The GPS-derived well data being collected by the State and water users will eventually include the entire Division.

3.15.2.3.2 Period of Record. The NHD data will be derived from USGS topographic maps. These maps have been developed over a period spanning the 1970s to the 1990s. The State data on the locations of water diversion structures has been developed over the past 10 years; wells data were acquired during the late 1990s and detailed locational data is scheduled for collection during 2001-2004. The CLPWUA data will use USGS topographic maps, created during the 1970s and 1980s, as the base and will be delineated during 2001.

3.15.2.3.3 Completeness of Record. Spatial coverage and length of record describe the completeness of maps. The State's data on diversion structures is complete. The State's data on GPS-located high capacity wells and service areas is only about 20 percent complete and similar data from GASP is only about 8 percent complete.

3.15.2.3.4 Reliability of Record. Comprehensive and accurate maps of irrigation structures, canals, ditches and drains presently do not exist. Maps of irrigation service areas in any form have yet to be located. The one known exception is a series of digital maps for the New Cache Ditch that was developed by NCWCD as a pilot project to test methods and to determine the level of effort required for such mapping. Maps for this one ditch system required four weeks to construct.

However, the maps and data described above should be valuable as sources for constructing the required maps. For example, when completed, the NHD data set is expected to be a reliable depiction of hydrography and large water resources, including canals and main ditches, as mapped on USGS topographic maps. The data also will include attributes from the USGS maps, such as canal and major ditch names. A limitation of these data is that only major features are identified on the USGS maps. Furthermore, the topographic maps were created during the 1970s-1990s, thus substantial updates may be required. Likewise, the Cache La Poudre Water Users Association maps will be useful, but they will require further work, particularly in creating geographically accurate alignment of the ditches. Also, these maps will not include any ditch service area delineation. Outside of the Poudre sub-basin, several of the larger ditch companies have maps in a variety of formats and stages of completion. Typically, the maps are hand-drawn on USGS topographic base maps, and include main canals and laterals. Many of these maps do not include delineation of irrigated areas nor of service areas under the ditches.

GPS-derived well data from Division 1 Engineer's office and GASP is considered to be very reliable, but it only covers a small percentage of wells. The schedule for completion of these data is about 2009 without SPDSS assistance and could be completed within three years with SPDSS assistance. Division 1 and Water District 47 data on diversion structures are complete and adequate for both location and attributes; wells attribute and location data are also adequate. However, for both diversion structures and wells, Division 1 has designed programs to enhance the location and attribute data, as described above.

3.15.2.4 Agricultural Statistics. Agricultural statistics were assessed to determine if they are adequate for supporting basin crop consumptive use.

3.15.2.4.1 Spatial Coverage. Colorado Agricultural Statistics (CAS) are compiled for the major cash crops only and the National Agricultural Statistics Survey (NASS) compiles crop information for both cash and non-harvested crops. All of these data are reported by county for the entire South Platte River basin, thus the spatial coverage is adequate but the spatial resolution is very course.

3.15.2.4.2 Period of Record. Yearly CAS data have been compiled throughout the State for more than 100 years and NASS have been compiled for more than 50 years. NASS are completed every 5 years. It is believed that CAS data may provide a basis for filling the NASS data for the years when surveys were not performed. Therefore, the length of available records is adequate for use in estimating historic irrigated acreage and assessing crop yield versus water use over time.

3.15.2.4.2 Completeness of Record. CAS data are available yearly and there are reported to be no missing years. NASS data are compiled every 5 years.

3.15.2.4.3 Reliability of Record. Annual CAS reports information supplied by producers for the main cash crops grown in Colorado. Statistics are generally not reported for crops not widely grown or crops not harvested for sale. "Pasture" type crops may not be accounted for, therefore, CAS reports likely do not provide an adequate representation of total irrigated acreage. NASS reports information from a more extensive survey of irrigated lands and includes "pasture" not harvested as well as dry land crops.

3.15.3 Additional Data Required

Interviews with basin stakeholders and Division 1 personnel (see Chapter 2) recommend construction of an irrigated acreage coverage for the entire basin and they expressed desire for enhancements not present in the RGDSS product. Potential users also indicated a strong interest in more precise locations of irrigation wells and service area delineation. As discussed above, there are activities in irrigation districts and in Division 1 to gather more accurate well location information. As mentioned above, these programs vary in their progress and completion dates. These data will be used where available.

Historical irrigated acreage in the RGDSS were estimated using crop production information from CAS. This technique yielded acceptable results in the RGDSS. However, these data are county-based and therefore gross estimates. Also, significant changes in land use have occurred in the South Platte River basin where large areas of formerly irrigated agricultural lands have been converted to urban areas. Most users felt that the CAS adjustments to irrigated acreage used in the Rio Grande basin would not yield an acceptable result in the South Platte River basin and that more detailed information was required.

The state of existing spatial information may be analogous to a patchwork quilt where some of the patches are complete, some are half finished, and there are many holes where there is nothing at all. The proposed approach is to include as much of the usable information as possible. However, for the data to be usable in the SPDSS, consistent and comprehensive maps and associated databases will be needed for historic and current land use, and for use in mapping irrigation water sources and service areas.

3.15.3.1 Current Land Use. A consistent and complete classification of current land use can best be accomplished by computer classification of satellite images, coupled with field investigations, review and editing by users. This process, illustrated on Figure 3-3, utilizes the attribute databases as well as the spatial database that will be constructed under this project (described in Section 3.16). The best satellite data source is Landsat TM for a single base year. The entire basin can be covered by a total of six Landsat frames. Cloud-free data are available for most of the basin. The precise data should be selected following a close scrutiny of those data with less than 10 percent cloud cover, shown in Table B-15 in Appendix B for the year 2000. Using satellite imagery, existing data and ground reference information, land use/cover maps can best be developed by applying a hierarchical classification system.

The land use/cover classification maps will depict irrigated lands and general vegetation types for non-irrigated areas. The latter will be used for developing consumptive use estimates of non-irrigated land for groundwater modeling. For this purpose, the main information source will be the MRLC, described in Section 3.15.1.2, along with vegetation indexes computed from the current Landsat TM data (e.g., using TM band ratios). This will produce several land cover classes to be used for estimating consumptive use for groundwater modeling, including: open water, developed, barren, forested upland, shrubland, herbaceous upland, herbaceous planted/cultivated (non-irrigated), woody wetlands and emergent herbaceous wetlands.

3.15.3.2 Historic Land Use. In addition to the current land use map three historic land use maps at several intervals beginning in the 1950s are recommended for development. The historic land use maps could be developed for the following:

- Late 1980s using satellite imagery
- Mid-1970s using satellite imagery
- 1950s using aerial photography

There are existing information on historic land use but none are complete and immediately applicable for this study. Thus, the first task will be to construct a consistent database using relevant existing data, and using the base GIS and other information to be constructed for this project. The approach will work backward from the current land use map described in Section 3.15.3.1 to examine historic land use and perform change analysis. Estimates of historic crop mix by area will be made using a combination of land use maps, the detailed crop maps from the current land use maps, and the Colorado Agricultural Statistics.

The method proposed for historic land use classification for two dates, one in the 1970s and one in the 1980s, is similar to that described for current land use. Existing data and maps will be used in classifying satellite images for specific years. For each of the dates, it is assumed that two satellite images would suffice for each of the six frames. Thus the total of 12 frames per each of two periods would require a total of 24 satellite images for this analysis.

If land use classification is performed for the 1950s then aerial photographs will be required. Relatively good quality aerial photographs are known to exist for a substantial part of the South Platte River basin, and it is expected that these cover most if not all of the study area.

3.15.3.3 Water Source and Service Areas. Sources of information for associating irrigated parcels with ditches and/or wells are described above. The State and water users are the best source for information from which a set of maps can be developed. As with other tasks, the method should use existing information to the extent possible. The GIS database (e.g. digital elevation data, ditch alignment maps) described in Section 3.16 should be utilized along with interpretation and local knowledge. A comprehensive image map base will be developed for mapping the irrigation ditches and their service areas, and for locating wells and associated service areas. This image base will be useful for many other database and modeling activities of the SPDSS, including current and historic land use mapping.

In addition to the image map base, production of irrigation service area coverage will require mapping of significant headgates, ditches and wells derived from State records, information from Division personnel, USGS maps and digital data, and from water users. First order mapping of service areas will use GIS data including digital elevation models, existing land use maps, population data, etc. Well data should be acquired from the State records and located using public lands survey section (PLSS) descriptions and/or other locational information developed by the State. Suggestions will be made to the State for correcting any locational errors. Locations determined by GPS could be utilized for approximately 17 percent of the high capacity wells using records from the State and water users (e.g., GASP). Locations of remaining wells would be estimated initially, then updated as more accurate information becomes available via Division 1 activities for locating wells using GPS along with research on decrees, permits and augmentation plans. Well service areas could be determined by combining well locations and corresponding attribute information, such as capacity and water rights, with land use classifications.

The process of mapping irrigation service areas will require visits to offices of many users, visits with Water Commissioners and others, and tedious methods of manual mapping. Preliminary results will be reviewed and edited by the users; thus, the process will be interactive and cooperative.

3.15.3.4 Agricultural Statistics. The agricultural statistics will be collected from the CAS office. This will require minimal effort to gather and incorporate into the analysis.

3.16 GEOGRAPHIC INFORMATION SYSTEM

Geographic information (e.g., maps) is important as a basic water resource data need and for use in water rights administration and modeling. The goal of this component is to construct a comprehensive and consistent geographic information data infrastructure for use in the development of the SPDSS. Accomplishment of this goal will require that locations of data sources (e.g., weather stations and stream gages) be digitized into GIS coverages to allow a proximity analysis. For example, Thiessen polygons, or their equivalent, will be developed and incorporated into the GIS coverages to facilitate selection of the most appropriate source of rainfall, temperature, evaporation or other data required for consumptive use calculations for a specific location.

The focus of this section is on (1) acquiring currently available GIS data that can be assimilated with minimal processing and made usable to the SPDSS team in consistent formats, projections, etc., and (2) on-time critical data that will be required by other activities in the early stages of

SPDSS implementation. This GIS database should be developed early in the project to enable team members to use the data and more efficiently accomplish their objectives.

This section does not fully describe all of the data sets that could be digitized into GIS coverages to allow proximity analysis; e.g., climate data are fully discussed in Section 3.13 and irrigated lands data are covered in Section 3.15.

3.16.1 Description and Inventory of Available Data

As shown in Table B-16 (Appendix B), five major categories of spatial data were considered: boundaries, river and water distribution systems, local government, climate and other. These data categories are described and assessed in the following sections, with the exception of climate data, which is addressed in Section 3.13, and snow data in Section 3.14.

3.16.1.1 Boundary Data. Boundary data that will be obtained and processed for viewing include water division and district boundaries, State HUC (hydrographic units) and county boundaries. These vector data are available for the entire study area and are derived from maps at scales of 1:100,000 to 1:250,000.

3.16.1.2 River System and Water Distribution. The river and water distribution category includes two versions of hydrography data that will be obtained and processed for viewing. The first are currently available from the USGS in DLG format and derived from 1:100,000 scale maps. The second data are a much-improved version derived from 1:24,000 scale USGS topographic maps and known as National Hydrography Data (NHD). The Colorado Division of Wildlife is developing the NHD maps under contract to the USGS. The digital coverages are about 50 percent complete for the study area, with the upper South Platte River basin already complete. The lower basin and the North Platte River Basin will be completed during 2001. The NHD digital maps include locations and names of all hydrographic features on 7.5-minute USGS maps, with the exception of springs and some types of water tanks. Also, the direction of flow will be captured and inherent in the vector database.

Other data to be obtained and processed for viewing in this category include names and location of over 7000 diversions and administered control structures within the study area. Typically, the locations of these structures are included in the State's database as a legal description and a UTM coordinate. The UTM coordinates described above will be used to derive the approximate location of the structures and depict them on the orthophoto/image base map described. Also, major reservoir/dams and all stream gauges are in the State's database along with a legal description of the location. These also will be mapped onto the ortho/image base using the UTM data as described. In addition, digital orthophotos of the South Platte River and adjacent floodplain will be incorporated. These raster images, recently acquired by CWCB with 2-foot ground resolution, cover the South Platte River and adjacent floodplain from Chatfield Reservoir to the state line. River cross-sections and floodplain contours in vector format are included. There are other data available from users—such as GASP, NCWCD, ditch companies, etc.—that may prove to be valuable for SPDSS. Some of these data are known to be useful for mapping irrigation service areas, as described in Section 3.15. These users have indicated a willingness to provide these data for use in SPDSS.

3.16.1.3 Local Government. Many of the county governments within the SPDSS study area have extensive spatial databases and capabilities. As well, most of the sizable municipalities have GIS departments and large databases. Contacts have been made regarding data availability with Larimer, Weld, Jackson, Boulder, Denver and Jefferson counties and with Fort Collins, Greeley, Boulder, Aurora and Denver. Relevant data layers will be requested for use in SPDSS, particularly recent information on urban boundaries and land use.

3.16.1.4 Climate. Climate and snow data stations are operated by the NOAA/NWS, CSU, NCWCD, USACE, NWS, NRCS and Denver Water Department at various locations throughout the South Platte Basin. Climate and snow data are described in Sections 3.13 and 3.14, respectively. The locations of these stations will be mapped under these GIS tasks.

3.16.1.5 Other Data. The category "other data" in Table B-16 includes highways, PLSS data, soils and wetlands data available in vector format covering the entire study area. These data are available from U.S. government sources at no cost, derived from various sources of maps, though typically at 1:100,000 scale. In addition, the digital raster graphics (DRGs) from the USGS will be useful as base information. DRGs are digitally scanned 1:24,000 scale topographic quadrangle maps, and will be especially useful for geo-referencing base spatial data. The PLSS data available from the USGS can be used for many applications and can be distributed because they are public domain data. A proprietary PLSS database has been purchased by the State for use within the DWR and cannot be distributed. Because these data are more precise, it is proposed to use them only for special processing, for example in locating diversion structures from legal descriptions. The digital elevation models (DEMs) from USGS's National Elevation Data (NED) are derived from 1:24,000 scale USGS topographic contours. These DEMs will be obtained and processed for viewing because they are substantially improved over the previous generation. They are edge-matched and with minimal processing can be used to create seamless data coverage.

3.16.2 Data Assessment

A collective assessment of the GIS data described above is provided in the following sections. For "reliability of record" each GIS data type is described separately.

3.16.2.1 Spatial Coverage. All the GIS data described above cover the entire SPDSS study area.

3.16.2.2 Period of Record. The spatial data are derived from maps created over the past 30 years. Data from the most recent maps will be used.

3.16.2.3 Completeness of Record. The record is complete for each of the data types, with exception of data that are still under development including NHD.

3.16.2.4 Reliability of Record. Overall GIS data are believed to be adequate for the purposes of the SPDSS. The data are in various formats, resolutions, scales, etc. Some of these data will need some processing to make them usable in the database, particularly to convert to a common projection and GIS format. A brief description of reliability for each of the GIS data categories is provided below.

3.16.2.4.1 Boundary. The existing boundary data shown in Table B-16 are derived from small-scale maps at 1:100,000 or less. The scale for some mapping and analyses under SPDSS will be at 1:24,000. Thus, the boundary data will require some modification by using USGS DRGs and other map sources to adjust boundaries for use in the more detailed applications. Otherwise, the data are appropriate and will require minimal additional processing.

3.16.2.4.2 River System and Water Distribution. At present about 50 percent NHD data of the South Platte Basin are available; the remaining area is scheduled for completion during 2001. As with most other USGS public domain data, NHD coverages are provided in a non-proprietary format and thus will need to be transformed into Arc Info format for use in the SPDSS, and projected into the common format to be used in this project.

The digital ortho-photos covering the South Platte River and adjacent floodplains, and the associated floodplain contours, will suffice as a base for mapping the river alignment, locating structures, and for interpreting river morphological features. Some of the GIS data of water users, for example NCWCD and GASP, have been discussed in some detail with the respective organizations. Others, such as ditch companies, have been discussed on a more general level.

3.16.2.4.3 Local Government. Some of the spatial data developed for use by local governments will undoubtedly be useful for the SPDSS. The areas particularly of use will include municipal boundaries, land use, planning and zoning maps, etc. Contacts have been made with several of these organizations, as described in Section 3.16.1.4. Several municipalities also have been consulted. These organizations appear willing to work with the State on development of the SPDSS, and many have already established an open access policy for certain data within their archives.

3.16.2.4.4 Climate Data. Climate and snow data station locations are considered to be adequate, as described in Sections 3.13 and 3.14. The data are associated with stations that are located as point data with longitude and latitude coordinates. A point data file will be established in the GIS with links to the climate and snow databases. Much of these data are already available in GIS format under SPMAP.

3.16.2.4.5 Other. As described above, it is recommended that the proprietary PLSS data should be used for analyses and for mapping structures and other features that are now located by legal description. These data are at an appropriate level of spatial accuracy for deriving locations. Conversely, the public domain PLSS data are appropriate for most other uses and can be distributed. Other vector data of natural resources, such as soils and wetlands, are mapped in sufficient detail for use in this project. The digital elevation models (DEMs) from NED and DRGs are recently updated products of the USGS and will require only limited processing to create seamless coverages, with a projection that is common for the entire spatial database. Data for the NCWCD are available within the SPMAP database. Land use data, both current and historic, are described in detail in Section 3.15.

3.16.3 Additional Data Required

As stated above, apart from the land use and irrigation service area data described in Section 3.15 and other spatially dependent data described in previous sections of this report (e.g., diversion structures, wells and climate station locations, etc.) there are no additional spatial data required for this GIS foundation database. Therefore, the costs for developing the GIS database are for processing and editing existing data and for incorporating them into a cohesive spatial database. As mentioned, GIS data will be needed for applications and these are described elsewhere.

The activities required to complete this foundation GIS database would include search, order and assessment of data, and processing, editing and assimilating into a coherent and comprehensive GIS database. Coverages will be packaged into ArcView projects that allow a final map to be viewed or printed without additional processing. In addition, metadata will be developed for each of the GIS themes describing data origin and other features.

3.17 SUMMARY

The SPDSS will be a data-centered system that will provide a comprehensive database of pertinent water resource data for the South Platte and Water District 47 in Colorado. The data will be available as (1) existing gaged data sets that require no further modification, (2) existing data sets that have had missing data filled in or have been subjected to additional QA/QC, and (3) where needed, additional data that will be collected during the first few years of implementation. These additional data are required to improve the spatial and temporal coverage, completeness and reliability of data from which the SPDSS will derive calculations and results.

A summary of (1) existing data to be used for the SPDSS, (2) necessary QA/QC and data filling required, and (3) additional data required for the SPDSS is presented in Table 3-1. The data sets listed in Table 3-1 would be required to meet the expressed needs of a decision support system in order to provide "data for data sake" and allow the detailed modeling identified in Chapter 2 to be performed. Estimated costs for obtaining these data sets and priorities for collection of these data are presented in *Chapter 5, Alternatives*.

Table 3-1. Summary of Data for SPDSS

Description of Data	Comments
Surface Water Data	
Missing streamflow records	Identify key streamflow gages in South Platte and North Platte River basins and fill missing records using CRDSS and RGDSS-developed techniques
Real-time streamflow gages	South Platte River near Fort Lupton – Renovate and reactivate existing gage, install satellite equipment
	South Platte River at Fort Morgan – Renovate and reactivate existing gage, install satellite equipment
	South Platte River at Atwood (near Sterling) – Install new gage and satellite equipment
	South Platte River at Cook Bridge – Install new gage and satellite equipment
	Cache la Poudre River below Chambers Lake – Install new gage and satellite equipment
	North Fork Cache la Poudre River below Seaman Reservoir – Install new gage, cableway, and satellite equipment
	South Boulder Creek at Denver Water Department diversion near Eldorado Springs – Replace gage and install satellite equipment
	Boulder Creek at Boulder – Install new gage and satellite equipment
Real-time diversion gages	Berthoud Pass Ditch – Install satellite equipment on transbasin diversion
	Michigan Ditch – Install satellite equipment on transbasin diversion
	Prewitt Reservoir Inlet – Install satellite equipment
	Peterson Ditch – Install satellite equipment
	Iliff & Platte Valley Ditch – Install satellite equipment
	Springdale Ditch – Install satellite equipment
	Bravo Ditch – Install satellite equipment
	Powell Ditch – Install satellite equipment
	South Platte Ditch – Install satellite equipment
	Upper Platte and Beaver Ditch – Install satellite equipment
	Jackson Lake Inlet Canal – Install satellite equipment
	Empire Reservoir Inlet Canal – Install satellite equipment
Rated control section streamflow gages	Conduct conceptual design investigation to evaluate potential technologies
	South Platte River at Julesburg – Relocate gages and install channel stabilization structures (control)
	South Platte River at Balzac – Relocate gage and install channel stabilization structure (control)
	South Platte River at Kersey – Relocate gage and install channel stabilization structures (control)
Maintenance of new gages	Division 1 would operate and maintain all new diversion gages, all rated control section streamflow gages, and up to 2 new streamflow gages under existing Division 1 program. The operation and maintenance of additional new streamflow gages would be funded by SPDSS and performed by the SPDSS contractor during the SPDSS implementation period (approximately 5 years following installation of gages)
Point-flow stream gaging (Denver Basin and Overlying Alluvium)	2 years of stream gaging, conducted 2 times per year, at 25 selected locations along perennial and intermittent tributaries of the South Platte River overlying the Denver Basin aquifer, to establish point-flow estimates and analyses for gain/loss studies in support of the groundwater modeling component (per SB 96-74 recommendations)

Table 3-1. Summary of Data for SPDSS (continued)

Description of Data	Comments
Point-flow stream gaging (Lower South Platte)	2 years of additional stream gaging, conducted over 4 separate events, along 4 mainstem reaches of the South Platte River from the St. Vrain River to Julesburg, to evaluate gains and losses in support of water rights administration by Division 1
Flow routing data	Channel characteristics data to establish reach lengths, channel geometry, roughness factors, and slopes along South Platte mainstem and major tributaries.
Identify Key Diversion Structures based on discussions with the Division Engineers, water users and historical diversion records for Division 1 and Water District 47.	Review HydroBase records, interview water users and Division 1 and 6 Engineers, and do analysis of historical diversion and streamflow records.
Estimate missing daily diversions records in Division 1 and Water District 47.	Fill data for 80 diversions (25 percent of approximately 319 major diversions).
Estimate missing daily transbasin diversion data in Division 1 and Water District 47.	For 19 transbasin diversions obtain available data, resolve differences in various sources of digitized data, contact structure owner to obtain any additional data and estimate any missing data.
Identify key reservoir structures in Division 1 and Water District 47.	Review HydroBase records, interview water users and the Division Engineers to identify the major reservoir structures that should be included in the initial surface water modeling effort.
Estimate missing storage records in Division 1 and Water District 47.	Gather available physical and operational data, digitize records, and estimate missing data for up to 59 reservoirs.
Gather, digitize and incorporate augmentation plan data in Division 1 and Water District 47.	Gather available data for up to 40 augmentation plans, substitute supply plans, and/or transfer decrees.
Incorporate CWCB instream flow tabulation into HydroBase in Division 1 and Water District 47.	Develop linkages to CWCB ISF tabulation or incorporate directly.
Gather, digitize and incorporate river call data into HydroBase for mainstem and major tributaries in Division 1 and Water District 47.	Collect, interpret, and digitize data. This could provide a source of uniform and consistent priority call data.
Groundwater Data	
Perform feasibility investigation to establish method to estimate pumping (power records vs. consumptive use)	Samples of existing well pumping data will be used with samples of power records and initial CU estimates to determine most accurate method to estimate GW pumping.
Collect available historical pumping data	Needed for calibration of pumping estimates.
Estimate historical pumping using selected methodology. This will be primarily in the South Platte River basin.	Will be estimated from either: (1) consumptive use and calibrated with existing well meter data, or (2) electric power records and calibrated with existing well meter data.
Collect & interpret existing aquifer configuration and characteristics data for Denver Basin and Overlying Alluvium Region, Lower South Platte Alluvium Region, North and South Park Region and Other Designated Groundwater Basins.	Based on SB 96-74 recommendations and general need for additional data to meet expressed needs for SPDSS.
Conduct streambed conductance tests at up to 80 sites, (60 sites in the Denver Basin and Overlying Alluvium Region, 10 sites in the Lower South Platte Alluvium Region and 10 sites in the other Regions).	Based on SB 96-74 recommendations and general need for additional data to meet expressed needs for SPDSS.
Drill/install up to 200 alluvial aquifer monitoring wells, (110 wells in the Denver Basin and Overlying Alluvium Region, 70 wells in the Lower South Platte Alluvium Region and 40 wells in the other Regions).	Based on SB 96-74 recommendation to gather data on streambed conductance.

Table 3-1. Summary of Data for SPDSS (continued)

Description of Data	Comments
Drill and install up to 25 bedrock monitoring wells in the Denver Basin and Overlying Alluvium Region.	Based on SB 96-74 recommendation to characterize vertical flow in the bedrock.
Conduct pumping tests in up to 4 of the new alluvial wells and up to 10 of the new bedrock monitoring wells.	Based on SB 96-74 recommendation to obtain additional data on aquifer properties.
Collect and evaluate available historical water level data in the Denver Basin and Overlying Alluvium Region, Lower South Platte Alluvium Region, North and South Park Region and Other Designated Groundwater Basins for up to 3 discrete time periods (1950s, 1970s and 1990s).	Used to characterize historical conditions. Required for development and calibration of groundwater models.
Collect future water level data on a monthly basis for up to 270 existing, up to 240 new and up to 20 converted wells (abandoned wells converted to monitoring wells) in the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions.	Based on SB 96-74 recommendation to obtain more data on groundwater levels, flow between aquifers, and stream-aquifer interactions.
Consumptive Use Data	
Climate data (temperature, precipitation, wind speed, solar radiation, and vapor pressure)	Required for irrigation water requirement estimates. Use existing data sources/stations including NCDC, CSU CoAgMet, NCWCD and NOAA.
Snow survey data (includes snow pack depth, SNOTEL data, previous years, averages and basin-wide summaries)	Use existing data sources including NWS and NRCS, both automated SNOTEL and manual snow course measurements. Real time snow course data could be used to forecast spring runoff quantities and patterns.
Ditch diversions (see Surface Water)	Required for supply-limited consumptive use estimates
Irrigated land/cropping patterns (see Land Use)	Required for irrigation water requirement estimates
Groundwater pumping estimates (see Groundwater)	Historic estimates required for supply-limited consumptive use estimates, or can be generated through CU analysis
Crop characteristics/crop coefficients	TR-21 or locally calibrated estimates used for Irrigation Water Requirement Estimates. Use existing data.
Ditch conveyance losses	Based on user interviews, required for Supply-Limited Consumptive Use Estimates. Use existing data.
Farm/well headgate losses for the range of conditions in the South Platte River basin	Based on irrigation methods (Section 3.15). Use existing data.
Native vegetation estimates/reports for South Platte River basin	Existing estimates used to compare with results of Water Budget Analysis (Section 3.12). Use existing data.
Wildlife area use estimates/reports	Required for basin consumptive use. Use existing data.
Population data for cities, towns and counties in study area	Used in conjunction with per capita use data to estimate municipal and domestic water supply. Use existing data.
Municipal consumptive use per capita estimates for cities, towns and counties in study area	Used in conjunction with population data to estimate municipal and domestic water supply. Use existing data.
Municipal indoor use return flows	Used in conjunction with municipal and domestic supply estimates to determine municipal and domestic consumptive use. Use existing data
Municipal outdoor use return flows	Used in conjunction with municipal and domestic supply estimates to determine municipal and domestic consumptive use. Use existing data.

Table 3-1. Summary of Data for SPDSS (continued)

Description of Data	Comments
Water Budget Data	
Initial Water Budget terms	Based on existing estimates and published reports. Use existing data.
Precipitation (see Consumptive Use)	Inflow term. Use existing data.
Transbasin diversions (see Surface Water)	Inflow term
Gaged and ungaged surface water inflow estimates (see Surface Water)	Inflow term, ungaged surface water inflow developed during SPDSS by Surface Water Contractor
Groundwater inflow	Inflow term, developed during SPDSS by Groundwater Contractor
Basin Consumptive Uses	Outflow terms, developed during SPDSS by Consumptive Use Contractor
Reservoir evaporation (see Surface Water)	Outflow term, required data to estimate developed during SPDSS by Surface Water Contractor
Surface Water outflow	Outflow term
Groundwater Outflow	Outflow term, developed during SPDSS by Groundwater Contractor
Change in Surface Water Storage	Change in storage term, developed during SPDSS by Surface Water Contractor
Change in Groundwater Storage	Change in storage term, developed during SPDSS by Groundwater Contractor
Land Use, Irrigation Service Areas and Geospatial Data	
Mapping of current land use in South Platte and North Platte River basins including vegetation maps for estimates of consumptive use.	Process to create map includes data purchase, processing and analysis. Existing data source will be six Landsat satellite images. Additional sources of land use maps include NCWCD's SPMAP, USGS National Land Cover Data, and FSA NHAP aerial photographs. Vegetation maps for consumptive use will be based on MRLC data (from early 1990s) and Landsat TM data.
Mapping of historic land use in South Platte and North Platte River basins	Process to create maps includes data purchase, processing and analysis for 3 snapshots (1950s, mid-1970s and late 1980s). Existing data sources include current land use map (described above), historic satellite images, land use and land cover classifications (MRLC, USGS), aerial photographs, and agricultural statistics data.
Water source and service area data (location of structures, water service areas, irrigated parcels, etc.)	Existing data sources needed for irrigated service map coverages includes information from Hydrobase, State records, Division personnel, DOW NHD, USGS maps and water users (e.g., Cache La Poudre water users association, GASP).
Agricultural statistics (annual acreage and yield by crop)	All available CAS data will be gathered for every county in the study area from 1950 to the present. Use existing data.
GIS Database for support to overall SPDSS activities (includes all spatial data discussed above and below)	Creation of database Includes data purchase, processing and results. Use existing data.
Boundary data derived from maps	Existing data includes water division and district boundaries, State HUC (hydrographic units) and county boundaries
River system and water distribution data (names, locations, structures)	Derived from existing USGS maps, DOW's National Hydrography Data, PLSS, State database, and other water user's databases
Spatial data from local government entities	Existing data has not been assessed, but assumed to be useful
Climate and Snow data including temperature, precipitation, evaporation, vapor pressure, solar radiation, soil temperature and station locations	Existing data available from NOAA/NWS, CSU, NCWCD the USACE, Denver Water Department, NWS and NRCS.
Other relevant GIS data including highways, PLSS, soils and wetlands	Existing data available from U.S. government sources in vector format.

Table 3-2. Summary of Diversion Records by Water District

Water District	Period of Record Data is Generally Available in HydroBase	Reliability of Records	Comments
1,2,3,4,5,6,7,8,9 and 64 (Middle and Lower South Platte River)	1950-Present	Good	Most structures are equipped with Parshall flumes and continuous recording devices. Diversion records on Plum Creek and upper Cherry Creek are less reliable due to the quality of the measuring devices and lack of continuous recorders. Installation of continuous recorders on most of the ditches in District 5 did not occur until the early 1990s.
23,80 (North Fork and South Fork of South Platte River)	1950-1963 and 1970s-Present	Poor to Average	Many ditches have incomplete and infrequent diversion records. Some ditches had inadequate measuring devices prior to the 1980s. Most structures do not have continuous recorders. Diversion records for most of the ditches are missing from 1964 to the early 1970s.
47,48,76 (North Platte and Laramie Rivers)	1970s-Present	Poor to Average	Some of the ditches have incomplete and infrequent diversion records. Most of the ditches had inadequate measuring devices prior to the 1980s.

Table 3-3. Wells and Pumping Data Assessment Summary

Area	Spatial Coverage	Period of Record	Completeness	Reliability
Denver Basin and Overlying Alluvium Region	Good	Fair	Poor	Poor
Lower South Platte Alluvium Region	Good	Fair	Fair	Fair
Other Designated Basins Region	Good	Fair	Poor	Poor
North Park/South Park Region	Good	Fair	Poor	Poor

Table 3-4. Geologic Structure and Aquifer Properties Data Assessment Summary

Area	Spatial Coverage	Period of Record	Completeness	Reliability
Denver Basin and Overlying Alluvium Region	Good/Fair*	n/a	Fair/Poor	Good/Fair
Lower South Platte Alluvium Region	Good/Fair	n/a	Good/Fair	Good/Fair
Other Designated Groundwater Basins	Fair/Poor	n/a	Fair/Poor	Fair/Fair
North Park and South Park Regions	Poor/Poor	n/a	Poor/Poor	Fair/Fair

* The first qualifier relates to geologic structure data and the second relates to aquifer properties.

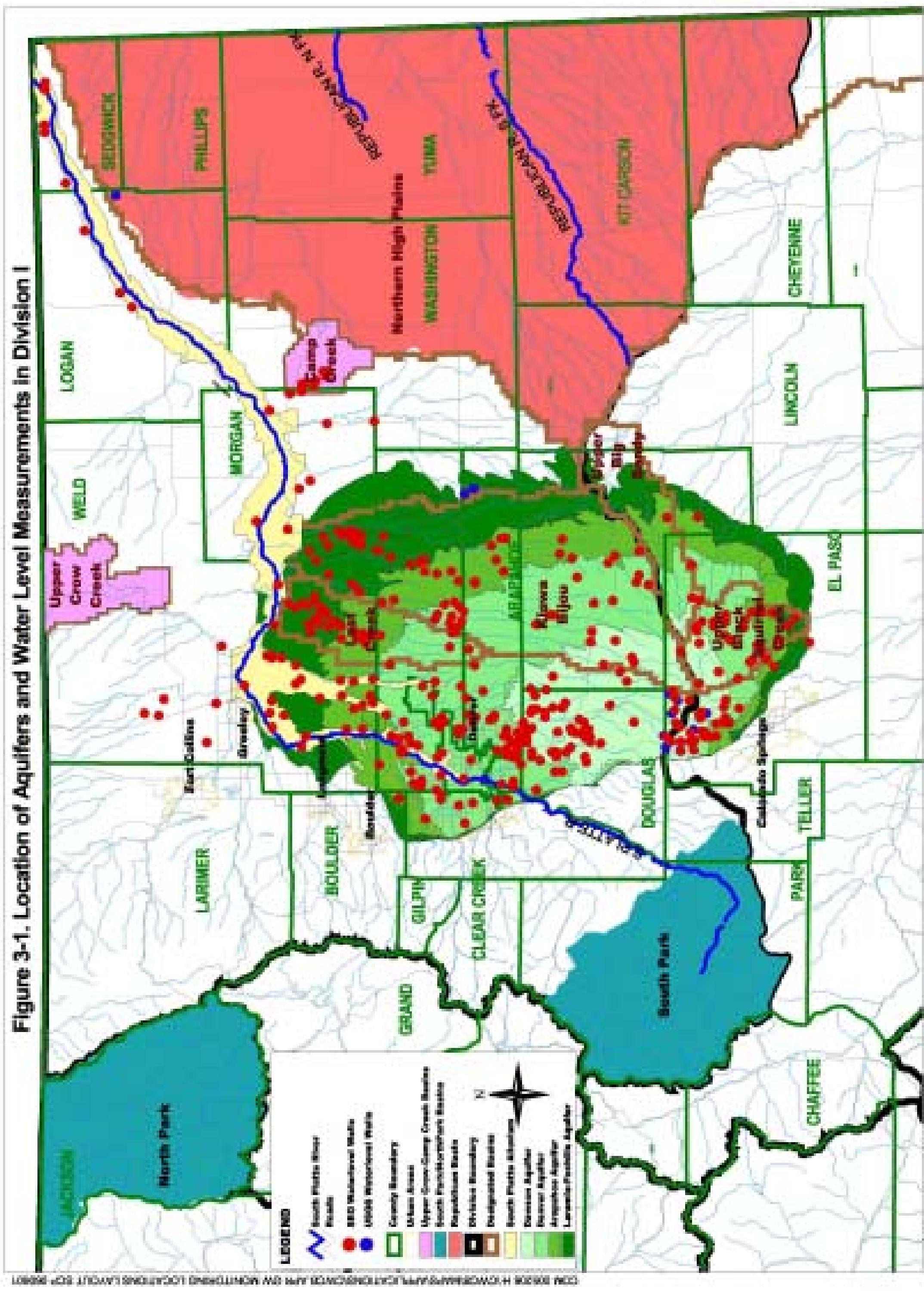
Table 3-5. Water Level Data Assessment Summary

Basin	Spatial Coverage	Period of Record	Completeness of Records	Reliability of Records
Denver Basin Region	Fair	Good	Poor	Poor
Lower South Platte Region	Poor	Poor	Fair	Poor
Other Designated Groundwater Basins Region	Poor	Poor	Poor	Poor
North Park & South Park Region	Poor	Poor	Poor	Poor

Table 3-6. Consumptive Use and Water Budget Component Required Data

Type of Data	Description	Municipal/ Crop	Data Source	Data Acquired By:
Time Series	Climate	Crop	Historic Records	CU
	Ditch Diversions	Crop/Municipal	Historic Records	SW
	Irrigated Land/Cropping	Crop	Analysis/Historic Records	GIS
	Agricultural Statistics	Crop	Historic Records	CU
	Groundwater Pumping	Crop/ Municipal	Analysis/Historic Records	GW or CU
	Crop Yields	Crop	Historic Records/ Interviews	CU
	Population	Municipal	User Interviews/ Historic Records	CU
Factor	Municipal CU/capita	Municipal	User Interviews/ Studies	SW, GW, CU
	Crop Characteristics Crop Coefficients	Crop	Local Calibration/ Lysimeters	CU
	Ditch Conveyance Loss	Crop	User Interviews/ Studies	CU
	Farm/Well Headgate Loss	Crop	User Interviews/ Studies	CU
	Municipal Indoor Use Return Flows	Municipal	User Interviews/ Studies	CU
	Municipal Lawn Irrigation Return Flows	Municipal	User Interviews/ Studies	CU
GW=Groundwater Component, SW=Surface Water Component, CU=Consumptive Use				

Figure 3-1. Location of Aquifers and Water Level Measurements in Division I



Groundwater Monitoring Locations

Figure 3-2. Climate Station Locations

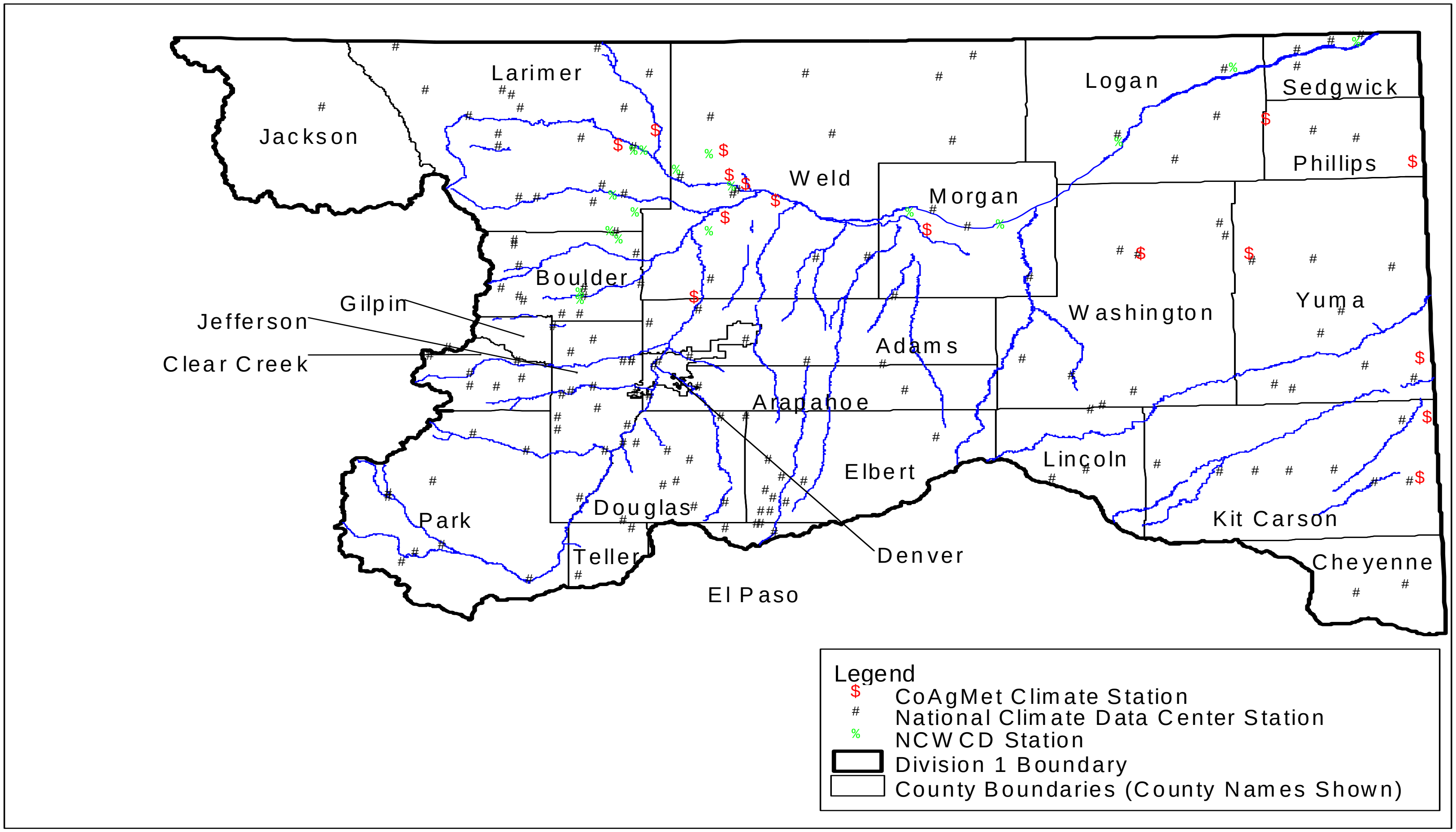
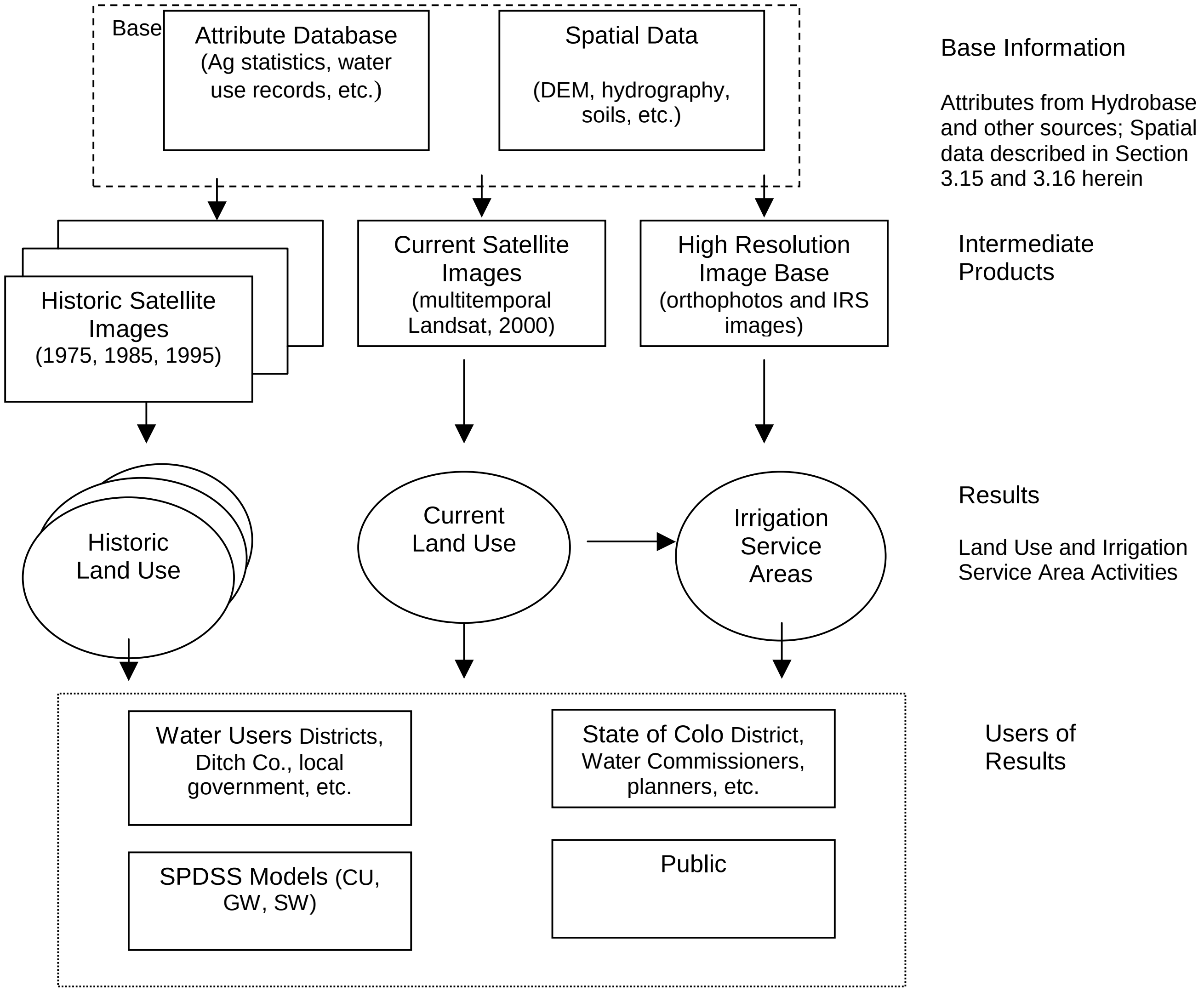


Figure 3-3. Information Flow for Mapping Land Use and Irrigation Water Supply Source



CHAPTER 4

DSS COMPONENTS

4.1 INTRODUCTION

The objective of this chapter is to identify decision support system (DSS) components that meet the needs identified in *Chapter 2, Needs Assessment*. The needs assessment identified both system needs and nine categories of application needs that the SPDSS could address. Some of the needs identified in Chapter 2 were determined inappropriate for SPDSS because they are the primary responsibility of other State and Federal agencies. The remaining system needs are addressed throughout this chapter under the following six major categories of application needs:

- Surface Water Resources Planning
- Water Rights Administration and Accounting
- Groundwater Resources Planning
- Consumptive Use Analysis
- Water Budget Analysis
- System Integration

Each category addresses the needs and purpose of the specified component, describes the existing applicable component, and provides recommendations for further SPDSS component needs (i.e. additions or enhancements). In addition, sections are included that discuss maintenance and user involvement.

The existing DSS was developed and applied to the Colorado River and Rio Grande basins and contains application components that are applicable to the South Platte River basin. To respond to the needs expressed in Chapter 2, however, modifications to these existing components and new components may be required.

In addition to Colorado's DSS, other entities such as the Northern Colorado Water Conservancy District (NCWCD), Denver Water, Colorado Water Conservation Board (CWCB) and the Division of Water Resources (DWR) have developed application components that may be appropriate for use by the SPDSS. For example, the NCWCD, Colorado Water Resources Institute, GASP, SEO, and other Lower South Platte water users have developed a DSS, SPMAP, that contains GIS, consumptive use, groundwater, data viewing and other capabilities. Denver Water has a water resources planning model, PACSIM, that covers the South Platte River basin from the headwaters to Henderson, Colorado and the Colorado River from the headwaters to the head of the 15-Mile Reach near Palisade, Colorado. The CWCB has an existing database and data entry system for instream flows. Finally, DWR has existing systems that handle real-time data (SatMon) and future plans to develop HydroBase entry tools.

An attempt is made to discuss each major application component identified during the interview process in the Existing Component Descriptions sections below. The potential use of components developed by entities other than the State in the South Platte River basin as part of SPDSS and the SPDSS's responsibility to improve and support coordination with such independent developments are discussed in *Chapter 5, Alternatives*.

Each application category described below has common data needs and linkages with other application categories. For example, the surface water model requires the consumptive use model's estimates of irrigation water requirement. Similarly, the groundwater model requires the surface water model's estimates of historic and future diversions. Therefore, component linkages are discussed in a comprehensive manner in *Section 4.7.3, System Linkages*, rather than under each application component.

4.2 SURFACE WATER RESOURCES PLANNING

The surface water resources component of the SPDSS addresses many of the surface and groundwater planning needs identified in Chapter 2. It will provide a comprehensive treatment of surface water and consideration of a range of alternative methods to evaluating groundwater use. User needs that will be met by the surface water resources planning component are presented below.

4.2.1 Needs and Purpose of Component

Many of the surface and groundwater needs presented in Section 2.2 relate to users' desires to better understand the water resources of the South Platte River basin within Colorado. This includes an understanding of how the supply, demand, and utilization of these resources have changed over time. Furthermore, users want to be able to evaluate the future use and management of these resources on a scale ranging from the examination of individual water rights to complex conjunctive use projects covering multiple tributaries of the South Platte River basin. A computer model of the surface and groundwater system of the South Platte River will best meet the myriad of planning needs expressed during the needs assessment. Properly designed and developed, a water resource model can be used to (1) simulate the operation and interaction of both surface and groundwater supplies and uses and (2) account for the physical, legal and institutional constraints of the system.

4.2.2 Existing Component Description

The existing surface water resources planning tool of the CDSS is the State of Colorado's Water Resources Model (StateMod). StateMod was originally developed for the State of Colorado as part of the Green Mountain Pump Back and Exchange Project (Colorado Water Resources and Power Development Authority 1987). The model has successfully been enhanced and supported by the State of Colorado since 1994.

StateMod is the water resources planning model used to assess past, present and future water management policies. It has the capability to evaluate many of the planning needs identified by water users in the South Platte River basin. StateMod is a water allocation and accounting model that (1) uses user-specified data to compute natural streamflow (streamflow absent of any impact of man) and (2) subsequently allocates flow for diversions according to water rights priorities (via diversions, storage, well pumping, instream flow requirements, and operational rights) in strict conformance with the prior appropriation doctrine. StateMod is a generic water rights planning model that can be configured for the South Platte River basin and implemented in the SPDSS with some modifications.

StateMod models river basins using a linked network of river nodes that represent physical structures (gaging stations, river confluences, diversion structures, reservoirs, and wells) and legal operational parameters. Reservoir operations and multiple storage accounting are addressed including transfers, exchanges between accounts, operating agreements, and other institutional policies. River networks typically include all key stream gages, diversions, reservoirs and instream flows. Small diversions can be modeled the same as key diversions or aggregated into combined structures so that 100 percent of the basin's consumptive use is reflected in the model without significantly increasing the model's size. Accounting is performed on a water right/ditch basis while reporting is performed by both structure and river node.

Enhancements to StateMod which have been developed for the RGDSS include:

- Allowing use of a daily time step
- Allowing groundwater from one or more aquifers (confined and/or unconfined) to be used as a water supply by simulating the pumping of wells
- Allowing a flow-limited futile call to be included that would allow tributary river reaches to operate independently under certain flow conditions
- Allowing surface water to be diverted for groundwater recharge
- Simulating the effect on streamflows of pumping and irrigation return flows through the alluvium via utilization of unit response functions (URF) developed in the groundwater planning component of the RGDSS
- Allowing variable efficiencies to be used to define conveyance and maximum on-farm efficiencies by each water right
- Allowing soil moisture accounting
- Allowing diversion demands to be calculated based on either water rights (decreed capacities) or consumptive use

StateMod requires the following data and information:

- Water rights expressed as priorities, locations and amounts
- Diversion requirements expressed either as historic or demand driven (e.g., crop requirements)
- Use parameters including ditch capacities, efficiencies and return flow criteria
- Reservoir parameters and operating rules

- Net evaporation from a free water surface (net reservoir evaporation)
- Historic streamflow, diversion, pumping and reservoir contents
- URFs to define the depletion effect of well pumping on streamflow over time
- Basin network information including diversion structures, reservoirs, instream flow reaches, wells and streamflow gages

A variety of tools have been developed by the State to access the database and prepare input data to StateMod. These data pre-processing tools, referred to as data management interfaces or DMIs, convert spatially distributed data such as stream gage data and water right locations into point data to define the model network configuration and process diversion and demand time series and efficiencies for StateMod. A more detailed discussion of DMIs is presented in Section 4.7.3.

During the last 30 years a number of entities have developed applications of water resource planning models for investigations of specific water projects or geographic areas. While the information contained in these applications will be researched during implementation of the SPDSS water resource component, most of the model components are expected to have limited value for the SPDSS because they lack consistency with Colorado's DSS development and documentation standards. One model currently in use and under development by Denver Water, however, may have value to the SPDSS. Denver Water has continued development of a water resource simulation model that integrates operations of water resources in the upper reaches of the South Platte and Colorado River basins (PACSIM). The South Platte portion of the model includes the headwaters downstream to Henderson, Colorado. PACSIM originates from the same source as StateMod. Features in PACSIM that could be useful to the SPDSS include capabilities to route flows through the system when modeling on a daily time step, transit losses, and simulating the effect of urban return flows on streamflows. Additionally, the database of detailed historic operations of Denver Water's system, as well as other entities' water rights and systems simulated in the model, would be a valuable resource to the SPDSS.

4.2.3 SPDSS Component Needs

In order to respond to the needs detailed in Chapter 2, the following water resource planning components should be considered:

- Refinement of operating rules to incorporate augmentation plans, direct flow exchanges and substitutions, and special operations of water rights
- Refinement of daily time step operations to include routing of daily flows, thereby accounting for the time of travel through the system
- Adding a river priority call report for each time step of the simulation. This may include a comprehensive list of all priority calls or a summary list of priority calls for several water rights.

- Provision of enhanced interaction with the groundwater modeling component to simulate the effect of channel losses, well pumping, irrigation return flows and urban return flows through interactive (as opposed to unit response file) linkage to the groundwater model
- Improvement of interaction with other DSS applications including the consumptive use and groundwater models
- Enhancement of linkage with transbasin models (e.g., CRDSS)
- Possibly building separate models for different sub-basins, tributaries or reaches
- Integration with Denver Water's PACSIM model and/or databases
- StateMod graphical user interface (GUI) enhancements, including to the network builder and GIS capabilities
- Adding a standard database structure for input and output data management (Section 4.7)
- Development and application of the water resources planning model to the South Platte River (Water Districts 1-9, 23, 64, & 80), North Platte River (Water Districts 47), and Laramie River (Water District 48) basins

4.3 WATER RIGHTS ADMINISTRATION AND ACCOUNTING

Water rights administration and accounting components for the SPDSS could address many of the administration and accounting needs identified in Chapter 2.

4.3.1 Needs and Purpose of Component

The needs identified for water rights administration and accounting fall into two main categories:

- Needs to support daily water rights administration by the Colorado State Engineer and his staff.
- Needs to facilitate additional water rights administration and accounting activities.

The first category of needs requires enhancements to existing CDSS components in order to assist the State engineer and his staff in administration of water rights. For example, administration of plans for augmentation is currently difficult because the specific sources of augmentation water are not currently reported. Including the sources of augmentation water and where the water went in reported diversion records would assist the State engineer and his staff with administration of plans for augmentation. Reporting this additional information may not, however, be feasible at the present time.

The second category involves more generic needs that may serve multiple purposes, for example, developing a generic, data transfer protocol for data transfers between State and non-State entities. These data transfers could include exchanging administrative and accounting data related to augmentation plans, reservoir operations, etc.

4.3.2 Existing Component Description

There are four existing tools associated with water rights administration and accounting: (1) the Colorado Water Rights Administration Tool (CWRAT), (2) StateView, (3) TSTool, and (4) SatMon.

CWRAT has been used successfully in Division 1. One of its main functions is to provide a spreadsheet that performs computations for daily administration by the Colorado State Engineer and his staff. This tool (1) allows import of real-time stream gage data and gaged diversions, (2) allows import of external data, (3) includes features to compute gain/loss, and (4) allows for dry river reaches. Point flow, natural flow and delivery flows are tracked from upstream to downstream. CWRAT has features to synchronize data between the central database and a local copy of the database. CWRAT displays both real-time and historic data.

StateView includes data displays without administration features.

The TSTool application can display and analyze time series data, including real-time, and historic data.

SatMon, developed by DWR, can also be used to download and view real-time station data.

4.3.3 SPDSS Component Needs

In order to respond to the needs detailed in Chapter 2, the following water rights administration and accounting components should be considered:

- Allow entry of additional administrative data, including water user and type, and data from external users
- Allow display of more than one day of administrative data
- Ability to export administrative data as provisional information for distribution
- Ability to create straight line diagrams listing structures and water rights. This activity requires that stream network data be developed.
- Ability to perform curtailment analysis. This could be used to identify structures with junior rights that are affected by calls, including priority calls necessary to meet Compact requirements. This activity also requires that stream network data be developed.
- Ability to notify a list of water rights holders, water users and State officials via e-mail, or other automated method, when a priority call is placed
- Ability to check administrative data against decrees and augmentation plans

- Ability to account for stream losses. (The current tool does compute gains/losses but does not allow the gains/losses to be specified as an input.) This activity requires that work be done to better estimate stream losses.
- Enhance performance of real-time data access by optimizing how these data are stored and queried
- Data entry tool for HydroBase so that the database contains current administrative data (this tool and CWRAT will be compatible)
- Provide access to additional real-time data, including snow and climate data, either through more streamlined access of data from other agencies or by implementing analysis/tools in CDSS
- Provide access to agency snowmelt forecasts and local precipitation/flow forecasts. This activity may involve collection and/or display of data from agencies responsible for providing forecast information.
- Add features to display historic statistics for real-time data display, (e.g., show the percent of the long-term mean)
- Provide historic priority call records in HydroBase
- Provide enhancement of HydroBase, CWRAT, special projects, and other tools to increase sharing of data by use of XML technology. In particular, this increased functionality will support exchange with non-State users that use a variety of tools for water accounting activities.
- Provide access to scanned images of Water Commissioner field books
- Provide access to the CWCB instream flow tabulation
- Add a tool or enhance an existing tool to provide bulk analysis of real-time (and possibly historic) data for instream flows
- Add a tool or enhance existing tools to display the current state of the river including flows, calls, and reservoir storage in a map-based display. This animated visualization tool could use something like the "tea-cup" display popularized by the U.S. Bureau of Reclamation (USBR).
- Enhance the water information sheet builder component of the graphical interface
- Add additional GIS capability to the graphical interface

4.4 GROUNDWATER RESOURCES PLANNING

The groundwater resources planning component of the SPDSS addresses those groundwater needs identified in Section 2 that relate to data analysis and modeling. The groundwater resources planning component of the SPDSS will have the capability to (1) provide information on the location and timing of groundwater return flows to stream systems, (2) characterize aquifer yields, (3) characterize groundwater flow at critical locations within the basin, and (4) provide maps of current and predicted groundwater level data.

4.4.1 Needs and Purpose of Component

The groundwater planning needs described in Section 2.5 fall generally into three categories (1) the effect of alluvial (tributary aquifer) pumping and recharge on stream depletions, accretions and underflow at various critical locations within the basin; (2) the impact of Denver Basin aquifer pumping on adjacent aquifers, including the overlying alluvial aquifer and hydraulically connected streams; and (3) the adequacy and accuracy of the SDF-based method for estimating stream depletions and accretions.

Additional data that could be collected to help address many of the individual groundwater planning needs listed in Section 2.5 are described in Chapter 3. Evaluating effects of pumping (and recharge) on streamflow and aquifer yield may require development of detailed groundwater flow models and other related tools. These tools could be applied in (1) the Denver Basin and Overlying Alluvium Region, (2) the Lower South Platte Alluvium Region, (3) the North Park and South Park Regions, and (4) the Other Designated Groundwater Basins. These tools and models are discussed below.

4.4.2 Existing Component Description

This section describes existing components that are relevant to the groundwater resources planning aspect of the SPDSS. Some components are part of the CDSS while others are not.

4.4.2.1 Existing CDSS Tools. Existing CDSS groundwater components that may be applicable for the SPDSS include the USGS groundwater flow model MODFLOW, HydroBase and various DMIs linking MODFLOW and HydroBase. Existing input to the MODFLOW model developed for the RGDSS is specific to the San Luis Valley. MODFLOW software and insights related to data management and modeling that were gained during RGDSS implementation, however, could be used in the SPDSS. These insights include, for example, the use of various preprocessors that were developed to prepare data inputs to the groundwater model for the RGDSS. A brief description of MODFLOW and the DMIs is provided below.

MODFLOW is a numerical groundwater flow model developed by the USGS (McDonald and Harbaugh 1988; Harbaugh and McDonald 1996; Harbaugh et al. 2000). It simulates groundwater flow in three dimensions using the finite difference method and can operate on a variety of platforms including personal computers. The model is very generalized, allowing the user to simulate complex layered aquifer systems that are irregular in shape and having aquifer properties that vary spatially. The area to be modeled can be discretized into as fine or coarse a resolution as needed based on the grid spacing, number of layers and model time intervals selected. MODFLOW includes a series of packages that simulate individual aspects of the groundwater hydrologic balance, including the river, stream, drain, lake, reservoir, well, recharge and evapotranspiration packages. The user can select the packages applicable to the aquifer system being simulated. Commercial software packages that utilize graphical approaches to model building and to evaluating model output are widely used; For the RGDSS, the MODFLOW software package GMS (Boss International 1999) was implemented.

A variety of tools collectively called StateGWP (groundwater preprocessor) have been developed by the State to access the database for purposes of evaluating and analyzing data and preparing inputs into groundwater models used in the RGDSS. These data pre-processing tools (i.e., DMIs) convert spatially distributed data such as irrigation-based recharge and canal locations into point data for each grid cell and model layer in the numerical model. DMIs have been developed in the CDSS for defining pumping locations and rates, recharge and evapotranspiration. These spatial data are processed by the DMIs into formats needed to run MODFLOW. The existing DMIs should be used and enhanced, as needed, to support the groundwater modeling needs of the SPDSS for each of the aquifer regions modeled.

4.4.2.2 Other Existing Tools. In addition to these CDSS tools, several groundwater models have been developed in the South Platte River basin. These include (1) a MODFLOW model of the Denver Basin aquifers developed under SB 96-74, (2) an analytical stream depletion factor model developed by the State engineer's office, (3) an analytical model (SDFView) of the Lower South Platte alluvial aquifer, and (4) numerical groundwater flow models in the Lower South Platte region. Because these models and their supporting databases likely will serve as the framework for the SPDSS, they are described in this section. Other components that may be needed to address groundwater resources planning needs are described at the end of this section.

4.4.2.2.1 SB 96-74 Model. The Denver Basin model developed by the State for the SB 96-74 study covers a 6,700-square mile area extending approximately between Greeley on the north, Colorado Springs on the south, the foothills on the west and Limon on the east, encompassing the extent of the four principal bedrock aquifers in the region. The model is a refinement of previous USGS MODFLOW models developed by Robson (1987) and Banta (1989) and the State's MODFLOW model developed under SB 85-5. It consists of six layers with 120 rows and 84 columns, with each model cell being 1 square mile. From shallow to deep, the Dawson aquifer is simulated as two layers, the Denver Formation as one layer, the Arapaho as two layers and the Laramie-Fox Hills aquifer as one layer. These layers range in thickness from near zero at their margins to between 200 and 800 feet near the center of the basin. Intervening low-permeability clay and shale layers between the aquifers, in places over 300 feet thick, are simulated indirectly through a conductance term between aquifer layers. The alluvial aquifer, which was not explicitly included in the model, was simulated using 2000 model cells that employed the MODFLOW River Package to represent flow between the South Platte River and the bedrock aquifers.

Historic pumping in the SB 96-74 model was based on assumptions of usage by well type (domestic, irrigation, and municipal) and number of wells in each category in the State's database. Pumping rates for the 1996 model scenario were based on an inventory conducted by the State. Model simulations were conducted from 1880 to 2000 on annual time steps with future scenarios to the year 2100 run on ten-year time steps. The State modified the public domain USGS MODFLOW program code to accept different file input formats and to write out selected data specific for the purposes of the SB 96-74 study. The State has developed a pre- and post-processor (AUG3) for this model to allow SEO staff to evaluate stream depletions when reviewing well permit applications.

The SPDSS could utilize this SB 96-74 model and incorporate as recommended by the SB 96-74 Technical Advisory Committee.

4.4.2.2.2 State Engineers Office Stream Depletion Model. This model, available from the State engineers office since 1987, includes analytical approaches developed by Glover (1977) and Jenkins (1970) for estimating stream depletions due to well pumping and stream accretions resulting from recharge projects. The model is written in BASIC and is compiled to run in DOS on a personal computer. This model and its governing equations have been used extensively throughout the South Platte River basin in association with augmentation plans, estimating return flow credits from recharge projects, and more recently the Three States Agreement. The user may select daily to yearly time steps in the model. This model is available for inclusion into the SPDSS, if applicable.

4.4.2.2.3 SDFView Model. The SDFView model has been developed as part of the SPMAP modeling package for the alluvial aquifer of the South Platte River from downstream of Denver to the Nebraska state line. The model utilizes the USGS analytical stream depletion equation (Jenkins 1970) and SDF values estimated and mapped by the USGS in 1972-73 to calculate stream depletions and stream accretions. The model is written for use on a personal computer with a Windows95 or more recent operating system. SDF values do not cover several of the tributaries of the South Platte River in which irrigation occurs. The SDFView model generally operates on a monthly time step.

4.4.2.2.4 Lower South Platte Numerical Models. Three groundwater flow models were developed by the USGS in the 1980s in the Lower South Platte region. Each of these models examined the effects of proposed water development activities for specific reaches of the Lower South Platte. In 1980, a recharge project in the Badger and Beaver Creek area in Morgan County was evaluated numerically. Diversions through the Bijou Canal to recharge the alluvial tributary aquifers beneath Badger and Beaver Creeks were simulated with a finite difference model using available hydrogeologic, pumping and diversion data (Burns 1980). In 1981, a modeling study was completed in which potential effects of the proposed Narrows Dam upstream of Fort Morgan was assessed. The model area in the Burns study included the South Platte alluvial aquifer from approximately Riverside Reservoir in Logan County to Brush in Morgan County. The numerical model assessed stream-aquifer interactions under various reservoir fill and release scenarios (Burns 1981). In 1984, a third numerical modeling study was completed for the region, near Proctor in Logan County (Burns 1984). This calibrated model examined stream depletions and accretions from four months of pumping and artificial recharge to a reservoir over a seven-year simulation period. It is not expected that these models or their results will be available in electronic format for inclusion in the SPDSS.

4.4.3 SPDSS Component Needs

This section discusses existing and potential new components needs for SPDSS groundwater resources planning.

4.4.3.1 Existing Components. In order to respond to the needs detailed in Chapter 2, the following enhancements to groundwater resource planning components should be considered for inclusion in the SPDSS. For the existing DMIs, enhancements could include:

- Incorporating SDFs into StateMod
- Translating MODFLOW stream gain/loss output into StateMod stream delay tables
- Adding methods to include municipal and industrial pumping wells into the MODFLOW Well Package preprocessor
- Developing a DMI to dynamically link the surface water and groundwater model results from StateMod and MODFLOW output
- Developing DMIs to query and provide model output for use in model calibration activities
- Developing a DMI to create a data set for the MODFLOW Streamflow Package

A more detailed discussion of the DMIs is presented in Section 4.7.3.

For the SB 96-74 model of the Denver Basin and Overlying Alluvium Region, enhancements could include:

- Increasing the horizontal discretization of the SB 96-74 model by decreasing node spacing in selected areas around rivers, ditches, and other surface water features from one to four nodes per square mile
- Improving the representation and understanding of the alluvial aquifers (including the Designated Groundwater Basins) overlying the Denver Basin by adding at least one layer to the SB 96-74 model.
- Improving the representation of municipal irrigation recharge
- Improving the representation and understanding of the low-permeability clay and shale layers between the major aquifers by adding up to five new layers to the SB 96-74 model
- Improving representation of municipal and industrial pumping over that provided in the SB 96-74 model
- Developing a direct link between MODFLOW and StateMod
- Improving the user interface
- Enhancing or replacing the SEO’s stream depletion analysis tool, AUG3, to better depict stream depletion due to pumping

For the SEO’s Stream Depletion Model, enhancements made for SPDSS could include:

- Improving links to HydroBase
- Improving links to StateMod

- Expanding the geographic areas of application into key tributary areas (such as Beaver Creek and Badger Creek)
- Improving the user interfaces

If the SDFView model was made available for use in the SPDSS, enhancements could include those listed above for the SEO's Stream Depletion Model as well as developing SDF values for areas where they currently do not exist in the SDFView model.

4.4.3.2 Other Components. The following is a list of new components that could be necessary to address groundwater resources planning needs identified in Chapter 2.

- Alternatives to using the analytical approaches for estimating stream-aquifer interactions (such as the Glover and SDF methods) should be developed, as appropriate. This may include developing a MODFLOW model of the Lower South Platte Alluvium Region below Weldona, and in combination with the Denver Basin and Overlying Alluvium model, computing URFs for the entire basin. An innovative approach would be to use MODFLOW stream gain/loss results directly in StateMod.
- Results from the SDFView model, the SEO's Stream Depletion model or the USGS SDF model, if used, will need to be incorporated into StateMod.
- Water balance accounting tools should be developed for the North and South Park Regions and the Camp Creek and Upper Crow Creek Designated Groundwater Basins.
- MODFLOW models may be developed for the North and South Park Regions and the Camp Creek and Upper Crow Creek Designated Groundwater Basins.
- A method should be developed to dynamically couple water rights, pumping, diversions, recharge and streamflow through linkages with MODFLOW and StateMod, or another combined groundwater and surface water model. This may be an enhancement to StateMod or require a different modeling approach than the current one that uses delay tables that are developed from groundwater simulations. The time required to develop such a tool may result in an expanded database and improved computing power to support this model.

4.5 CONSUMPTIVE USE ANALYSIS

The consumptive use component of the SPDSS addresses the expressed user need to quantify historic consumptive use in the South Platte, North Platte, and Laramie River basins and to estimate future consumptive use in these basins. User needs that will be met by the consumptive use component are presented in the following sections.

4.5.1 Needs and Purpose of Component

A consumptive use model is the tool that will assist in responding to the expressed needs involving consumptive use (Section 2.6). Specifically, a consumptive use model can provide a tool that can quickly produce basin-wide results from data-centered input files to quantify:

- Basin crop consumptive use for historic and current time periods to understand how agricultural consumptive use has changed over time
- Non-crop consumptive uses and losses (municipal and industrial, mining, exports, reservoir and stockpond evaporation, wildlife area, native vegetation, and livestock) for historic and current time periods to understand how growth has affected water use in the basin
- The relationship between crop water use and crop yields
- How crop demands are satisfied during dry, average and wet hydrology
- How irrigation practices affect water use efficiencies, consumptive use and available return flows
- How consumptive use based estimates of groundwater pumping compare with (1) methodologies currently used by basin water users and (2) estimates based on electric power records
- The effects of sub-irrigation on water use

4.5.2 Existing Component Description

The existing consumptive use tool of the CDSS is the State of Colorado's Consumptive Use Model (StateCU) which was developed to estimate and report both crop and non-crop consumptive use within the state. It consists of a FORTRAN based computer program and an associated GUI. The crop consumptive use methods employed in the program and the user interface are the modified Blaney-Criddle and the original Blaney-Criddle consumptive use methods with calculations on a monthly basis. Other crop consumptive use methods available outside the interface include the Penman-Monteith and Modified Hargreaves methods, which operate on a daily time step.

StateCU allows several types of analysis including:

- Crop irrigation water requirement by structure (monthly or daily)
- Water supply limited crop consumptive use by structure (monthly)
- Water supply limited crop consumptive use by structure and priority (monthly)
- River depletion by structure and priority (monthly)
- Groundwater pumping (monthly)
- Other non-irrigation consumptive uses (monthly)
- Consumptive uses and losses summary

StateCU determines crop consumptive use by structure. A structure can be a specific diversion structure, a combination of diversion structures, a well or group of wells, a climate station or a specific area of land. A structure is defined by a location, associated climate stations, crop types water supply and acreage.

Non-irrigation consumptive uses include municipal, industrial, domestic and livestock use; basin exports; recreational and wildlife uses; and evaporation losses from reservoirs and stock ponds. StateCU has the ability to (1) combine crop and non-irrigation consumptive uses for a basin or other specified area and (2) create a consumptive uses and losses summary.

Much of the information required to estimate consumptive uses through StateCU is stored in HydroBase. The DMI, preCU, is currently under development and will extract information required for either a crop consumptive use or non-irrigation consumptive use analysis from HydroBase and create input files for StateCU analyses.

The SPMAP CU model has been developed by Colorado State University (CSU) with input and guidance from water users in the Lower South Platte River basin, as part of the SPMAP modeling package. SPMAP CU was developed by starting with the same FORTRAN based CU analysis program developed for the Colorado River DSS in 1996. The focus of the model has been the estimation of real-time crop consumptive use and associated augmentation requirements. The SPMAP CU model offers many of the same analysis options as StateCU. However, each model has enhanced features that are not available in the other model. For this reason, selected features from SPMAP CU could be incorporated into StateCU for an enhanced modeling package.

4.5.3 SPDSS Component Needs

In order to respond to the expressed needs detailed in Chapter 2, the following consumptive use components should be considered:

- Incorporate the modified Kimberly-Penman monthly analysis methodology developed by CSU
- Allow multiple crop coefficients to be used with the Blaney-Criddle methodology to accommodate different conditions at different elevations
- Allow automated estimations of lake evaporation
- Improve the file management system
- Provide additional GIS-based capabilities to the graphical interface
- Streamline the graphical interface to separate standard from more complex consumptive use analyses
- Add the daily crop consumptive use equations to the graphical interface
- Add a standard database structure for input and output data management (Section 4.7)

4.6 WATER BUDGET ANALYSIS

The water budget component of the SPDSS will provide a simple tool for quantifying the major supplies and use elements in the South Platte, North Platte and Laramie River basins that were identified in Chapter 2.

4.6.1 Needs and Purpose of Component

The water budget component provides a tool that describes the major inflow, outflow and storage terms in the South Platte River basin. It can be used to understand the interaction among different water uses and how they may have changed over time.

In addition, the water budget component will meet an important internal need during the SPDSS development by providing a preliminary estimate of a basin's or sub-basin's water balance. It can be used during project development to quantify major water budget components and evaluate preliminary consumptive use, surface water, and groundwater modeling results for reasonableness. Upon project completion, it will combine the final results of other SPDSS data and modeling components to provide overall basin and sub-basin water budgets.

4.6.2 Existing Component Description

The existing State of Colorado's Water Budget Model (StateWB) was developed to combine water uses and sources on a basin or sub-basin basis. StateWB is a graphical program designed in the Visual Basic programming language. It is a simple mass balance tool that accounts for both surface and groundwater components of inflows, consumptive uses and losses, surface and groundwater outflows, and changes in storage for a specified area. StateWB can solve for a single unknown component or a group of unknown components. Results can be displayed in tabular, graphical, and diagram formats.

The following summarizes the inflow, outflow and change in storage information that can be provided or estimated by StateWB when developing a water budget for a specific area:

- Inflow data including precipitation, gaged surface water inflow, ungaged surface water inflow, imports and groundwater inflow.
- Outflow data including crop consumptive use, native vegetation consumptive use, municipal and industrial consumptive use, livestock consumptive use, basin exports, reservoir and stock pond evaporation, gaged and ungaged stream outflow and groundwater outflow.
- Change in storage including change in aquifer storage and change in surface storage.

4.6.3 SPDSS Component Needs

In order to respond to the expressed needs detailed in Chapter 2, water budgets could be developed for the entire South Platte, North Platte, and Laramie River basins and at least two sub-basins that include, but are not necessarily limited to, key groundwater regions such as the Denver Basin and Overlying Alluvium. Preliminary basin and sub-basin water budgets should be developed using readily available information to provide initial estimates to be used as reality checks for other modeling efforts. These preliminary estimates should be regularly updated and used as an accounting check throughout the SPDSS process to assure that the same base data are used in consumptive use, surface water and groundwater modeling efforts. The final water budgets could be used to estimate water budget parameters that could not be determined directly, for instance, consumptive use from native vegetation.

Other possible enhancements of water budget components to meet the expressed needs include:

- Providing additional GIS-based capabilities to the graphical interface
- Adding a standard database structure for input and output data management (Section 4.7)

4.7 SYSTEM INTEGRATION

System integration includes relational database management, spatial database management, system integration tools, system linkage, product documentation and access, and system maintenance. The CDSS have been developed as data centered systems. In these systems the database serves as the repository and master copy of observed data. This approach ensures the DSS tools use the same database and, therefore, the same data. This philosophy promotes data consistency, requires development of fewer tools for data entry and visualization, and allows analysis results to be duplicated. It also encourages private developments such as NCWCD's DSS to interact and build on the State's DSS system.

The CDSS database includes both relational and spatial data. For structures and other point features, the relational and spatial data are linked using database keys. Some non-point features are linked and others are not. The following sections describe components related to the spatial and relational databases, including the databases themselves, linkages needed between major components, tools used to provide an integrated working environment, and product access and documentation.

4.7.1 Relational Database Management System

4.7.1.1 Needs and Purpose of Component. Many of the needs identified for SPDSS involve data. Some of these data needs are for additional or more accurate data (e.g., streamflow gage data at more locations or additional groundwater level data). Other data needs result from the tools that facilitate more efficient access to data. Direct data needs are presented in Chapter 3. This section describes database requirements and tools to facilitate more efficient access.

4.7.1.2 Existing Component Description. The existing relational database for CDSS, HydroBase, has been designed, implemented, and populated through the efforts of DWR staff and consultants. HydroBase stores observed data only and contains no model results or engineering estimates. It is available on a central server in Denver that uses SQL Server relational database system software. Microsoft Access databases derived from the central database are also available for use on a PC. Efforts continue by the State to implement a system where a production database, which contains provisional data for the current year, and a public database, which contains officially released data for historic year, are updated once per year. Currently, this database serves the needs of the CRDSS (Western Slope) and RGDSS (Rio Grande) projects, as well as containing data for Division 1 and partial data for Division 2. The databases are described in documentation available on the CDSS web site (http://cdss.state.co.us) and contain extensive data about structures, stations and water rights, as well as other data.

4.7.1.3 SPDSS Component Needs. HydroBase has a robust database design that can be used to meet SPDSS needs with relatively few enhancements. The following are new tools and enhancements that should be considered to fulfill the expressed needs of the users:

- Add scanned images of Water Commissioner field books
- Enhance storage of data related to augmentation plans and exchanges
- Work with CWCB staff to determine how best to include CWCB's database of instream flow and lake level rights
- Enhance database and communications to include more real-time data, including snow conditions and agency-provided streamflow and climate forecasts
- Implement a mechanism to transfer provisional data to historic archives, in particular to allow access to the most recent year of daily streamflow and other real-time data
- Features to simplify data exchange, including implementation of XML or other technology
- Work with DWR staff to determine how best to enhance diversion record coding to promote consistency, allow coding of water type and user, and allow correlation with externally provided data (e.g., augmentation plans)
- Associate wells with their respective decrees and well permits for Division 1, where possible
- Add pumping records for Division 1
- Add transit loss information
- Evaluate and, if necessary, enhance storage of groundwater and well data
- Develop stream network data to allow display of straight line diagrams, implementation of priority call features for administration and visualization of the physical system

4.7.2 Spatial Database Management System

4.7.2.1 Needs and Purpose of Component. Spatial data management involves the construction and use of GIS databases for reference, analysis and presentation of results. The spatial data management components will address the GIS needs identified in Chapter 2, including:

- A comprehensive GIS database for use throughout the SPDSS
- Improved spatial data visualization and data presentation
- Improved user access to spatial data and DSS results
- An efficient system for assessing irrigated lands and other land/water use issues

4.7.2.2 Existing Component Description. The existing CDSS includes extensive GIS databases for the Colorado and Rio Grande basins. Although most of these data would not be directly useful for the SPDSS, their format, projection and structure can be used in SPDSS database construction. There are other spatial databases covering the South Platte River basin including databases developed by NCWCD, Denver Water and USGS. These data should be used directly; however, substantial spatial data remain to be acquired and/or developed for the SPDSS. These spatial data are described in detail in Chapter 3.

Several GIS-based models and analysis tools were developed for use in the existing DSS basins and should be utilized in the SPDSS. These include:

- GIS tools for extracting point data from HydroBase on headgates, gauging stations, climate stations, etc.
- ArcView scripts and tools for assigning wells to irrigated parcels
- Spatial analysis components of the State GWP for groundwater modeling
- Data access and visualization tools developed using MapObjects that link attributes of point data to their location

Other GIS-based decision support tools have been developed outside of the CDSS including SPMAP, USGS's Front Range Infrastructure Project, and Denver Water's resource planning model. Components from these tools will be used as available. Most of these components and/or tools are applications developed with ESRI's commercial, off-the-shelf GIS software. This provides a consistent GIS platform that allows consultants, State agencies and water users to share data and applications and to communicate effectively.

4.7.2.3 SPDSS Component Needs. The SPDSS should capitalize on technological developments and both existing and new data availability as described below in order to meet user needs. Special consideration could be given to (1) improving visualization and data presentation for communicating CDSS results and (2) improving access to CDSS spatial data, especially for users without GIS or spatial data viewing tools. This improved access could broaden the range of users for schools, researchers and interested citizens. The following are new tools and enhancements that should be considered to fulfill the expressed needs of the SPDSS:

- A system for constructing and storing base spatial data, including both vector coverages and raster files, using ArcInfo version 8.x GeoDatabase. This system will allow final data layers to be converted to ArcInfo coverages and/or ArcView shapefiles for compatibility with a wide range of users.
- A system for processing raw satellite images, digital aerial photographs and other images for direct use in ArcInfo and ArcView applications
- Data compression software such as Mr. Sid for use with very large image data files
- Enhanced interface between HydroBase and GIS data with improved location attributes and identifiers in HydroBase
- A GIS network of the surface water hydrology, structures and water distribution system using a network topology with stream and reach identifiers for linkage with HydroBase and other spatial data
- A system for easy maintenance and updating mapping of irrigated lands
- Applications using scripting and macro languages from commercial software (i.e., ArcInfo, ArcView, MapObjects, and ERDAS) that are compatible with existing

CDSS components. Most likely there will be a migration away from Avenue scripting to Visual Basic and similar tools.

- Enhanced CDSS spatial data visualization and presentation using commercial software tools (e.g., ArcView 3D-Analyst)
- Access to spatial data and information products continued through the CDSS web site via FTP for use in GIS packages and with viewing tools such as ArcExplorer
- A major new component, such as ESRI's Internet Map Server (IMS), to web-enable GIS data. IMS does not require downloading of large data files to a local computer, nor the use of GIS software. Data visualization, access and Web-based applications could be given to anyone with a Web browser and Internet.

4.7.3 System Linkages

System linkage refers to the associations and dependencies (e.g., order of use) between different SPDSS components. At a fundamental level, the linkages are common data dependencies. However, to facilitate data processing and minimize the number of different tools that are used, it is beneficial to identify not only data associations, but also the tools that are needed to process the data.

This section outlines the types of linkages needed between the major components of the SPDSS. The following section will then address the system integration tools that will provide the means for those linkages, in addition to the relational and spatial database management systems described above.

4.7.3.1 Needs and Purpose of Component. A DSS is a complicated system. Because of the different types of problems to be solved, a complete DSS includes multiple tools and models. Each model has a primary focus and does not address all the needs, so the system includes surface water, consumptive use, groundwater, and other components. The DSS relies on the strengths of each component to focus on specific problems and links the components together to provide an overall solution that addresses many problems. The components that provide linkage need to address the following needs:

- Allow data sharing between system components
- Promote consistent data format by using the HydroBase database, common database structures and file formats
- Promote efficient storage and access of data and results for different uses (e.g., modeling and simple data viewing)

4.7.3.2 Existing Component Description. The existing components can be collectively described as follows:

- HydroBase database stores observed data (not model output) and provides input to all activities
- DMI utilities facilitate querying the database, viewing data, and formatting results for modeling. An effort has been made to minimize the number of DMI utilities and focus their scope on specific areas. For example TSTool formats time series data.
- Models and DMIs use command files that allow reproduction of an analysis. DMIs print standard information at the top of model files, including information about the version of HydroBase that was used, a list of the commands used to run the program, the location where it was run, the date, and the software version. This allows results to be reproduced and helps users learn how to use the system.
- Common file formats have been adopted to facilitate reuse of tools. For example, time series files for the surface water and consumptive use models typically use the StateMod convention.
- A standard directory structure for modeling has been implemented in which preliminary input, active model files, and model output are stored. This provides structure to the modeling environment.
- GIS files used for displays and analysis use ESRI shapefiles, which have attributes that allow linking to HydroBase and model files

4.7.3.3. SPDSS Component Needs. The following linkage needs specific to each application component have been identified. The enhancements to the components which provide the means for these linkages are discussed above, in Sections 4.7.1 and 4.7.2 *(Relational and Spatial Database Management Systems)*, as well as in *Section, 4.7.4, System Integration Tools*.

4.7.3.3.1 Surface Water Resources Planning Linkages. The following linkages are required for the surface water resources planning components:

- Interaction with the groundwater modeling component, specifically the exchange of data to define flows between aquifers and streams (Section 4.4)
- Consistency of the data formats and interfaces used for similar features of StateMod and StateCU (Section 4.5), including water use efficiencies and diversion records
- Processing of spatial data into river network information (Section 4.7.2)
- Enhancing existing DMIs or developing new DMIs for StateMod, including makenet, watright, demandts and TSTool under the system integration tools (Section 4.7.4)
- Maintaining consistent format and interpretation of call records with the water rights administration component (Section 4.3)

4.7.3.3.2 Water Rights Administration and Accounting Linkages. Administration activities in past CDSS projects have been linked to planning activities by including the same key structures in both activities. Administration, accounting and planning activities are all dependent on the HydroBase database and effective communication of data. Section 4.7.1 discusses possible SPDSS enhancements to HydroBase and specifies new data required for SPDSS.

4.7.3.3.3 Groundwater Resources Planning Linkages. The groundwater resources planning tools link with the consumptive use, water budget and surface water resources planning and administration models as summarized below. Many of these linkages have been developed under the RGDSS and can be enhanced as needed to address the different circumstances existing in the South Platte River basin:

- Links from the CU/water budget models include estimates of well pumping, recharge (both native and irrigation-based), and groundwater evapotranspiration losses (e.g., from phreatophytes)
- Links to StateMod include stream depletions and accretions for each stream reach and time step, and (potentially) for historical simulations and well pumping
- Links from StateMod include stream flow, stream stage, and canal diversions. Potential links from StateMod include stream gain/loss for each stream reach and time step.
- Potential links to the water rights administration model with simulated stream depletions and accretions for each reach and time step

4.7.3.3.4 Consumptive Use Linkages. In order to meet the needs expressed in Chapter 2, input to the consumptive use analysis should be coordinated with other components during SPDSS development and implementation. These include interaction with relational and spatial database management systems for the following:

- Historic irrigated acreage, crop type and source of supply data
- Historic diversion records, pumping records or permitted pumping rates

In addition, results from the consumptive use analysis should be provided for use in the following SPDSS components:

- Surface water resources planning component (Section 4.2.2)
  - Historic irrigation water requirements
  - Historic groundwater pumping
  - Average monthly ditch system and well pumping efficiencies
- Groundwater planning component (Section 4.4.2)
  - Historic groundwater pumping
  - Ditch system conveyance losses
  - Surface water and groundwater application losses
- Water budget analysis component (Section 4.6.2)
  - Historic crop consumptive use
  - Historic other (non-agricultural) consumptive uses and losses

4.7.3.3.5 Water Budget Linkages. Inputs and results from the other SPDSS components can be either directly input into a water budget analysis model or used to develop input to the water budget as follows:

- Surface water resources planning component inputs
  - Gaged surface water inflows
  - Estimated surface water inflows from ungaged watersheds
  - Basin imports
  - Basin exports
  - Reservoir and stockpond end-of-month contents
  - Evaporation rates
  - Gaged surface water outflow
  - Estimated surface water outflow from ungaged watersheds
- Groundwater planning component inputs and results
  - Groundwater inflow
  - Groundwater outflow
  - Change in aquifer storage
- Consumptive use component results
  - Crop consumptive use
  - Municipal and industrial consumptive use
  - Livestock consumptive use

4.7.4 System Integration Tools

4.7.4.1 Needs and Purpose of Component. System integration tools consist of supporting utilities that help with data viewing, formatting and processing. They are generally applied to one or more application and are therefore described as a group in the following sections.

4.7.4.2 Existing Component Description. A number of tools have been developed to support data analysis, viewing and formatting as part of the existing DSS including:

- makenet–This DMI queries HydroBase and processes river network files for the surface water model
- watright–This DMI queries HydroBase and processes water rights and structure files for the surface water and consumptive use models
- demandts–This DMI queries HydroBase and processes diversion and demand time series and structure efficiencies for the surface water, consumptive use, groundwater and water budget models

- TSTool–This DMI queries HydroBase and processes time series for modeling tools, and provides a general interface for time series display and analysis
- PreCU–This DMI queries HydroBase and processes files for the CU model
- spload–This DMI processes e-mail for special projects applications from primarily non-State users and exchanges data from these applications with HydroBase
- StateGWP–This DMI processes spatial data for the MODFLOW groundwater model
- makertn–This DMI processes irrigated acreage and URF data for the surface water model
- Well File Analysis Program–This DMI allows well permit and water right data to be evaluated for unique and duplicate entries
- Other–Miscellaneous other tools that have been implemented to simplify data processing exist in an unsupported undocumented fashion, because of their relatively simple use. An example is an ArcView application that queries HydroBase to create ESRI shapefiles for structure and station locations.

4.7.4.3 SPDSS Component Needs. The DMI utility programs described above are robust programs developed under the CDSS project. The same tools used for the CRDSS and RGDSS projects can also support the SPDSS effort. The following enhancements should be considered to meet the SPDSS needs. Enhancements consist of features needed to address specific SPDSS needs (e.g., to process new data types) and enhancements to simplify the use of tools and provide better access to data (including relational and spatial data).

4.7.4.3.1 Enhancements to Existing Tools. The following enhancements to existing CDSS tools will improve linkages and access to data. Other utilities or enhancements to existing utilities may also be identified during implementation of the SPDSS. It is anticipated, however, that most functionality is included in the existing system components or will be added to HydroBase data processing tools.

- makenet DMI:
  - Add a GUI that displays GIS data and allows overlay of the model schematic with map data. The interface would allow users to interactively build the model network by defining nodes and upstream/downstream relationships. Currently users must edit a text file that describes the model network. Implementing a GUI would allow additional error checks during network editing.
- watright DMI:
  - Add a GUI to interactively edit program commands, view results, and create model files. Currently users must edit a text file with program commands. Implementing a GUI would allow error checking during command editing. Graphical viewing of results would allow additional error checking before using the output for modeling.

- Display right and structure information in tabular form and summarized on a map display
- Add enhancement to process Division 1 well and permit data

- demandts DMI:

  - Add a GUI to interactively edit program commands, view results, and create model files. Currently users must edit a text file with program commands. Implementing a GUI would allow error checking during command editing. Graphical viewing of results would allow additional error checking before using the output for modeling.
  - Display structure information in tabular form and summarize on a map display
  - Display time series summary information in tabular and graphical forms and make accessible from the map display
  - Consider moving the features in demandts to other programs. The functionality provided by demandts focuses on processing diversion and demand time series for structures. Recent enhancements to the TSTool, PreCU, StateMod, and StateCU can provide similar functionality.

- TSTool DMI:

  - Provide enhancement process any time series data types added to HydroBase for SPDSS
  - Enhance process to read MODFLOW time series
  - Enhance process to extract time series data from the StateMod binary model files
  - Add a map display to provide a spatial reference for time series stations and allow summary information (e.g., time series statistics) to be displayed on the map as well as additional analysis tools to evaluate time series data.
  - Given that StateMod now performs more dynamic data calculations related to demands and efficiencies, consider moving demandts features into TSTool

- PreCU DMI:
  - Add a map interface to display irrigated acreage and other data and add features to process and display time series of irrigated acreage
- spload DMI:
  - Enhance spload data submission from external sources using XML technology
- StateGWP DMI:
  - Enhance StateGWP to include municipal and industrial (M&I) well locations and pumping estimates
  - Enhance to create MODFLOW Streamflow package input
  - Develop a DMI to query model output for results and calibration
  - Develop a DMI to translate MODFLOW streamflow gain/loss into StateMod delay tables
  - Create a DMI to dynamically link StateMod and MODFLOW.

4.7.4.3.2 New System Integration Tools and Applications. The following section describes new applications that will improve system efficiency and presentation of results.

Animated Visualization Tool: There is a general need to provide more visualization of real-time, historical, and model input and results. The features needed in this tool are:

- Be able to display structure/station information as symbols, with reservoir levels shown as "teacups"
- Be able to use time series from HydroBase (e.g., real-time or historic streamflow, diversions, and reservoir levels)
- Be able to use time series from the surface water model (StateMod)
- Be able to use time series from the consumptive use model (StateCU)
- Be able to use time series from the groundwater model (MODFLOW)
- Provide a map interface to spatially display information, using GIS data developed for SPDSS and other DSS projects
- Provide an animation feature to display time series over a historic or modeled period
- Use a consistent configuration to allow a data set to be created from any of the above or other sources. The data format would ideally be simple enough that creation of data sets could occur by a number of approaches and users.

Model Input/Output Database: To date, most of the system integration tools have consisted of DMIs that process model files into common formats, using consistent standards (e.g., file headers, command files). However, the addition of more modeling features to the system (e.g., daily modeling, groundwater, longer period of record) have imposed new system requirements. For example, a monthly surface water model for several hundred structures for a 20-year period resulted in data and output that could be manipulated and viewed without much difficulty. However, data sets that use the new system features are becoming much larger and more difficult to manipulate and view.

Although models can process large amounts of data in a sequential fashion, users often want to view results in a random fashion, and the optimal data storage to support both methods is difficult to achieve using text or binary model files (both of which are used in existing components). Additionally, applications such as ArcView can readily link to data sets stored in open database connectivity-compliant (ODBC) databases, but custom enhancements are necessary to convert model files into a database format that can be used by such applications.

To facilitate efficient access to model input and results in the SPDSS, there is a need to enhance the current approach to managing model data sets, due to more detailed modeling efforts. Rather than using text and binary files, a relational database could be used for model input and output, which allows for efficient random access and relies on the optimized performance of database software. Similar to the main database, HydroBase, using a relational database also enforces common use and integrity of data among applications. The implementation of such a solution would require that an overall understanding of model data structures be evaluated so that a complete and consistent model database design could be implemented. Because DMIs, models, and GUIs currently interact with model files, enhancements to all components would be required for complete implementation. A complete integration would result in expanded use of common analysis and visualization tools but would require transition from the current modeling environment. The model database should not be a part of HydroBase but would be compatible so that links between the databases could occur.

4.7.5 Product Documentation and Access

Products from each component category need to be produced and packaged in a form that can be placed on the web site for easy download, installation and use. Users who install a product (software, data, or results) related to one component should be able to install a similarly packaged and compatible product from other components.

4.7.5.1 Needs and Purpose of Component. The need for easy access to data and system components was identified in Chapter 2 as a primary need. This component will ensure SPDSS products will (1) be easy to access, (2) be quick to access, and (3) provide different levels of access for different types of users.

4.7.5.2 Existing Component Description. The existing CDSS includes a web site (http://cdss.state.co.us) that provides overview information; on-line access to HydroBase; and access to products that have been developed, including HydroBase, GIS data, tools, models and result documentation.

Database files are provided as Microsoft Access database files and GIS data are provided as ESRI shapefiles. Consequently, off-the-shelf products like Microsoft Access, ArcView, and ArcExplorer can be used to view data. Additionally, tools have been developed that provide a tailored interface to data. The StateView and CWRAT applications and the CDSS web site provide viewing tools for HydroBase.

Data and results for models are available as downloads. Users can read the documentation and, if appropriate, can install the software and run the models and model interfaces, which are available for each model.

All current CDSS components run on personal computers under the Windows 95/98/NT operating system. It is envisioned that Windows/Office 2000 will need to be supported within the next year, while continuing support for older operating systems (Windows 95/98/NT) and Office 97. Some specific applications require commercially available or free, third-party software. Machines with more memory and faster processors perform best. A large monitor is best for map-based displays but is not a requirement. Additionally, products and data are distributed from the CDSS web site; therefore, access to the Internet is desirable. CD distribution of software and products is being developed. A web browser is necessary to access the web site including viewing the on-line database.

4.7.5.3 SPDSS Component Needs. Possible enhancements for SPDSS focus on simplifying access to the system, providing more information and increasing performance to meet the needs of the users. These include:

- Providing database, FTP and web servers sufficient to handle necessary traffic. DWR is currently in the process of upgrading web servers but at this time it is not clear whether additional upgrades are necessary. A new server for GIS data may be required.
- Updating the web site to provide more database information. Add new data types associated with SPDSS and update existing displays to maintain a consistent interface.
- Adding additional documentation to clarify data reports
- Adhering to the State's web portal guidelines
- Implementing newer technology such as Active Server Pages and XML to enable more advanced features on the web site and to simplify maintenance
- Adding additional graphics, maps and other visual aids to provide information in different forms for a variety of users
- Using the web site to provide more CDSS products so that installation of software is not required. This feature will require more processing by the web server
- Providing CDSS products on CDs, including stand-alone viewing tools that can be run from a CD (initial efforts are currently underway for RGDSS to implement CD product distribution)
- Exploring using e-mail to automatically distribute some results of administration or real-time data analysis (e.g., summary of current conditions)

4.8 MAINTENANCE

4.8.1 Needs and Purpose of Component

A maintenance program is needed to ensure that the CDSS and SPDSS components continue to function as designed and can be enhanced in response to changes in the operating environment. Because the DSS is a large system, it is important that every component be maintained so that linkages between components are functional. By maintaining the system, not only are the database and software functioning, but the important issues being studied can also continue to be studied. The maintenance activities should consider not only the needs of the SPDSS but also those of existing CDSS components.

4.8.2 Existing Component Description

To date, maintenance of the CDSS components has occurred as a part of the DSS development and upon completion as part of a separately funded maintenance program. Expanding the system to the South Platte will require that an expanded maintenance plan be implemented, especially as components are used for daily CWCB and DWR activities.

4.8.3 SPDSS Component Needs

The following components of an enhanced maintenance plan have been identified to meet the needs of the SPDSS:

- Develop an overall data flow diagram showing how data are entered and processed and which components are involved. This information will help users and maintainers understand the system as well as help to identify linkages between components. This is important because changes to one part of the system may have unexpected impacts on other parts.
- Implement statewide guidelines for data entry. The goal is to have a database and data entry that support the data storage needs of every division without exceptions.
- Provide resources to update all database interaction software to allow for centralized maintenance of database queries. This has been identified as a way to allow changes to HydroBase while minimizing impacts to software.
- Provide resources to update system components due to operating system and commercial software updates (e.g., update to Windows 2000)
- Provide resources to maintain data collection systems implemented for CDSS. This includes groundwater data collection activities such as collecting well pumping data on an annual basis and collecting water levels from wells twice per year. In addition, wells

scheduled for abandonment should be reviewed quarterly to identify candidates for conversion to monitoring wells.

- Provide resources for maintenance of all the CDSS components. Activities that are envisioned include (1) maintenance enhancements and trouble shooting of the database and tools; (2) updating databases with new information from ongoing data collection activities, analyzing the data for relevant trends and relationships, and updating mapping of the information; and (3) updating the models (most likely through DMIs from HydroBase) to reflect the new and/or more detailed information that has become available.
- Provide resources to upgrade system components in response to technology changes. Examples include updating PC operating systems or upgrading components to use new software tools. It is expected that at least one major operating system update will occur during SPDSS.

4.9 USER INVOLVEMENT

4.9.1 Needs and Purpose of Component

User involvement assists system users by helping to solve problems, provide education and solicit input for improvements. User involvement is needed because the system and its components can be complex and difficult to use. Ideally, user involvement makes the system as easy to use as possible in the current environment and provides a mechanism for increasing ease-of-use in future environments.

4.9.2 Existing Component Description

User involvement currently consists primarily of an advisory committee group and related meetings that occur several times a year during the implementation of new projects. This was used for the RGDSS and is being used for the SPDSS. There are currently no coordinated meetings for existing systems (e.g., CRDSS), although presentations are made to the American Society of Civil Engineers (ASCE) and American Water Resources Association (AWRA) at conferences, etc. Training exists as a component in the existing CDSS but is occurring at a limited level funded by the maintenance budget and competes for budget and staff resources with other maintenance activities. All CDSS software, database and modeling products are fully documented and could be used for training purposes.

4.9.3 SPDSS Component Needs

A more formal user involvement program could meet expressed needs for the SPDSS by including the following:

- Regular meetings (e.g., monthly or quarterly) consisting of State, contractor, and system users. Different levels of meetings may be necessary to support discussion of broader issues and specific modeling or data issues.
- Regular training sessions by State and contractor staff which provide documentation and software with assistance to install and run applications
- A mechanism to provide help to users through e-mail, web site, and telephone through a single point of contact (a CDSS help desk)
- A mechanism to provide input on system enhancement through e-mail, web site, and telephone.
- A formal, and efficient, way to distribute information about the system (e.g., an electronic newsletter) which would be distributed monthly or quarterly.

In addition to these activities, certain components previously discussed in this chapter will aid in facilitating more user involvement. These mechanisms include enhancements to the CDSS web site and improvements to system documentation, access and visualization (Sections 4.7.2.3 and 4.7.5).

4.10 SUMMARY

The existing CDSS has many of the functions and tools that are needed in the SPDSS to meet the needs identified in Chapter 2. To fulfill many of the expressed user needs, however, modifications to some existing components and development of new components would be required. These modifications and new tools are summarized below. Alternatives for prioritization of data collection and modifications to the DSS components for inclusion in the SPDSS are discussed in *Chapter 5, Alternatives*.

4.10.1 Surface Water Resources Planning

The existing water resource planning model, StateMod, is a generic water rights planning model that can be configured for the South Platte River basin and implemented in the SPDSS with some modifications including:

- Refinement of operating rules to incorporate augmentation plans, direct flow exchanges, and special operations of water rights
- Refinement of daily time step operations to include routing of daily flows
- Adding a "river call" report for each time step of the simulation
- Provision of enhanced interaction with the groundwater modeling component to simulate the effect of channel losses, well pumping, irrigation return flows and urban return flows, through interactive (as opposed to unit response file) linkage to the groundwater model
- Improvement of interaction with other DSS applications including the consumptive use and groundwater models
- Enhancement of linkage with transbasin models (e.g., CRDSS)
- Possibly building separate models for different sub-basins, tributaries or reaches
- Integration with Denver Water's PACSIM model and/or databases
- StateMod GUI enhancements, including to the network builder and GIS capabilities
- Adding a standard database structure for input and output data management
- Developing and applying the water resources planning model to the South Platte River (Water Districts 1-9, 23, 64, & 80), North Platte River (Water District 47), and Laramie River (Water District 48) basins

4.10.2 Water Rights Administration and Accounting

CWRAT, StateView, TSTool and SatMon are the current existing components associated with water rights administration and accounting. To meet the expressed needs listed in Chapter 2 would require several new features for the SPDSS that would involve the following:

- Allow entry of additional administrative data into CWRAT and HydroBase, display of more than one day of administrative data, and the ability to check administrative data against decrees and augmentation plans
- Ability to export administrative data as provisional information for distribution
- Ability to create straight line diagrams listing structures and water rights
- Ability to perform curtailment analysis
- Ability to notify a list of water rights holders, water users and State officials via e-mail, or other automated method, when a priority call is placed
- Ability to account for stream losses

- Enhance performance of real-time data access by optimizing how these data are stored and queried
- Provide access to additional real-time data including snow and climate data, either through more streamlined access of data from other agencies or by implementing analysis/tools in CDSS
- Provide access to agency snowmelt forecasts and local precipitation/flow forecasts
- Add features to display historic statistics for real-time data display
- Provide historic priority call records in HydroBase
- Provide enhancement of HydroBase, CWRAT, and other tools to increase sharing of data by use of XML technology
- Provide access to scanned images of Water Commissioner field books
- Provide access to the CWCB instream flow tabulation
- Add a tool or enhance an existing tool to provide bulk analysis of real-time (and possibly historic) data for instream flows
- Add a tool or enhance existing tools to display the current state of the river including flows, calls, and reservoir storage in a map-based display
- Enhance the water information sheet builder component of the graphical interface
- Add additional GIS capability to the graphical interface

4.10.3 Groundwater Resources Planning

The groundwater components in CDSS that may be applicable for the SPDSS include the USGS groundwater flow model MODFLOW, and various DMI's linking MODFLOW and HydroBase. To fulfill user needs, enhancements to these CDSS components would be needed, as well as other tools that have been developed by other non-State entities for the South Platte River basin.

Enhancements to existing DMIs could include:

- Incorporating SDFs into StateMod
- Translating MODFLOW stream gain/loss output into StateMod Stream Delay Tables
- Developing a DMI to link surface water and groundwater model results from MODFLOW to StateMod
- Developing DMIs to query and provide model output
- Developing a DMI to create a data set for the MODFLOW Streamflow Package

Enhancements to the SB 96-74 groundwater model of the Denver Basin and Overlying Alluvium Region could include:

- Increasing the horizontal discretization of the SB 96-74 model
- Improving the representation and understanding of the alluvial aquifers overlying the Denver Basin

- Improving the representation of municipal irrigation recharge
- Improving the representation and understanding of the low-permeability clay and shale layers between the major aquifers
- Improving representation of municipal and industrial pumping over that provided in the SB 96-74 model
- Developing a direct link between MODFLOW and StateMod
- Improving the user interface
- Enhancing or replacing the SEO's stream depletion analysis tool, AUG3, to better depict stream depletion due to pumping

Enhancements to the SEO's Stream Depletion Model could include:

- Improving links to HydroBase
- Improving links to StateMod
- Expanding the geographic areas of application
- Improving user interfaces

New components that would be necessary to address some of the groundwater resources planning needs identified by water users and State officials in Chapter 2 would include:

- Alternatives to analytical methods for estimating stream-aquifer interaction (e.g., Glover and SDF methods)
- Incorporation of results from the SDFView model, SEO's Stream Depletion model or the USGS SDF model into StateMod
- Development of water balance accounting tools for the North and South Park areas, Camp Creek Designated Groundwater Basin and the Upper Crow Creek Designated Groundwater Basin
- Development of MODFLOW models for the North and South Park areas, Camp Creek Designated Groundwater Basin and the Upper Crow Creek Designated Groundwater Basin
- Linkage of water rights, pumping, diversions, recharge and streamflow with MODFLOW and StateMod

4.10.4 Consumptive Use Analysis

The StateCU consumptive use model is a generic, data driven model that can be applied to the SPDSS using existing crop evapotranspiration methods. Possible modifications to this model to meet the expressed needs include:

- Incorporate the modified Kimberly-Penman monthly analysis methodology developed by CSU
- Allow multiple crop coefficients to be used with the Blaney-Criddle methodology to accommodate different conditions at different elevations
- Allow automated estimations of lake evaporation
- Improve the file management system
- Provide additional GIS-based capabilities to the graphical interface
- Streamline the graphical interface to separate standard from more complex consumptive use analyses
- Add the daily crop consumptive use equations to the graphical interface
- Add a standard database structure for input and output data management

4.10.5 Water Budget Analysis

StateWB is the existing CDSS tool that provides the link between various water uses and sources and provides an overall understanding of how their interaction has changed over time, through calculation of water budgets. In addition, StateWB provides preliminary estimates of a basin or portion of a basin's water supply and water use components in order to serve as a reality check during the modeling efforts.

In order to meet the expressed needs detailed in Chapter 2, the following enhancements could be considered:

- Development of up to three separate water budgets to represent different basins, tributaries or reaches due to the complexity of the South Platte River basin
- Improved GIS and data construction capabilities for the GUI
- A generic database structure for model input and output

4.10.6 System Integration

Data Centered System Integration refers to (1) the components related to the spatial and relational databases, including the databases themselves; (2) tools used to provide an integrated working environment; and (3) access and dissemination tools. Most of these components already exist in CDSS. The following enhancements would enable the SPDSS to fulfill the expressed needs of the users:

Additional relational data could include:

- Scanned images of Water Commissioner field books
- Augmentation plans and exchanges
- CWCB's database of instream flow and lake level rights
- Additional real-time data, including snow conditions, and agency-provided streamflow and forecasts
- Division 1 well pumping records
- Transit loss information
- Stream network data which would allow display of (1) straight line diagrams, (2) implementation of priority call features for administration, and (3) visualization of the physical system

HydroBase functions could be enhanced to improve data quality and transfer including:

- Enhanced storage of groundwater and well data
- Linkage between well permit and water rights databases for Division 1
- Implementation of a mechanism to transfer provisional data to historic archives
- Addition of features to simplify data exchange
- Determination of how best to enhance diversion record coding to promote consistency, allow coding of water types and user, and allow correlation with externally provided data

Possible spatial database management system modifications include:

- A system for constructing and storing base spatial data, including both vector coverages and raster files (i.e., ArcInfo version 8.x GeoDatabase)
- A system for processing raw satellite images, digital aerial photographs and other images for direct use in ArcInfo and ArcView applications
- Data compression software such as Mr. Sid for use with very large image data files
- Improvement of location attributes and identifiers in HydroBase to enhance the interface between HydroBase and GIS data
- Creation of a GIS network of the surface water hydrology, structures and water distribution system using a network topology with stream and reach identifiers to allow linkage with HydroBase and other spatial data
- Creation of a system component for easy maintenance and updating mapping of irrigated lands
- Applications using scripting and macro languages from commercial software (i.e., ArcInfo, ArcView, MapObjects, and ERDAS) that are compatible with existing CDSS components

- Enhanced CDSS spatial data visualization and presentation using commercial software tools (e.g., ArcView 3D-Analyst)
- Access to spatial data and information products continued through the CDSS web site via FTP for use in GIS packages and with viewing tools such as ArcExplorer
- Web-enable the GIS data through a product such as ESRI's Internet Map Server (IMS)

To increase functionality of the SPDSS, the following system integration tools could be enhanced:

- makenet: add a GUI and integrate with GIS data to allow overlay of model schematic with map data
- watright: add a GUI, display right and structure information in tabular form and summarized on a map display, and improve linkage between decreed water rights for wells and well permit data for Division 1
- demandts: add a GUI, display structure information in tabular form and summarize on a map display, display time series summary information in tabular and graphical forms and consider moving features into other tools
- TSTool: consider moving demandts features into TSTool, and enhance to (1) process any time series data types added to HydroBase for SPDSS, (2) read MODFLOW time series, (3) extract time series data from the StateMod binary model files, (4) add a map display to provide a spatial reference for time series stations and allow summary information to be displayed on the map, and (5) add additional analysis tools to evaluate time series data.
- PreCU: add map interface to GUI to display irrigated acreage and other data and add features to process time series of irrigated acreage
- spload: enhance spload data submission from external sources using XML technology
- StateGWP: include M&I well locations and pumping estimates, create MODFLOW Streamflow package input, develop a DMI to query model output for results and calibration, develop a DMI to translate MODFLOW streamflow gain/loss into StateMod delay tables and create a DMI to dynamically link StateMod and MODFLOW.

In addition to improving these existing tools, new applications could be added including:

- New model visualization tool
- Model input/output database

To improve user understanding of SPDSS tools and products, the following enhancements to promote product access and documentation with the current system should be considered:

- Provide database, FTP, and web servers sufficient to handle necessary traffic and GIS data
- Update the web site to provide more database information and additional documentation

- Add new data types associated with SPDSS and update existing displays to maintain a consistent interface
- Add additional documentation to clarify data reports
- Adhere to the State's web portal guidelines
- Implement newer technology such as Active Server Pages and XML to enable more advanced features on the web site and to simplify maintenance
- Add additional graphics, maps and other visual aids to provide information in different forms use for a variety of users
- Use the web site to provide more CDSS products so that installation of software is not required
- Provide CDSS products on CDs, including stand-alone viewing tools that can be run from a CD
- Explore using e-mail to automatically distribute results of administration or real-time data analysis

4.10.7 Maintenance

The following maintenance measures should be considered to ensure that the SPDSS is well understood and continues to be a useful tool as technology and information change:

- Develop an overall data flow diagram showing how data are entered and processed and which components are involved
- Implement statewide guidelines for data entry
- Provide resources to update all database interaction software to allow for centralized maintenance of database queries
- Provide resources to update system components due to operating system and commercial software updates (e.g., update to Windows 2000)
- Provide resources to maintain data collection system implemented for CDSS
- Provide resources for maintenance of all the CDSS components
- Provide resources to upgrade system components in response to technology changes

4.10.8 User Involvement

User involvement is a component that enhances the user's experience with the system by helping to solve problems, providing education, and soliciting input for improvements. A formal user involvement program could include:

- Regular meetings consisting of State, contractor, and system users
- Regular training sessions by State and contractor staff which provide documentation and software with assistance to install and run applications

- A mechanism to provide help to users through e-mail, web site, and telephone by contacting a single point of contact (a CDSS help desk)
- A mechanism to provide input on system enhancement through e-mail, web site, and telephone
- A formal, and efficient, way to distribute information about the system (e.g., an electronic newsletter) which would be distributed monthly or quarterly

In addition to these activities are other component enhancements discussed in previous sections, which could improve user involvement by improving product access, documentation and information dissemination.

CHAPTER 5

ALTERNATIVES

5.1 INTRODUCTION

This chapter defines alternative collections of data and components that will address the needs identified in Chapter 2. The current CDSS provides many components suitable for SPDSS and, therefore, the proposed system will be an extension of the existing system using much of the same technology. Existing system architecture will not be replaced. The hardware platform used for the CDSS is the PC with Windows 95/98/NT/2000, which is consistent with Colorado Division of Water Resources (CDWR) policy.

The South Platte River basin is more complex than either the Colorado River basin or the Rio Grande basin in every respect: hydrologically, hydrogeologically and institutionally. In addition, the management and development of the basin's water resources is more complex in the South Platte River basin as compared to the Colorado River and Rio Grande basins. Finally, the greater competition for the limited water resources in the South Platte River basin places increased administration demands on the State Engineer as compared to administration in the Colorado River and Rio Grande basins. Consequently, while many of the components from the CRDSS and the RGDSS can be utilized in the SPDSS, the additional complexity of the South Platte River basin will require modification of some of these components and development of new components to meet the needs expressed in Chapter 2.

Three alternatives for development of the SPDSS are presented in this chapter:

- Alternative 1 gives the water users, CWCB and DWR a "good start alternative" that begins to collect data and develop tools for administration and planning. It includes a data collection program that is required to better manage the system, develops monthly water resource planning tools and provides limited support for improving water administration. It also includes updating the existing SB 96-74 groundwater model of the Denver Basin. Because alternative 1 is the "good start alternative", neither the data collection nor planning tools will meet many of the needs of the CWCB, DWR or water users in the near future nor all the needs listed in Chapter 2.
- Alternative 2 is the "recommended alternative" that provides the water users, CWCB and DWR a cost effective DSS that collects necessary data and develops appropriate tools for administration and planning. Alternative 2 builds on the activities listed under Alternative 1, plus the additional data collection and components that will be needed by the CWCB and DWR to efficiently carry out their respective duties both at the monthly and daily level. Alternative 2 expands the data collection program to include diversions that represent 85 percent of the average recorded diversions annually. Additional monitoring wells will be constructed, providing needed information on the geologic structure and aquifer properties of the groundwater basins. The surface and groundwater planning tools will be expanded to enable water users, the CWCB and DWR to address

present and future water policy, development and administration issues in a timely, efficient and cost effective manner.

- Alternative 3 is the "full-featured alternative" that provides water users, the CWCB and DWR a DSS that collects data and develops tools for administration and planning at a detailed, but expensive, level. Alternative 3 includes everything from Alternative 1 as well as Alternative 2, plus additional data collection and components. The additional data collection includes augmentation plans, substitute supply plans, transfer decree data, installation of additional stream gages and additional monitoring wells. Alternative 3 would produce an SPDSS that would meet nearly all of the expressed needs of the water users as well as all of SB 96-74 recommendations applicable to the SPDSS.

The following sections describe these three alternatives in detail. Each alternative begins with a discussion of the recommended data collection activities that are envisioned to take place during the first two years of SPDSS implementation (FY 2002 and 2003) and possibly continue throughout implementation in specific cases. The data collection discussion is followed by a discussion of the recommended components for that alternative. These components would be developed and implemented primarily after completion of data collection.

Estimated capital costs for the three alternatives are presented in Tables C-1 through C-7 in Appendix C and summarized in Table 5-1 at the end of this chapter. Consistent with previous DSS developments, the estimated operation and maintenance costs during the seven-year SPDSS development period are also included in these same tables. Estimated capital costs for those data collection activities and development of components recommended by the SB 96-74 study are listed in Table C-8 in Appendix C.

Operation and maintenance required for the SPDSS after the seven-year development period is discussed at the end of this chapter, and costs summarized in Table 5-2. A phased development approach is also recommended and discussed at the end of the chapter.

5.2 PROPOSED STUDY PERIOD

The study period defined for cost effective modeling studies is partially dependent on the digital data record available. While data exist in the South Platte River basin for streamflow and diversions back to the 1930's, most of the diversion records prior to 1950 have not been digitized. The cost of digitizing additional diversion records is relatively high and significant effort would be required to check and digitize these records. Therefore, it is recommended that for all alternatives the study period for the SPDSS be 1950 through 2000.

This study period could be further refined during the data collection phase of SPDSS implementation, when more is learned about the quality of available data. For example, surface water data could be reviewed to:

- Quantify the range of hydrologic events included (flood and drought events)
- Document the effects of significant changes in management, operations or administration during the period

5.3 ALTERNATIVE 1

5.3.1 Data Collection

Chapter 3, Data Assessment, described the data required to fulfill the expressed needs of potential SPDSS users. The following sections summarize the minimum data collection efforts that will fulfill the basic required functions of the SPDSS as expressed by the users.

5.3.1.1 Surface Water Data. Surface water data collection activities proposed for Alternative 1 would satisfy basic data needs that are required to develop a functional DSS. This minimum level of data collection focuses on the most significant or key elements. Data will typically be collected for a daily time step, if available, though filling of missing records in Alternative 1 is proposed on a monthly time step. The collected data will provide a comprehensive database of surface water related information that can be used by the DWR to administer water rights in Division 1 and Water District 47 in Division 6 and by the CWCB for developing a monthly water resources planning model. The data can also be used by water users for (1) water resources development and management, (2) water resources planning, and (3) water accounting purposes.

Surface water data collection activities are grouped into three information categories, as presented below. Field activities will be preceded by development of a work plan. Capital cost estimates for the surface water data collection alternatives are presented in Table C-1 in Appendix C, as well as in Table 5-1 at the end of this chapter.

5.3.1.1.1 Streamflow Records. Existing streamflow records will be reviewed for the defined study period to identify their quality rating and completeness:

- Identify key (approximately 75) streamflow gages in the South Platte and North Platte River (including the Laramie River) basins which have good or excellent records, have at least 70 percent of the records complete throughout the study period, or represent the best data available at key locations in the basin
- Fill missing records on a monthly basis for identified key streamflow gages

5.3.1.1.2 Diversion and Storage Records. The existing HydroBase database of stream diversion, transbasin diversions and reservoir storage records for the South Platte and North Platte River (including the Laramie River) basins will be reviewed to:

- Identify key diversion structures comprising more than an average annual diversion of 5,000 acre-feet (approximately 163 structures, representing about 75 percent of the annual diversions in Division 1 and Water District 47 in Division 6)
- Perform a QA/QC analysis to identify potential problems with key structure diversion records (e.g., run-on of one diversion record for the entire irrigation season, a diversion record exceeding the decreed amount for the structure, comparing total diversions to irrigated acreage, etc.)

- Fill missing monthly data for the key diversion structures (fill missing diversion data for approximately 25 percent of the 163 structures, or approximately 41 structures)
- Identify all transbasin diversion structures (19 existing structures)
- Fill missing monthly data and/or resolve conflicting data for the 19 transbasin diversion structures
- Identify key storage reservoirs (estimated to be approximately 50 storage facilities with greater than 10,000 acre-feet and nine storage facilities with less than 10,000 acre-feet). This total of 59 key storage facilities represents approximately 85 percent of total annual storage in Division 1 and Water District 47 in Division 6).
- Fill missing monthly storage records and physical/operational data for approximately 59 reservoirs

5.3.1.1.3 Streamflow and Diversion Gaging. As noted in Sections 2.3 and 3.2.3, the Division 1 Engineer's office and basin water users have identified a number of gaging-related needs to support the administration of water rights in the Division. These needs include additional real-time satellite monitoring of existing diversion structures, installation of new streamflow gages on the South Platte River and major tributaries, replacement of key streamflow gages on the mainstem of the South Platte with rated controls, and implementation of a point flow monitoring program on the lower South Platte to define gains and losses. In addition, SB 96-74 included recommendations for the measurement of gains and losses in stream base flow in valleys with thin alluvium overlying the Denver Basin aquifer.

Gaging activities in Alternative 1 will meet the minimum needs and priorities defined by the Division 1 Engineer and water users, and are described below (needs not addressed in Alternative 1 are incorporated into Alternatives 2 and 3):

- Conduct a point-flow stream gaging program on the mainstem of the lower South Platte River to better understand gains and losses on deliveries of water down the South Platte River. The program will be conducted by Division 1 staff and take place over two years, with gaging performed during three distinct periods: late fall (October-Nov) of year one, early spring (March-April) of year two, and late summer of both years 1 and 2 (August). Four reaches of the river will be gaged, from the Jay Thomas Ditch (near the St. Vrain River) to Julesburg.
- Conduct a point-flow stream gaging program per the recommendation for gain/loss studies in the SB 96-74 report (see Section 3.2.3.5). The program will include the measurement of gains and losses in stream base flow in valleys with thin alluvium overlying the Denver Basin aquifer, with measurements done twice per year over a two-year period at approximately 25 locations. This information will be used in coordination with the Alternative 1 groundwater modeling component of the SPDSS to evaluate the accuracy and validity of the Denver Basin and Overlying Alluvium groundwater model (see Section 5.3.2.3).

5.3.1.2 Water Rights Administration and Accounting Data. Water rights administration and accounting data collection activities proposed for Alternative 1 would satisfy basic data needs and allow enhancements to the CWRAT application that is currently available in CDSS. Many of the data needs for administration are consistent with other areas (e.g., surface water, groundwater, and consumptive use) and detailed discussion is provided only where needs differ substantially. One of the main differences is that administration requires real-time data (e.g., streamflow) and current structure and water rights data. In some cases, data are actually entered using administration tools (e.g. calls, diversion records) and data collection consists primarily of extending the database back in time or performing additional QA/QC efforts.

Capital costs for water rights administration and accounting data collection alternatives are presented in Table C-2, and summarized in Table 5-1.

5.3.1.2.1 Structure and Water Rights. Structures (e.g., diversions and reservoirs) and their associated water rights are fundamental parts of administration. Basic structure data, including location and water rights, need to be correct in order to create water information sheets for administration and allow calls to be set. The following data-collection activities are needed to implement administration tools:

- Key structures identified during implementation of other system components (e.g., surface water model) should be used to implement water information sheets for South Platte basins. Additional structures important for administration identified during interviews can also be used. The quality of the structure and water rights data for the structures should be evaluated. Because Division 1 data have been included in HydroBase for several years and because CWRAT water information sheets are already used in Division 1, only minimal review of existing data may be necessary.
- A greater focus on using CWRAT in conjunction with minimum streamflow monitoring will require that the attributes of the CWCB's instream flow database be integrated with HydroBase to allow use by administration tools. For example, instream flow water rights will need to be available based on a location (point or reach) consistent with other physical structures. The database population is described in Section 5.3.2.6.1. The displays are described in Section 5.3.2.2.
- Water rights administration often depends on current structure and water rights data. Therefore, the implementation of data entry tools (State activity) should consider issues related to providing current information to CWRAT users.

5.3.1.2.2 Stream Network. The existing HydroBase database provides storage for streamflow stations (gages) and stream reaches (using State of Colorado identification conventions). Structures (e.g., diversions) are located with legal descriptions and are tied to a stream, optionally with a stream mile. GIS stream information consists of station locations and hydrography without stations. The current implementation of CWRAT water information sheets relies on the available data to allow the creation of an upstream to downstream water balance tool; however, there is currently not sufficient data to check that the order is correct or to build automated tools to traverse the river network. In order to enhance the current administration tools, the following data collection activities are required to support tabular and GIS-based administration tools:

- Create or obtain from an existing source (e.g., USGS) a stream network GIS layer and determine how best to relate to the State's database to identify streams (e.g., verify that stream reaches are consistent and that it is possible to traverse the data upstream to downstream). The relational HydroBase data and the GIS layer attributes should be consistent. Section 5.3.2.6.2 describes the GIS task that will accomplish these results and for the following bullets.
- Associate the gage with a stream reach and stream mile for each stream gage being used in administration
- Associate the structure with a stream reach and a stream mile, allowing upstream to downstream checks for each structure being administered
- The needs assessment indicated that stream loss information is important in some reaches. These data, whether collected for modeling or strictly for administration, can be applied to stream reaches in the stream network.

5.3.1.2.3 Real-Time Streamflow. Real-time streamflow data are needed for administration to provide basic data for water balance for current conditions. Data can also be used to help understand the time-dependent behavior of flows including lagging and return flows. The following data-collection activities are required for water rights administration:

- The surface water discussion lists recommendations for additional stream and diversion gages. Once installed, the data collection system and HydroBase will need to be configured to make the data available for administration, including defining the data types that are being transmitted.
- Experience with the existing CWRAT application and the SatMon tool indicate that transferring actual real-time measurements for administration can be slow. Therefore, real-time data that are currently collected should be converted to average values (hourly or daily) to increase performance.

5.3.1.2.4 External Data. HydroBase can store data from external sources (e.g., diversions for municipalities). CWRAT can use this external data (called special project data) in water information sheets for daily water balance analysis. To date, these data have typically been identified during the surface water modeling process and during the implementation of the Division 5 Workbook (which includes South Platte demands for Eastern Slope municipalities). The following data-collection activities associated with external data would benefit administration efforts:

- Review previous administration efforts using special project data and adjust the external data (number of structures, frequency) that are being passed to HydroBase, as appropriate. A change in approach will likely require software changes.

- Use data such as local climate information, which may be useful for administration in some areas. Additional real-time data feeds may need to be enabled to transfer information from external web sites to the SPDSS.

  Much of the data currently being collected for administration is available at some level of quality. However, to provide features that have been identified in needs, including more visual displays, data need to be more completely cross-referenced. For example, structures and stations in HydroBase need to be cross-referenced with a GIS stream layer.

5.3.1.3 Groundwater Data. Groundwater data collection for Alternative 1 involves collection of limited historical and new field data from the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions (see Figure 3.1 at the end of Chapter 3 for the location of these regions). The groundwater resources planning data include the following:

- Well logs (boring logs, well completion information and soil descriptions)
- Water levels
- Geophysical data
- Geotechnical data
- Well locations (for new wells)
- Aquifer pumping test data
- Pumping data (historical records from providers and users, GASP, CCWCD, etc.)
- Aquifer property data (aquifer extent, transmissivity, storage coefficients, SDFs and saturated thickness)

Alternative 1 includes development of a database to organize data for analyses and mapping, and to support enhancements to the SB 96-74 groundwater model for the Denver Basin and Overlying Alluvium. Data collection will also be performed to support expanding the current mapping of stream depletion factors (SDF) in the Lower South Platte Alluvium Region. Alternative 1 includes data collection activities for the following categories: pumping data, geologic structure and aquifer property data and water level data.

5.3.1.3.1 Pumping Data. Data collection activities associated with pumping data include:

- Investigate methods to estimate pumping (electric power records versus CU based estimates)
- Collect available historical pumping records from the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions that are in electronic format, for calibration purposes. Approximately 200 to 300 records are expected.

5.3.1.3.2 Geologic Structure and Aquifer Property Data. Data collection activities associated with these data include:

- Collect and incorporate into SPDSS-compatible databases the available published historical aquifer configuration and property data for the Denver Basin and Overlying Alluvium Region and to a limited extent for the Lower South Platte Alluvium Region
- Collect streambed sediment samples and conduct percolation tests on approximately 40 sites, including approximately 35 sites within the Denver Basin Region and 5 sites within the Lower South Platte Region. Install paired staff gages and shallow monitoring wells at approximately 5 sites within the Denver Basin Region for water level monitoring.
- Drill, log and construct up to 40 alluvial aquifer monitoring wells, including approximately 30 wells within the Denver Basin Region and approximately 10 wells within the Lower South Platte Region to characterize aquifer structure and properties.
- Drill, log and construct up to four bedrock monitoring wells in the Denver Basin and Overlying Alluvium Region to characterize aquifer structure and properties
- Conduct up to four aquifer pumping tests in the Denver Basin and Overlying Alluvium Region to characterize aquifer properties

5.3.1.3.3 Water Level Data. Data collection activities associated with water level data are as follows:

- Collect and incorporate into SPDSS-compatible databases the available historical water level data for Denver Basin and Overlying Alluvium Region and to a limited extent for the Lower South Platte Alluvium Region
- Collect water levels on approximately 5 paired staff gages and shallow monitoring wells, located in the Denver Basin and Overlying Alluvium Region, using continuous water level recording devices for one season.
- Collect water levels from approximately 180 existing production wells and 40 new wells, located primarily within the Denver Basin and Overlying Alluvium Region and to a limited extent in the Lower South Platte Alluvium Region, once per year to complement current SEO water level collection efforts
- Identify candidate production wells within the Denver Basin and Overlying Alluvium Region that are scheduled to be abandoned for conversion to monitoring wells

Estimated capital costs for groundwater alternatives are presented in Table C-3 in Appendix C, and summarized in Table 5-1. Table C-8 in Appendix C lists the groundwater activities included in each alternative that respond to SB 96-74 recommendations together with their associated costs.

5.3.1.4 Consumptive Use Data. The following data are required to meet the needs, as expressed in Chapter 2, for the consumptive use components for Alternative 1. Many of the data are collected or developed as part of other SPDSS components and the applicable sections are referenced below.

- Irrigated acreage tied to surface water source (Section 5.3.1.4)

- Irrigation method information (Section 5.3.1.4)
- NWCD climate data collection and filling (approximately 40 climate stations temperature, precipitation, evaporation)
- Well data assigned to ditch systems (Section 5.3.1.4)
- Diversion records (approximately 163 structures – see Section 5.3.1.1.2)
- Previously generated local calibrated Blaney-Criddle crop coefficients.
- Conveyance and application efficiency estimates (developed from interviews and published values)
- Soil water holding capacity estimates based on STATSGO mapping
- Previously generated local estimates of potential crop consumptive use for verification and comparisons
- Published information for the basin and western United States on precipitation recharge to groundwater aquifers
- Published information for the basin and western United States on native vegetation consumptive use from groundwater by vegetation classification as a function of depth to groundwater
- Population estimates
- Industrial use estimates (based on user information)
- Agricultural statistics and livestock counts (gather existing data from CAS)
- Reservoir and stockpond end-of-month contents
- Transbasin diversion (Section 5.3.1.1.2)
- Wildlife area consumptive use studies and reports, information regarding water application practices and use estimates from the Division of Wildlife

Estimated capital costs for the consumptive use alternatives are presented in Table C-4 in Appendix C and summarized in Table 5-1.

5.3.1.5 Water Budget Data. The following data are required to meet the needs, as expressed in Chapter 2, for the water budget component for Alternative 1. Most of the data required is discussed in other sections of 5.3.1. In addition, the following are required:

- Non-irrigated land classification for groundwater model areas (Section 5.3.1.4)
- Published reports to summarize and prepare "initial" estimates for water budgets
- Published reports on native vegetation consumptive use

Estimated capital costs for the water budget alternatives are presented in Table C-5 in Appendix C and summarized in Table 5-1.

5.3.1.6 Land Use, Irrigation Service Areas and Geospatial Data. Spatial databases containing approximately 25 layers of water resources and location data will be developed to serve the DSS effort in Alternative 1 (Table 3.1). Data will be acquired from existing sources and used for developing a foundation database to cover the South Platte and North Platte River basins. New data will be acquired and developed for mapping and classifying land use, irrigated areas and irrigation service areas for both ground and surface water.

Because the GIS database is essential to meet many of the SPDSS needs as expressed in Chapter 2, major components of the GIS database are proposed for development in Alternative 1:

- Mapping of current land use, including irrigated areas, crop types and vegetation (within the groundwater modeling area) using multiple satellite images from the 2000 season, GIS data and analyses
- A digital, seamless base map developed for the entire South Platte River basin using moderately high-resolution (6m) satellite imagery and digital orthophoto quadrangles
- Mapping of irrigation distribution systems served by approximately 500 key diversion structures, well locations and associated irrigation service areas using (1) GIS data and analysis and (2) input from water commissioners and water users
- Compilation and construction of a comprehensive and consistent GIS database covering the entire South Platte and North Platte River basins. The GIS database categories, described in more detail in Section 3.16, will include (1) boundaries, (2) river and water distribution systems, (3) local government, (4) climate, and (5) other data (e.g. public lands survey system (PLSS), soils, wetlands).

Estimated capital costs for land use, irrigation service areas and geospatial data alternatives are presented in Table C-7 in Appendix C and summarized in Table 5-1 at the end of this chapter.

5.3.2 Components

Chapter 4, DSS Components, outlined the components required to fulfill the expressed needs of the potential SPDSS users. The following sections summarize components that are needed, at a minimum, to fulfill the basic required functions of the SPDSS for Alternative 1.

5.3.2.1 Surface Water Resources Planning. StateMod is recommended as the primary water resources planning tool under Alternative 1. The existing model (as developed in the CRDSS and refined in the RGDSS) is applicable to the SPDSS and minimal logic refinements are recommended for this alternative. Three separate models are expected to be developed for the following basins:

- South Platte (Water Districts 1-9, 23, 64, and 80)
- North Platte (Water District 47)
- Laramie (Water District 48)

Explicitly modeled will be the most significant or key structures including approximately 163 diversions, 19 transbasin diversions, and 59 reservoir structures that were identified in the data collection phase. Wells associated with either surface diversion systems or sole source irrigated areas will be identified for aggregation in the modeling. Transbasin diversions, either historic or estimated future, will be input as static values to the surface water resources planning model and not operated through a dynamic connection to other basin models. Non-key structures will be aggregated in the modeling such that 100 percent of the man-induced consumptive use is modeled. Surface water/groundwater interaction capabilities will be included in the model using existing SDF maps and analytical techniques.

Tasks to implement the water resources planning model include:

- Modeling will be done on a monthly time step for the recommended 1950-2000 study period.
- Meet/interview with approximately 163 key structure operators and Division 1 and Division 6 personnel to develop understanding of operations. In Alternative 1, it is anticipated that in-person interviews will be conducted with water administrators and 50 of the key structure operators. Interviews with the remainder of the key structure operators are anticipated to be conducted by phone. This extensive level of information gathering is dictated by the geographic size and associated complexity of the water resource use in Division 1.
- Develop operational/administration memoranda for approximately 163 key structures based on operator meetings/interviews. These memoranda will discuss operational components, data, and concepts, as well as interrelationships with other structures, in both a current and historic setting for the key diversion systems in the basin. It is envisioned that for each of the major water users (Denver, Aurora, Thornton, NCWCD, GASP, etc.) one to three weeks of labor will be required to understand, document, and develop modeling guidelines.
- Coordinate with groundwater consultant to develop return flow factors, delay tables and other groundwater parameters using existing SDF mapping and analytical techniques such as the Glover procedure
- Construct StateMod input files:
    - Stream network
    - Key structure and associated water rights files
    - Aggregated (non-key) structure and associated water rights files
    - Operating rules files
    - Demand files
    - Reservoir files
    - Instream flow files
    - Well files
    - Water use/return flow files
- Generate baseflows

- Calibrate/validate model over 1950-2000 study period
- Develop a baseline data set
- Coordinate with system integration component to enhance StateMod GUI (minimum level)
- Document basin modeling efforts

Capital cost estimates for the surface water resources planning component alternatives are presented in Table C-1 in Appendix C and summarized in Table 5-1.

5.3.2.2 Water Rights Administration and Accounting. *Chapter 4, DSS Components*, discussed water rights administration components that address the needs identified in Chapter 2. This section presents the Alternative 1 level components in response to those expressed needs.

The CWRAT application that was originally implemented on the South Platte and enhanced as part of CRDSS has been used successfully for administration in several districts in Division 1 by Water Commissioners and Division 1 staff. This tool has generally satisfied the needs of users. In response to expressed needs, however, new features have been identified. For Alternative 1, it is recommended that CWRAT be enhanced with the following features that have been specifically identified by users:

- Display more than one day of administrative data at the same time (e.g., show more than one Water Information Sheet).
- Export provisional water information sheet in a summary form for distribution to non-State entities. Actual decision values would be included.
- Update CWRAT to use new stream reach data described in Section 5.3.2.6.2. These data are proposed to be developed as part of data collection to allow the State's structures to be located using current GIS stream data. These data will allow the CWRAT water information sheet builder to list structures upstream of a given structure and also streamline water information sheet editing by showing data associated with a specific stream.
- Create straight-line diagrams for stream reaches, including water rights and structure information. For example, the positions of structures on simple diagrams may be offset from a line, consistent with the row positions in water information sheets. Additional location information (see previous bullet) may also be used to create branching diagrams. Structure and water right information can be queried directly from HydroBase.
- Based on adding the stream reach data, add a call curtailment feature thereby allowing determination of which upstream structures/rights will be impacted by a call
- Enhance performance of accessing real-time data. For example, use hourly and daily averages rather than real-time data.
- Enhance data exchange methodology used by the Division 5 Workbook, HydroBase, and CWRAT to be more robust and streamlined

- Purchase personal computers for approximately 25 water commissioner, capable of running SPDSS software at a good performance level

It is also recommended that in Alternative 1, the following general enhancements be made to support administration activities:

- Implement data entry tool for HydroBase in order to keep the production database up to date. Currently, administrative data are updated annually from dBase files that are updated in division offices. This activity is planned to occur internally at DWR and is not budgeted in subsequent cost tables (Tables C-2, 5-1 and 5-2).
- Provide access to more real-time data by adding links to the CDSS web site (e.g., to the NRCS)
- Add features to display historic statistics for real-time data display (e.g., ranking of historic values)
- Add displays to StateView/CWRAT for the CWCB instream flow data

Capital cost estimates for the water rights administration and accounting component alternatives are presented in Table C-2 in Appendix C, and summarized in Table 5-1.

5.3.2.3 Groundwater Resources Planning. The Alternative 1 groundwater resources planning components of the SPDSS include tasks for (1) collecting the data and placing it into HydroBase, (2) data analysis, (3) data mapping, and (4) modeling. These tasks are discussed below.

The data obtained during collection activities will be organized and where appropriate placed in electronic format prior to being imported into HydroBase. Data analyses will be performed to characterize groundwater flow systems and surface water/groundwater interactions. Analyses will include:

- Well pumping evaluations
- Aquifer parameter estimates
- Streambed conductance evaluations
- Head difference evaluations (Denver Basin and Overlying Alluvium Region)
- SDFs developed for tributary areas where they currently do not exist based on historic and newly collected data and analytical (Glover-type) modeling
- Underflow estimates
- Stream gain/loss estimates

Data mapping will be performed to help evaluate the data and characterize spatial trends as needed to manage the groundwater resources of the South Platte River basin, with a focus on the Denver Basin and Overlying Alluvium Region. Types of mapping that will be included in the SPDSS include:

- Water levels (spatial and temporal)

- Aquifer properties (spatial and temporal)
- Aquifer extent (spatial)
- Pumping (using measured and estimated values, spatial and temporal)
- Stream gain and loss (spatial and temporal)

The CU analysis will provide to the groundwater component estimated values for well pumping, canal loss, and deep percolation by key ditch or aggregated systems. The water budget will provide an estimate of total evapotranspiration from the groundwater model area which will be used to calibrate the more detailed depth to water calculations performed by the groundwater model. The existing State preprocessors developed for the RGDSS will be enhanced as needed and applied to distribute these and other data, such as the locations of streams and ditches, and aquifer structure and properties, to groundwater model cells for the Denver Basin and Overlying Alluvium model.

Groundwater modeling will include:

- In the Denver Basin and Overlying Alluvium Region, use the SB 96-74 Denver Basin groundwater model and enhance it by:
  - adding an alluvial layer for a total of seven layers,
  - decreasing model cell size from a section to a quarter-section in selected critical areas such as near pumping centers and near streams,
  - reducing model time steps to represent seasonal to monthly periods,
  - refining streambed conductance, aquifer properties and pumping through new field data and interpretations and through model calibration, and
  - developing Unit Response Factors (URFs) for stream-aquifer interactions.
- In the Lower South Platte Alluvium Region, work with the surface water contractor to incorporate existing SDFs into StateMod, and extend SDFs into areas where they currently do not exist.
- Calibrate and document modeling efforts

Estimated capital costs for groundwater alternatives are presented in Table C-3 in Appendix C, and summarized in Table 5-1. Table C-8 in Appendix C lists the groundwater activities included in each alternative that respond to SB 96-74 recommendations together with their associated costs.

5.3.2.4 Consumptive Use Analysis. The following summarizes the consumptive use analyses and implementation efforts required to meet the Alternative 1 needs for the consumptive use component of the SPDSS.

- Provide technical guidance and review for the GIS land classification and attribution
- Develop and implement an approach to estimate historic irrigated acreage and crop types using the current (2000) irrigated acreage mapping and historic agricultural statistics
- Assign climate stations to irrigated acreage

- Estimate ditch system efficiencies based on information from user interviews
- Provide technical guidance and review for the selection of key structures, user interviews, and diversion record filling
- Use TR-21 or existing Blaney-Criddle calibrated crop parameters to represent available local consumptive use estimates in lower South Platte River basin
- Develop historical consumptive use estimates for approximately 163 key structures plus aggregate structures using the existing monthly Blaney-Criddle technique available in StateCU. This analysis will estimate groundwater pumping and groundwater consumption as a function of the irrigation water requirement not met by surface water, acres served by wells, acres served by sprinklers, and well capacities.
- Employ separate data sets representing the South Platte, North Platte, and Laramie River basins
- Document historic consumptive use analysis results for the three basins
- Enhance the existing StateCU model to simplify its use and application
- Provide technical guidance and review for the groundwater pumping estimates described in Section 5.3.2.3
- Estimate recharge from precipitation over the groundwater model areas based on published information and previous studies
- Estimate native vegetation consumptive use rates from groundwater based on published information and previous studies
- Prepare estimates of municipal and domestic consumptive (indoor and outdoor) use using USBR per capita use estimates and population counts
- Prepare estimates of reservoir and stockpond evaporation from historic end-of-month contents and evaporation rates
- Prepare estimates of livestock use based on per capita use and livestock counts
- Prepare estimates of consumptive use to create and maintain wildlife areas based on Division of Wildlife regarding water application methods and uses and published reports
- Prepare consumptive uses and losses summary and documentation for South Platte, North Platte, and Laramie River basins

Estimated capital costs for the consumptive use alternatives are presented in Table C-4 in Appendix C, and summarized in Table 5-1.

5.3.2.5 Water Budget Analysis. The following summarizes the water budget analyses and implementation efforts required to meet the Alternative 1 needs for the water budget component of the SPDSS. As discussed in Chapter 3, the water budget is expected to estimate native vegetation consumptive use as the closure term to assure basin water balances.

- Develop initial basin water budgets using StateWB and published or general water budget estimates for the South Platte, North Platte, and Laramie River basins. These three initial water budgets will be prepared using an average annual time step and are expected to provide guidance for contractors responsible for the detailed estimated of consumptive use, surface water flows, and groundwater flows used in the final water budget and other modeling efforts. Because input to these initial water budgets may come from a variety of sources, it is likely that the time period used for each component may vary.
- Develop up to three intermediate water budgets for each of the three basins using StateWB and more refined water budget estimates as they are developed by other SPDSS efforts. These intermediate water budgets are expected to provide guidance to other contractors and to serve as an "accounting" tool to coordinate modeling efforts. Intermediate water budgets will be prepared using an average annual time-step.
- Develop final basin water budgets using StateWB and final estimates from other component efforts using an annual time-step from 1950 through 2000. These final water budget analyses will provide an estimate of native vegetation consumptive use, which is the closure term or residual, in each of the three basins.
- Document the water budget analysis results for the three basins
- Compare and document the native vegetation consumptive use estimates with previously published estimates

Estimated capital costs for the water budget analysis alternatives are presented in Table C-5 in Appendix C, and summarized in Table 5-1.

5.3.2.6 System Integration. This section describes the system integration activities and components included in Alternative 1.

System integration components and activities are necessary to support the efficient and simple exchange of data in a decision support system. The level of integration activities depends on the amount of proposed system enhancements including (1) system size (i.e., the number of components), (2) expected number of users, and (3) amount of data to be processed. System integration components and maintenance activities have been categorized into alternatives to support the alternatives for the various areas (e.g., surface water resources planning) and also for more general needs (e.g., web site maintenance). The primary goals of the proposed system integration are consistent with those described in *Chapter 2, Needs Assessment*.

Estimated capital costs for system integration alternatives are presented in Tables C-6 and C-7 in Appendix C and are summarized in Table 5-1 at the end of this chapter.

5.3.2.6.1 Relational Database Management System. The following components/activities are proposed for Alternative 1 for the relational database management system (these enhancements are needed to support the activities of the major system areas):

- Store CWCB instream flow database in HydroBase and link to existing water rights and other tables as much as possible. Evaluate whether redundant data can be eliminated and determine how best to link to GIS data.
- Develop a procedure to transfer real-time data into provisional daily data thereby allowing users to view up to a year of real-time daily data. This activity will support a number of CDSS display tools.
- Implement a more streamlined and robust data exchange format for the special project feature. This will allow external users to easily obtain and submit data to HydroBase.
- Match well permits with decrees for Division 1 and Water District 47 in Division 6 in order to obtain a unique list of physical wells and decrees
- Store pumping records for Division 1 and Water District 47 in Division 6 that are collected by the Groundwater group (Section 5.3.2.3)
- Load other data from groundwater group into HydroBase using current design
- Evaluate and enhance the storage of groundwater data. The previous design implemented for RGDSS may require enhancement for the SPDSS.
- Store updated stream network data to support activities such as priority call curtailment
- Enhance irrigated acreage data storage to include time series of crop acreage by structure

5.3.2.6.2 Spatial Database Management System. The following components and activities are proposed for Alternative 1 for the spatial database management system:

- Develop a GIS interface to HydroBase using location attributes (e.g., feature identifier) to link HydroBase and GIS layers
- Develop a GIS network of surface water features that contains approximately, 500 diversion structures and major canals which are accurately located, linked and topologically based
- Provide GIS support and data maintenance for years 3 through 6 of SPDSS project. This includes incorporating some essential GIS and other spatial data products that become available during the project development from outside agencies (e.g. USGS). Also included is specific but limited response to requests for GIS applications from the State and others involved in SPDSS development.

5.3.2.6.3 System Integration Tools. The following components/activities are proposed for Alternative 1 for system integration tools:

- To support the unique size and data needs of the SPDSS modeling activities, the following DMI utilities will be enhanced:
    - makenet
    - watright
    - demandts

- TSTool
- PreCU
- StateGWP

- Add a map-based interface to the PreCU DMI utility to review irrigated acreage data
- Evaluate use of a database to store model input and results and to replace existing text and binary files. Design and implement a pilot for a selected model or subset of data/results (e.g., basic station and structure information and time series). The initial implementation would focus on features in surface water DMIs, the surface water model and its graphical interface necessary to use the model database.
- Implement a generic animation tool for the presentation of real-time streamflow and administration data. This map-based tool will be capable of reading a table of data values recorded at different times, which are plotted on the GIS layers for the basin. Key reservoirs will be displayed with graduated fill levels. Real-time data available for visualization will depend on the State's data collection system.

5.3.2.6.4 Product Documentation and Access. The following components and activities are proposed for Alternative 1 and involve product documentation and access. These items are mainly focused on providing simple and efficient ways to access CDSS data and tools.

- Upgrade servers to sufficiently handle necessary traffic and GIS data
- Update CDSS web site to adhere to State's web portal guidelines and new Internet technologies
- Add additional documentation to the web site to describe standard data reports. Currently, reports are used by State staff who are familiar with the contents but little explanation is provided to others.
- Rework the CDSS web site to make additional use of Active Server Pages in order to simplify maintenance of the site and increase its dynamic content
- Add static maps to the CDSS web site to provide summary information and help users find information specific to geographic areas. Add basic graph types (line and bar) for time series data available on the web site.
- Add web site summary of current real-time streamflow conditions to CDSS
- Implement procedure to distribute all CDSS products on CDs

5.3.2.7 Maintenance. The following components and activities are proposed for Alternative 1 for maintenance activities:

- Develop data flow documentation of the system. This will be used to educate users and help understand additional enhancements and maintenance items.
- Implement stored procedure approach to database queries. In this approach queries are saved in the database so that changes to the database design do not require a software change. This task can help reduce software maintenance costs due to database changes.

- Maintenance of CDSS components available in Alternative 1 including making minor enhancements and data updates
- Infrastructure upgrade (e.g., performing one operating system upgrade for the entire system)

A summary of maintenance costs that are expected to occur during the SPDSS development period are presented in Table C-6 and summarized in Table 5-1.

5.3.2.8 User Involvement. The user involvement program for the SPDSS will consist of a framework to facilitate meetings and provide support to users of the various system components. Technical subcommittee meetings specific to implementation activities will occur within those areas at appropriate levels. User involvement meetings will occur at several levels, described below. The following components and activities are proposed for Alternative 1 for improving user involvement:

- Create and maintain a database of contacts for system users and those interested in the system, and provide a point of contact for communication. This database will be used to notify people of updates to the system and upcoming user involvement activities, which are described below. The database will indicate a person's area(s) of interest and the method to contact the user (e-mail, fax, phone, etc.).
- Newsletters will be produced 4 times per year discussing the status of the project and advertising upcoming meetings. The newsletter will be distributed by each person's preferred method. Users will be able to e-mail or phone the point of contact to update personal information.
- Conduct SPDSS advisory committee meetings twice per year. These open meetings are conducted by State staff and contractors and present the status and plans for the project to a general audience of interested users (State staff, water suppliers, municipal and various agency staff, local interest). Meetings will typically be rotated throughout the South Platte area.
- Conduct technical subcommittee meetings throughout the development of the project to aid contractors in coordinating with experts in their respective fields while developing SPDSS products.
- Conduct SPDSS core group meetings two times per year. These meetings are attended by key agency personnel and the consultant project manager to discuss high-level project issues.
- Conduct user group meetings four times per year and provide a mechanism for communication on technical topics. Each user group meeting will focus on topics important to hands-on system users and will discuss general information (e.g., features of and enhancements to HydroBase and general tools like StateView). Additionally, each meeting will focus on one selected topic based on the major system areas (e.g., StateMod, StateCU, groundwater model, GIS), rotating the topics throughout the year. Users of CDSS tools from any basin and at any level will be able to meet with the developers and maintainers of the system to receive face to face instruction. This feedback from the user

group will be used by developers to plan future enhancements to the system. Notification of meetings and coordination of communications will occur as part of the general user group coordination (first item above). Meeting times and locations may be coordinated with other SPDSS meetings and training events.

A summary of user involvement costs that are expected to occur during the 5-year development period are presented in Table C-9 and summarized in Table 5-1. The advisory committee meetings and technical subcommittee meetings costs are shown in the individual contractor cost tables (C-1 through C-7) as they are dependent on the involvement of the contractor.

5.3.2.9 Training. The SPDSS training program will provide information to users in technical areas to increase their knowledge of the system and thereby increase the efficiency and scope using the system components. The following components and activities are proposed for Alternative 1 for improving user involvement. It is proposed that on-line training be developed, which can be used for self-paced training.

- Implement on-line web-based training modules for HydroBase and StateView, for general users. Update the materials during the life of the project based on major system enhancements (e.g., inclusion of instream flow database features). Training materials will be generic because features are consistent for all basins.
- Implement on-line web-based training module for CWRAT, describing water administration features. Update the materials during the life of the project based on major software enhancements. Training materials will be generic because features are consistent for all basins.
- Implement on-line web-based training module for GIS tools. Update the materials during the life of the project based on major software enhancements. The training materials will not be a replacement for GIS training provided by ESRI but will focus on the use of GIS data within SPDSS and CDSSS.
- Implement on-line web-based training module for StateMod and the StateMod GUI. Update the materials during the life of the project based on major enhancements. Training materials will be developed for simple example data sets or baseline data sets.
- Implement on-line web-based training module for StateCU. Update the materials during the life of the project based on major enhancements. Training materials will be developed for simple example data sets or baseline data sets.
- Implement on-line web-based training module for the groundwater model. Update the materials during the life of the project based on major enhancements. Training materials will be developed for the SPDSS baseline data set.

5.3.3 Technical Coordination and Project Management Assistance

SPDSS is expected to be managed by existing State personnel with assistance from a contractor. The technical coordination and project management assistance contractor is required to assist the State in coordinating activities among the various consultants and between the State and the consultants. The contractor will (1) assist the State in development and implementation of the SPDSS, (2) serve as a liaison, at the direction of the State, between the State and consultant team, and (3) provide technical expertise and coordination during SPDSS development and implementation.

Specific tasks for the technical coordination and project management assistance contractor include:

1. Assisting the State with all monthly progress meetings with the contractors
2. Assisting the State with all Advisory Committee and Core Advisory Group meetings. The contractor will prepare the agenda and coordinate the meeting locations, as well as record minutes, questions, comments, etc.
3. Reviewing all consultant invoices and preparing an overall status report and progress summary for the State. The contractor will also prepare its individual progress reports and billings for the State to review.
4. Technically reviewing all draft and final Task Memoranda developed as part of the SPDSS. Products developed as part of the SPDSS will also be checked for completeness and accuracy. GIS coverages will be checked for completeness, consistent datum and accuracy of attributes. Programs will be tested for installation and operation.
5. Assisting the State in providing technical guidance and assistance during the course of the SPDSS. This will involve tasks similar to design of the StateGWP that was performed as part of the RGDSS and input to the design of the proposed water administration tool. This will also involve meeting with high ranking water officials and State officials to explain and promote the SPDSS
6. Participating in weekly telecoms with the State to address concerns, questions, issues, etc., which develop over the course of the development period.

5.4 ALTERNATIVE 2

The data collection activities and components described in Alternative 2 are in addition to those detailed in Alternative 1; consequently those data collection activities and components included in Alternative 1 are not repeated below. The additional data and components proposed to be included in Alternative 2 will enhance the SPDSS and fulfill the majority of expressed needs in Chapter 2.

5.4.1 Data Collection

The following data collection activities have been described in Chapter 3 and are included in the Alternative 2 level of data collection.

5.4.1.1 Surface Water Data. In addition to the basic data needs satisfied under Alternative 1, additional data collection activities for Alternative 2 are recommended to provide a more robust DSS. It is noted that for Alternative 2, the suggested time step of both the data collection and filling of missing records is on a daily time step.

5.4.1.1.1 Streamflow Records. Data collection of streamflow records for Alternative 2 is anticipated to be at the same level indicated for Alternative 1, with the following additional analysis activity for Alternative 2:

- On a daily basis, fill missing records at the key streamflow gages identified in Alternative 1

5.4.1.1.2 Diversion and Storage Records. The following are the additional data collection activities recommended for diversion and storage records in Alternative 2:

- Identify additional key diversion structures that divert at least an average of 2,000 acre-feet per year. This is estimated to be approximately 156 additional structures, which would result in a total of 319 structures representing approximately 85 percent of the average annual diversion volume in Division 1 and Water District 47 in Division 6.
- Perform a QA/QC analysis to identify potential data problems, similar to Alternative 1 activities, with additional key structure diversion records
- Fill missing data, on a daily basis, for the additional key diversion structures (estimated to be approximately 25 percent of 156 additional structures or data for 39 additional structures filled)
- Fill missing daily data and/or resolve conflicts in data for all (19) transbasin diversion structures
- Fill missing daily storage records and physical/operational data for all (approximately 59) key storage facilities

5.4.1.1.3 Water Rights Data. The collection of additional water rights data is recommended for Alternative 2 to (1) provide greater understanding of historic and current water administration and (2) better define use of augmentation plans, substitute supply plans and water rights transfers in the South Platte River basin. Water rights data collection was not recommended in Alternative 1. Alternative 2 tasks include:

- Collection, review and incorporation into HydroBase of river call data for the South Platte River mainstem. This effort would be based on the existing interpretation of historic call records from 1950 through 2000 from the Division 1 Engineer's Office. Available historic call records for major tributaries in Division 1 and Water District 47 in Division 6 would be collected, digitized and incorporated into HydroBase.
- Collection, digitization and incorporation into HydroBase of primary elements of augmentation plans, substitute supply plans and transfer decrees (10 of largest plans/transfers). The complexity of these augmentation plans and the lack of consideration in previous decision support systems dictates that a dissection/understanding of a few larger plans would provide more insight than a general review of many plans.

5.4.1.1.4 Streamflow and Diversion Gaging. As described in Section 5.3.1.1.3, the Division 1 Engineer's office and basin water users have identified a number of gaging-related needs to support the administration of water rights in the Division. Under Alternative 2, the most critical of these needs will be met. In addition to the point-flow gaging tasks under Alternative 1, the following tasks are recommended for inclusion in Alternative 2:

- Install up to eight satellite monitoring systems on existing diversion structures. The structures will be selected in coordination with Division 1 and basin water users from the list identified in Table 3-1.
- Install one new streamflow gage at Julesburg and one new gage at Atwood (near Sterling). Division 1 staff will install the Julesburg gage and is exploring the possibility of cost sharing with Nebraska for this location.

The two streamflow gaging locations have been identified by the Division 1 Engineer as the most critical associated with statewide goals on the South Platte. These gages have specific applicability for the Three States Agreement, Compact, and well augmentation purposes. Based on feasibility level cost estimates for the other gage locations and the three rated control structures identified in Table 3-1, including the uncertainty associated with the rated controls, the Division 1 Engineer has recommended that these be excluded from Alternative 2 and only the two streamflow gages be installed. Once installed, the satellite monitoring systems at the diversion gages and the two new streamflow gages will become part of the existing Colorado Satellite Monitoring System Program and operated under the State program.

Capital cost estimates for the surface water data collection alternatives are presented in Table C-1 in Appendix C and summarized in Table 5-1.

5.4.1.2 Water Rights Administration and Accounting Data. The data needs for administration for Alternative 2 are very similar to those for Alternative 1. The difference between the alternatives is primarily the level of effort for other activities. For example, adding additional gages (surface water component) or locating more structures on the stream network (GIS component) will result in more data being available for administration without additional data collection in the water rights administration component.

5.4.1.3 Groundwater Data. Alternative 2 includes all the groundwater data items described under Alternative 1 (Section 5.3.1.2) plus additional historical and new field data from both the Denver Basin and Overlying Alluvium and the Lower South Platte Alluvium Regions. These additional data collection efforts will support the goals stated for Alternative 1 as well as the following: (1) development of the database and allow for data analyses and mapping to better evaluate groundwater resources in the Lower South Platte Alluvium Region, and (2) development of a MODFLOW-based numerical groundwater flow model for the Lower South Platte Alluvium Region. Alternative 2 includes the following data collection activities in addition to those specified for Alternative 1.

5.4.1.3.1 Pumping Data. Data collection activities associated with pumping data are as follows:

- Collect and incorporate into SPDSS-compatible databases the additional historical pumping records from the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions that are in hard copy format, for purposes of calibrating estimated pumping estimates. Approximately 200 additional records are anticipated.

5.4.1.3.2 Geologic Structure and Aquifer Property Data. Data collection activities associated with these data are as follows:

- Collect and incorporate into SPDSS-compatible databases the available historical aquifer property and configuration data for the Lower South Platte Alluvium Region, the North Park and South Park Region, and the Other Designated Groundwater Basins Region, to better define aquifer properties and structure
- Drill, log and construct up to 20 additional alluvial aquifer monitoring wells, including 10 wells in the Denver Basin and Overlying Alluvium Region and 10 wells in the Lower South Platte Alluvium Region, to further characterize aquifer structure and properties
- Drill, log and construct up to two additional bedrock monitoring wells in the Denver Basin and Overlying Alluvium Region to further characterize aquifer structure and properties
- Perform up to four additional aquifer pumping tests, including two in the Denver Basin and Overlying Alluvium Region and two in the Lower South Platte Alluvium Region, to better characterize aquifer properties

5.4.1.3.3 Water Level Data. Data collection activities associated with water level data are as follows:

- Collect and incorporate into SPDSS-compatible databases the available historical water level data for the Lower South Platte Alluvium Region, the North Park and South Park Region and the Other Designated Groundwater Basins Region
- Collect water levels from approximately 90 additional production wells, 20 additional new monitoring wells and 10 converted monitoring wells (all from the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions) once per year to complement current SEO water level data collection efforts
- Identify additional candidate wells in the Lower South Platte Alluvium Region that are scheduled to be abandoned for conversion to monitoring wells

Estimated capital costs for groundwater alternatives are presented in Table C-3 in Appendix C and summarized in Table 5-1. Table C-8 in Appendix C lists the groundwater activities included in each alternative that respond to SB 96-74 recommendations, together with their estimated costs.

5.4.1.4 Consumptive Use Data. The following additional data are included in Alternative 2 to meet the needs for the consumptive use component of the SPDSS (note that these are in addition to Alternative 1 data collection):

- NCWCD and CoAgMet climate data collection and filling (approximately 20 climate stations, wind, vapor pressure, and solar radiation)
- Published reports and studies on conveyance and application efficiencies. Water right transfer decrees and augmentation plans
- Lysimeter data available from existing sources
- Published information on high altitude adjustments for consumptive use parameters and coefficients
- Detailed information on NCWCD Kimberly-Penman method available from NCWCD
- Documentation on SPMAP Consumptive Use model
- Per capita per day water use data from cities and towns
- Outdoor municipal use data from existing studies

Estimated capital costs for the consumptive use data collection alternatives are presented in Table C-4 in Appendix C, and summarized in Table 5-1.

5.4.1.5 Water Budget Data. The following additional data are included in Alternative 2 to meet the needs for the water budget component of the SPDSS. Note that these are in addition to Alternative 1 data collection.

- Published reports to summarize and prepare basin and groundwater model area (2) "initial" water budgets
- Unpublished current studies on native vegetation consumptive use

Estimated capital costs for the water budget data collection alternatives are presented in Table C-4 in Appendix C, and summarized in Table 5-1.

5.4.1.6 Land Use, Irrigation Service Areas and Geospatial Data. Most of the GIS data required for the SPDSS are recommended in Alternative 1. Additional data acquisition and development that are recommended for Alternative 2 include:

- Mapping of historic land use for three historic time periods including one each from the 1950s, 1970s and late-1980s using GIS analysis of satellite imagery and aerial photographs in addition to agricultural statistics
- Accurate identification and location of all non-exempt groundwater wells in Division 1 using on-ground GPS survey along with background research on decrees, well permits and augmentation plans. This is already an on-going program within Division 1 and additional funding through the SPDSS will speed the process so that results are available for SPDSS development.

Estimated capital costs for land use, irrigation service areas and geospatial data alternatives are presented in Table C-7 in Appendix C and summarized in Table 5-1 at the end of this chapter.

5.4.2 Components

The following components are recommended for inclusion in Alternative 2. The components listed below are in addition to the components included in Alternative 1 which are not repeated below. The additional components detailed below are described in *Chapter 4, DSS Components*.

5.4.2.1 Surface Water Resources Planning. StateMod will continue to be the primary water resources planning tool under Alternative 2 but will be developed to a greater level of detail with some refinements. The following tasks will be conducted under Alternative 2:

- The modeling will initially be conducted on a monthly time step for the same basins as in Alternative 1, but will use the additional data collected as discussed in Section 5.4.1.1. Alternative 2 modeling will then be expanded to simulate on a daily time step in order to more accurately model conditional water right availability, instream flow investigations, and compact investigations.
- Refine model logic to report priority call situation at nodes for each time step
- Meet with approximately 156 additional key structure operators and Division 1 and Water District 47 in Division 6 personnel to develop understanding of operations. In Alternative 2, it is anticipated that in-person interviews will be conducted with water administrators and 50 additional key structure operators (100 total). Interviews with the remainder of the key structure operators are anticipated to be conducted by phone.
- Develop operational/administrative memoranda for approximately 156 additional key structures based on operator meetings/interviews
- Coordinate with groundwater consultant to update return flow factors and delay tables using groundwater modeling results
- Construct input files (stream network, key and aggregated structures and water rights, operating rules, demands, reservoirs, water use and return flows) reflecting additional key structures identified and augmentation plan data collected in Alternative 2
- Generate baseflows to reflect explicit modeling of additional key structures and augmentation plans
- Calibrate StateMod to reflect explicit modeling of additional key structures and augmentation plans
- Develop a baseline data set to reflect explicit modeling of additional key structures and augmentation plans
- Conduct a typical application to test the planning model and demonstrate its use as a planning tool
- Coordinate with system integration component to enhance StateMod GUI (intermediate level)

- Document basin modeling efforts to reflect explicit modeling of additional key structures and augmentation plans

Capital cost estimates for the surface water resources planning alternatives are presented in Table C-1 in Appendix C, and summarized in Table 5-1.

5.4.2.2 Water Rights Administration and Accounting. The following enhancements to CWRAT are proposed for Alternative 2 (in addition to Alternative 1) and include a number of items that would streamline and optimize the system, including providing information to more users:

- Provide an interface for additional administration data entry. For example, an enhancement to the State's diversion records program would be to record the water user with diversion records, rather than just the physical structures involved in water delivery.
- Add a check of diversion amount against decreed diversion amount when entering values in water information sheets. This would prevent some data entry errors and provide QA/QC for the database.
- Allow stream gain/loss to be input to Water Information Sheets. Stream gains and losses can currently be calculated based on known point flows but stream losses can not currently be provided as user-supplied data.

The following enhancements to other components are proposed for inclusion in Alternative 2 to aid in water accounting:

- Update StateView/CWRAT/web displays for historic call data. It is anticipated that a number of changes will be required as historic data are populated in the database.
- Develop a general data exchange procedure between HydroBase and external applications (including spreadsheets). This procedure could be used by anyone who accesses data from HydroBase or needs to submit data.
- Add a tool to analyze in bulk real-time or historic data for critical performance measures. For example, to aid in instream flow monitoring, the point flow values from the Water Information Sheets can be queried and checked against instream flow decrees. This analysis could be done in bulk rather than opening every water information sheet.

Capital cost estimates for the water rights administration and accounting component alternatives are presented in Table C-2 in Appendix C, and summarized in Table 5-1.

5.4.2.3 Groundwater Resources Planning. For Alternative 2, groundwater resources planning components will be expanded beyond the Alternative 1 level to include:

- In the Denver Basin and Overlying Alluvium Region:
  - Revise aquifer properties based on additional field data
  - Enhance pumping estimates based on additional historical municipal and industrial records and CU/ water balance estimates for agricultural pumping

- Use the Stream Package in MODFLOW
- Refine Unit Response Factors (URFs) based on enhanced data and modeling
- Calibrate and document

- In the Lower South Platte Alluvium Region:
  - Develop a MODFLOW model of the alluvial aquifer, using cell sizes from one to one-quarter square mile in area and time steps ranging from seasonal to monthly
  - Compute URFs for use with StateMod
  - Develop pumping estimates based on historical municipal and industrial records and CU/ water balance estimates for agricultural pumping
  - Calibrate and document
- In the North and South Park and Other Designated Groundwater Basins Regions:
  - Create databases of existing groundwater-related data for incorporation into HydroBase

Estimated capital costs for groundwater alternatives are presented in Table C-3 in Appendix C and summarized in Table 5-1. Table C-8 in Appendix C lists the groundwater activities included in each alternative that respond to SB 96-74 recommendations together with their associated costs.

5.4.2.4 Consumptive Use Analysis. The following summarizes the additional consumptive use analyses and implementation efforts that are recommended for inclusion in Alternative 2 (note that these analyses are in addition to the efforts for Alternative 1 listed above):

- Enhance StateCU to include the Kimberly-Penman methodology, and other specific SPMAP CU features including ditch share options
- Use StateCU Kimberly-Penman methodology and lysimeter data to calibrate Blaney-Criddle additional or refined crop coefficients for lower South Platte River basin analysis. Use information on high altitude adjustments to calibrate additional or refined Blaney-Criddle crop coefficients for the upper South Platte River basin, the North Platte River basin, and the Laramie River basin.
- Estimate ditch system efficiencies from published reports, studies, and review of water right transfer decrees
- Use Blaney-Criddle with calibrated crop parameters to estimate historic crop consumptive use.
- Prepare input files for the SPMAP Consumptive Use model to represent the StateCU historic data sets
- Prepare estimates of indoor municipal and domestic consumptive use using city supplied consumptive use estimates or city supplied consumptive use rates and population counts
- Prepare estimates of outdoor municipal and domestic consumptive use based on information from published lawn irrigation use studies

Estimated capital costs for the consumptive use component alternatives are presented in Table C-4 in Appendix C and summarized in Table 5-1.

5.4.2.5 Water Budget Analysis. The following summarizes the additional water budget analysis efforts to be included in Alternative 2 (note that these tasks are in addition to the efforts for Alternative 1 listed above):

- In addition to the three initial water budgets detailed in Alternative 1 for the South Platte, North Platte, and Laramie River basins, two subbasins of the South Platte will be added as necessary to support the groundwater analyses (five total). These initial water budgets will be prepared using an average annual time step and are expected to provide guidance for contractors responsible for the detailed estimated of consumptive use, surface water flows, and groundwater flows used in the final water budget and other modeling efforts. Because input to these initial water budgets way come from a variety of sources, it is likely that the time period used for each component may vary.
- In addition to the three intermediate water budgets detailed in Alternative 1 for the South Platte, North Platte, and Laramie River basins, two subbasins of the South Platte will be added as necessary to support the groundwater analyses (five total). Each of the five basins and subbasins will be developed using StateWB and more refined water budget estimates as they are developed by other SPDSS efforts. These intermediate water budgets are expected to provide guidance to other contractors and to serve as an accounting tool to coordinate modeling efforts. Intermediate water budgets will be prepared using an average annual time-step.
- In addition to the three final basin water budgets detailed in Alternative 1 for the South Platte, North Platte, and Laramie River basins, two subbasins of the South Platte will be added as necessary to support the groundwater analyses (five total). These will be developed using StateWB and final estimates from other component efforts using a monthly time-step from 1950 through 2000. These final water budget analyses will provide an estimate of native vegetation consumptive use, which is the closure term or residual, in each of the three basins.
- Document the water budget analysis results for the five basins and subbasins
- Compare and document the native vegetation consumptive use estimates with previously published estimates and on-going studies
- Enhance StateWB with refinements identified during RGDSS development, including allowing input files to be interactively developed through the GUI, enhanced printing and plotting capabilities, and allowing the user to select more than one residual or closure term, and to accommodate unique data requirements of the SPDSS

Estimated capital costs for the water budget alternatives are presented in Table C-5 in Appendix C, and summarized in Table 5-1.

5.4.2.6 System Integration. Alternative 1 identified necessary system integration activities and components to support the entire system at the Alternative 1 level. Alternative 2 identifies additional activities and components that support all component areas at the Alternative 2 level. Additionally, general system enhancements are proposed that are consistent with the needs that were identified by users.

Estimated capital costs for system integration alternatives are presented in Table C-6 and C-7 in Appendix C and summarized in Table 5-1 at the end of this chapter.

5.4.2.6.1 Relational Database Management System. The following additional components and activities are proposed for Alternative 2 for the relational database management system (these enhancements are in addition to those presented under Alternative 1 in order to support the activities of the major system areas):

- Store data for augmentation plans and exchanges (collected by surface water contractor)
- Store additional real-time data in HydroBase from the State's Satellite Monitoring System, including climate data. Currently, mainly streamflow and reservoir elevations are stored but additional data types could be stored for use by various CDSS tools.
- Store transit loss data for stream reaches

5.4.2.6.2 Spatial Database Management System. The following additional components and activities are proposed for Alternative 2 (these enhancements are in addition to those presented under Alternative 1 for the spatial database management system)

- Expand the GIS network of surface water features to include approximately 1,500 diversion structures, for use with administration and other tools
- Develop techniques and templates for improved visualization and presentation of SPDSS results using commercial GIS software, including enhanced project map templates, surfacing of thematic data, 3-D displays of results using terrain models and satellite images, animation of time series spatial data. For example, use 3-D elevation data as a backdrop, draped with satellite imagery showing fields, superimposed with diversion and well locations, and labeled with time-based data, such as the monthly demand. Standard ways of viewing data can be applied at different locations and resolutions throughout the basin, as appropriate. Users will be able to dynamically select layers and view the data using a standard web browser. However, unlike the basic data views, these applications will include more results-based views.
- Provide three years of essential maintenance and support of mapping and visualization applications with incorporation of new products as available

5.4.2.6.3 System Integration Tools. The following components and activities are proposed for Alternative 2 for system integration tools (these activities are in addition to those presented in Alternative 1 and consist of adding graphical interfaces to the utilities to simplify application use):

- Add a GUI to the makenet DMI utility, including an optional map-based display on which model nodes can be added and linked in a schematic fashion

- Add a GUI to the watright DMI utility, including a command editor similar to the current TSTool application. Output will be viewable before saving as model files
- Transfer the functionality currently within the demandts DMI to TSTool and PreCU or enhance demandts to include a GUI and command editor
- Add a map-based query/display tool to the TSTool GUI to allow spatial queries on data
- Enhance the State GWP DMI to use the new ArcView version (8.x or later) and add additional viewing feature supported by the new version
- Alternative 1 proposed implementing an animation display tool real-time data. Alternative 2 proposes expanding this functionality to include historic data from HydroBase and model input/output time series from StateMod. In order to implement a generic tool, the input to the tool will need to be preprocessed from HydroBase and the StateMod files.

5.4.2.6.4 Product Documentation and Access. The following additional components and activities are proposed for Alternative 2 related to product documentation and access. These items are in addition to Alternative 1 and are mainly focused on providing simple and efficient ways to access CDSS data and tools.

- Additional graph types (e.g., duration, running average) to the web site
- Addition of a summary of calls using a map display

5.4.2.7 Maintenance. It is recommended that the maintenance budget for Alternative 2 be the same as for Alternative 1. A summary of maintenance costs that are expected to occur during the SPDSS development period are presented in Table C-6 and summarized in Table 5-1.

5.4.2.8 User Involvement. It is recommended that the user involvement activities and budget for Alternative 2 be the same as for Alternative 1.

5.4.2.9 Training. It is recommended that the training activities and budget for Alternative 2 be the same as for Alternative 1.

5.4.3 Technical Coordination and Project Management Assistance

No additional level of effort beyond that included in Alternative 1 is expected under Alternative 2 for technical coordination and project management assistance.

5.5 ALTERNATIVE 3

In order to fulfill most of the user needs and SB 96-74 recommendations, Alternative 3 includes the following data collection activities and components in addition to Alternative 2.

5.5.1 Data Collection

The following data collection activities are recommended to be included in the Alternative 3 level of effort.

5.5.1.1 Surface Water Data. Alternative 3 includes additional data collection to support a greater level of detail in the modeling effort and directly support SB 96-74 recommendations. The additional data collection tasks include:

- Collect augmentation plan, substitute supply plan, and transfer decree data (30 additional of the largest augmentation plans and/or water rights transfers)
- Collect data required for implementing flow routing in the water resources planning model (channel characteristics including geometry, slope, loss factors, geomorphology)
- Install up to four additional satellite monitoring systems on existing diversion structures (see list in Table 3-1)
- Expand the Division 1 Engineer's Lower South Platte point flow monitoring program to include six monitoring events, with the spring, summer, and fall events conducted in both years 1 and 2.
- Install an additional seven new streamflow gages (see list in Table 3-1)
- Conduct a Conceptual Design Investigation (CDI) to identify and evaluate solutions for establishing a stable rated control on the lower South Platte River, and based on the results, develop recommended solutions for the key gages at Julesburg, Kersey, and Balzac (see Section 3.2.3.3)
- Based on the CDI, implement the recommended solutions at Julesburg, Kersey, and Balzac to replace the existing gages at these locations. For costing purposes, it is assumed that grouted rock grade control structures near the existing stream gage locations will be constructed. Note that the standard stream gage at Julesburg (included in Alternative 2) will not be required if the Alternative 3 rated control structure is built.

At current staffing levels, Division 1 can maintain two of the eight standard streamflow gages and all three rated control gages. However, the six additional new standard streamflow gages would be rated, operated and maintained under the SPDSS for the duration of the SPDSS implementation program. After SPDSS implementation, responsibility for all gages would be turned over to the State. Capital cost estimates for the surface water alternatives are presented in Table C-1 in Appendix C and summarized in Table 5-1.

5.5.1.2 Water Rights Administration and Accounting. The data needs for administration for Alternative 3 are the same as those for Alternatives 1 and 2. The difference between the alternatives is primarily the level of effort for other activities. For example, adding additional gages (surface water component) or locating more structures on the stream network (GIS component) will result in more data being available for administration without additional data collection in the water rights administration component.

5.5.1.3 Groundwater Data. Alternative 3 incorporates the items described under Alternatives 1 and 2 (Sections 5.3.1.2 and 5.4.1.2) including collection of additional field data from the Denver Basin and Overlying Alluvium Region, Lower South Platte Alluvium Region, North Park and South Park Region and the Other Designated Groundwater Basins Region. Alternative 3 includes the following additional data collection activities:

5.5.1.3.1 Pumping Data. Data collection activities associated with pumping data include:

- Collect and incorporate into SPDSS-compatible databases additional historical pumping records, primarily from the North Park and South Park and Other Designated Groundwater Basins Regions
- Collect historic power data and perform well rating tests on approximately 150 high-capacity wells throughout Division 1

5.5.1.3.2 Geologic Structure and Aquifer Property Data. Data collection activities associated with these data are as follows:

- Collect and incorporate into SPDSS-compatible databases additional historical aquifer property and configuration data to support MODFLOW models in North Park and South Park and Other Designated Groundwater Basins Regions
- Collect streambed sediment samples and conduct percolation tests on approximately 40 additional sites, including approximately 25 sites within the Denver Basin and Overlying Alluvium Region and 5 sites within the Lower South Platte Alluvium Region and 10 sites within the other Regions. Install paired staff gages and shallow monitoring wells at approximately 5 additional sites within the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions for water level monitoring.
- Drill, log and construct up to 160 additional alluvial aquifer monitoring wells, including 70 in the Denver Basin and Overlying Alluvium Region, 50 in the Lower South Platte Alluvium Region and 40 in the other Regions to further characterize aquifer structure and properties
- Drill, log and construct up to 19 additional bedrock monitoring wells in the Denver Basin and Overlying Alluvium Region to further characterize aquifer properties
- Conduct up to 8 additional aquifer pumping tests, including six in the Denver Basin and Overlying Alluvium and two in the other Regions to characterize aquifer properties

5.5.1.3.3 Water Level Data. Data collection activities associated with water level data are as follows:

- Collect and incorporate into SPDSS-compatible databases additional historical water level data to support MODFLOW models in North and South Park and Other Designated Groundwater Basins Regions
- Collect water levels from approximately 180 additional new monitoring wells and 10 additional converted monitoring wells, once per year, to complement current SEO water level collection efforts
- Collect water levels on approximately 5 additional paired staff gages and shallow monitoring wells, located in the Denver Basin and Overlying Alluvium and Lower South Platte Alluvium Regions, using continuous water level recording devices for one season.
- Identify additional candidate wells that are scheduled to be abandoned for conversion to monitoring wells in North Park and South Park and Other Designated Groundwater Basins Regions

Estimated capital costs for groundwater alternatives are presented in Table C-3 in Appendix C and summarized in Table 5-1. Table C-8 in Appendix C lists the groundwater activities included in each alternative that respond to SB 96-74 recommendations together with their estimated costs.

5.5.1.4 Consumptive Use Data. The following additional data are recommended for inclusion in Alternative 3. Note that these data are in addition to Alternative 1 and Alternative 2 data collection activities.

- Detailed mapping of wildlife areas
- Crop yield statistics

Estimated capital costs for the consumptive use data collection alternatives are presented in Table C-4 in Appendix C, and summarized in Table 5-1.

5.5.1.5 Water Budget Data. There are no additional data collection activities recommended for Alternative 3.

5.5.1.6 Land Use, Irrigation Service Areas and Geospatial Data. The following activities are recommended for inclusion in Alternative 3:

- Additional field work for verifying and refining maps of current land use, including irrigated areas and crop types in Division 1 and Water District 47 in Division 6
- Improved irrigation service area maps through field survey of ditch locations and service area and by ground survey (by Division 1 and Water District 47 of Division 6) of wells. All field activities would use GPS for locations.
- Collection of additional aerial photographs and more detailed analysis for mapping historic irrigation and crop types for the selected year during the 1950s and 1970s

- Accurate identification and location of key diversion structures (500) using GPS and on-ground survey in Division 1 and Water District 47 in Division 6
- On-ground surveys of groundwater well irrigation service areas coupled with more intensive background research on court decrees, well permits and augmentations. This would be carried out in conjunction with GPS surveys of well locations proposed to be conducted by Division 1 (Section 5.4.1.6).
- Use very high resolution (1m) IKONOS satellite imagery for the majority of irrigated lands in the South Platte basin for use as an image base. This irrigated block includes about 6000 sq. km (1.5 million acres). A special license agreement would allow sharing of the imagery by DWR with any other State agency, counties, local governments and water districts.

Estimated capital costs for land use, irrigation service areas and geospatial data alternatives are presented in Table C-7 in Appendix C and summarized in Table 5-1 at the end of this chapter.

5.5.2 Components

The additional components described under Alternative 3 will enhance the SPDSS to ensure that nearly all tools and functions required by the users are available. This alternative also includes components that will illustrate the vision of the SPDSS to be a continuing state-of-the-art DSS.

5.5.2.1 Surface Water Resources Planning. StateMod will be further refined under Alternative 3 to provide a detailed, fully integrated water resources planning tool that accounts for the time variability of flow throughout the basin and the interrelationships between groundwater and surface water. Refinements in Alternative 3 include:

- Implement flow routing logic in StateMod for daily time step
- Develop interactive information flow (by time step) with groundwater model
- Develop interactive information flow for transbasin diversions with other DSS products
- Refine StateMod input logic to integrate point flow gain/loss evaluation in response to SB 96-74 study recommendations
- Revise input files reflecting additional augmentation plan data collected and point flow data
- Construct flow routing data sets
- Generate baseflows to reflect explicit modeling of additional augmentation plans
- Calibrate model to reflect explicit modeling of additional augmentation plans
- Develop a baseline data set to reflect Alternative 3 model enhancements
- Conduct comparative evaluation of surface water modeling results with results independently developed by Denver Water and the NCWCD
- Integrate with Denver Water's PACSIM model and/or databases

- Coordinate with system integration component to enhance StateMod GUI (expanded level)
- Document basin modeling efforts to reflect Alternative 3 model enhancements

Capital cost estimates for the surface water resources planning alternatives are presented in Table C-1 in Appendix C and summarized in Table 5-1.

5.5.2.2 Water Rights Administration and Accounting. There are no additional enhancements proposed in Alternative 3 for the water rights administration tool (CWRAT). Additional system enhancements proposed in Alternative 3 provide additional levels of functionality to aid in water accounting.

- Alternative 1 proposed adding simple links to the CDSS web site to access useful data at other agencies. Alternative 3 proposes adding links to the CDSS web site to automatically link to, and process useful data from, other web sites. For example, real-time snow survey data on the NRCS web site may be more useful if reformatted.
- Additional links to external web sites to display streamflow forecast information should be specified.
- StateView displays should be enhanced to show digitized water commissioner field books, assuming the scanning of field books is in the selected alternative.
- Priority call notification should be automated (e.g., send e-mail to list of people when a priority call is set).
- Alternative 2 proposed implementing a tool to analyze water information sheets in bulk for instream flow criteria. In Alternative 3 it is proposed that this analysis tool be updated to allow bulk analysis of any real-time data, including streamflow data.

Capital cost estimates for the water rights administration and accounting alternatives are presented in Table C-2 in Appendix C and summarized in Table 5-1.

5.5.2.3 Groundwater Resources Planning. This alternative will include data management, analysis and mapping activities, as described in Section 5.4.2.3 for Alternative 2, with a higher level of effort to reflect the larger amount of field information collected. In addition, the modeling effort in the Denver Basin and Overlying Alluvium, Lower South Platte Alluvium, North Park and South Park and Other Designated Groundwater Basin Regions will be expanded beyond that described for Alternative 2 as indicated below:

- In the Denver Basin and Overlying Alluvium Region:
  - Add up to five model layers to the SB 96-74 MODFLOW model (for a total of 12 layers) to allow aquifers and lower-permeability strata to be simulated independently
  - Compute stream gain/loss using MODFLOW output directly
  - Estimate historical pumping based on electric power records
  - Have MODFLOW and StateMod models interact dynamically for canal leakage, stream gain/loss, pumping and irrigation-based recharge

- In the Lower South Platte Alluvium Region:
  - Compute stream gain/loss using MODFLOW output directly
  - Have MODFLOW and StateMod models interact dynamically for canal leakage, stream gain/loss, pumping, and irrigation-based recharge
  - Estimate historical pumping based on electric power records
- In the North Park and South Park Region and Other Designated Groundwater Basin Region:
  - Develop MODFLOW models for each region, with seasonal to monthly model time steps
  - Compute URFs for use with StateMod
  - Develop pumping estimates based on historical municipal and industrial records and CU/ water balance estimates for agricultural pumping

Estimated capital costs for groundwater alternatives are presented in Table C-3 in Appendix C and summarized in Table 5-1. Table C-8 in Appendix C lists the groundwater activities included in each alternative that respond to SB 96-74 recommendations together with their estimated costs.

5.5.2.4 Consumptive Use Analysis. The following summarizes the additional consumptive use analyses and implementation efforts required under Alternative 3 to meet the needs for the consumptive use component of the SPDSS in addition to the efforts in Alternatives 1 and 2:

- Enhance StateCU with the lake evaporation calculation capabilities, high altitude adjustment factors, application depth nomographs, and Penman-Monteith capabilities through the GUI
- Use StateCU results and published information to investigate crop yield relationships

Estimated capital costs for the consumptive use alternatives are presented in Table C-4 in Appendix C and summarized in Table 5-1.

5.5.2.5 Water Budget Analysis. No additional refinements of the Water Budget analyses are required under Alternative 3 to meet user needs.

5.5.2.6 System Integration. Alternative 3 identifies activities and components that support all component areas at the Alternative 3 level. Additionally, general system enhancements proposed are consistent with the needs that were identified by users.

Estimated capital costs for system integration alternatives are presented in Table C-6 and Table C-7 in Appendix C and summarized in Table 5-1.

5.5.2.6.1 Relational Database Management System. The following activity is proposed for Alternative 3 for the relational database management system:

- Store scanned images of water commissioner field books. The cost of this activity is substantial due to the labor needed to scan books and the computer resources needed to store the data.

5.5.2.6.2 Spatial Database Management System. The following components and activities are proposed for Alternative 3:

- In addition to developing the visualization tools, maps and presentation templates described under Alternatives 1 and 2, create map projects, 3-D and animated presentations and other presentations for use by the State and by other contractors.
- Enhance interfaces and user options in IMS applications and associated databases
- Additional GIS support and data maintenance during years 3-6 of SPDSS development
- Implement an Internet Map Server (ArcIMS) application that will fully web-enable maps and spatial data created under SPDSS. Views created with IMS support dynamic zooming and links to HydroBase. Identify the data layers that are of interest to State, consultant team, and external users and implement a variety of IMS views to disseminate the data. For example, include a view of basic data including streams and roads and optionally allow viewing of more specific data such as land use, irrigated acreage, structure locations. Users will be able to dynamically select layers and view the data using a standard web browser.
- Expanded support and maintenance of IMS applications, interfaces and databases

5.5.2.6.3 System Integration Tools. The following components and activities are proposed for Alternative 3 for system integration tools:

- Alternatives 1 and 2 propose implementing a pilot model database for the surface water model. Alternative 3 proposes expanding this database to include the consumptive use and groundwater models, with associated enhancements to the PreCU DMI, StateCU graphical interface, and groundwater DMIs.

5.5.2.6.4 Product Documentation and Access. The following components/activities are proposed for Alternative 3 related to product documentation and access (these items are mainly focused on providing simple and efficient ways to access CDSS data and tools):

- Set aside an additional increment of funds for additional updates, including simplifying ease of use based on Alternative 3 system enhancements
- Use IMS to replace static summary maps with interactive maps. These displays are independent of the raw data displays implemented elsewhere with IMS.
- Alternative 1 proposed adding to the CDSS web site a summary of current real-time streamflow conditions and Alternative 2 proposed adding a summary of priority calls using a map display. In Alternative 3 it is proposed to optimize labeling and zooming of the other information by providing scale-dependent information.

5.5.2.7 Maintenance. No additional items are proposed for Alternative 3 for maintenance activities.

5.5.2.8 User Involvement. The following components and activities are proposed for Alternative 3 to improve user involvement:

- Implement an outreach program where project team members visit schools, present at water forums and meetings, etc., to educate people about SPDSS and CDSS to increase usage. Grassroots outreach will be conducted at multiple levels between the State, the State's contractors, and local water users to solicit informal and formal feedback, manage expectations, and share project information with the various water users.

5.5.2.9 Training. The following activity is proposed for Alternative 2 training.

- Provide hands-on half-day training sessions four times per year (ideally co-located with user group or other meetings) using training materials from on-line modules and additional materials. These meetings could focus on more advanced topics not addressed by the on-line modules, including overlap between components. Ideally, users could bring their computers and receive help installing the software. Depending on the number of interested parties, facilities with computers may need to be rented to carry out the training. Similar to user group meetings, it is proposed that training for general tools like HydroBase and StateView occur more frequently and that training for models occur once or twice per year. Users would receive CDs with CDSS software and the HydroBase database.

5.5.3 Technical Coordination and Project Management Assistance

Additional technical coordination and review will be required in Alternative 3 as a result of the increased number and complexity of the components required at this level of effort. For example, enhancements to the surface water model including flow routing, interaction with groundwater model, comparison of modeling results with Denver Water's and NCWCD's models and interaction with transbasin diversion models will all require additional effort for scoping, coordination and technical review.

5.6 OPERATION AND MAINTENANCE

The estimated operation and maintenance costs associated with the SPDSS upon completion are summarized in Table 5-2. The FTE and costs associated with the SPDSS maintenance are in addition to the existing maintenance plans in place for the Colorado River DSS and requested for the Rio Grande DSS. As presented in Table 5-2, three FTEs and approximately $420,000 per year are required to maintain the SPDSS for the recommended alternative 2. The required employees and agency assignments are as follows:

- One water resource modeler assigned to the Division of Water Resources modeling branch to maintain the consumptive use, water budget, groundwater and surface water models. This level of commitment does not allow each model to be updated on an annual basis. Rather it expects the modeler will float from one application to another as unique needs, enhancements and applications for the SPDSS arise. This approach is expected to result in a data refresh, reevaluation, application, and calibration review of each model approximately once every five years.
- One GIS and water resource modeling expert assigned to the Colorado Water Conservation Board interstate stream section. This person will be responsible for participating in the ongoing DSS irrigated acreage updates that allow coverages for each DSS basin to be updated once every five years. In addition this person will allow the CWCB to cooperatively participate in the maintenance and application of the SPDSS consumptive use, water budget, groundwater and surface water models described above.
- One FTE assigned to the Division of Water Resources and shared by the Geology and Technical Services sections. This FTE will allow approximately 6 months of effort to manage the observation and publication of the 161 new groundwater level monitoring stations and pumping data constructed under SPDSS. In addition, it will allow approximately six months of effort to maintain the Water Administration Tool, database, network, personal computers, web site and limited software maintenance.

Also presented in Table 5-2 is the costs associated with a full time contract employee and other maintenance costs. The contract employee is required to assist in software, database and system maintenance. Other costs include the replacement of personal computers and servers, network line maintenance, travel, and the purchase of GIS and tabular data.

5.7 PHASED DEVELOPMENT

In cooperation with the SPDSS Advisory Group it is recommended the SPDSS be developed in three phases over a seven year period as follows:

- Phase 1, expected to require approximately two years, will focus on data collection and water administration tools. Certain data collection activities, such as groundwater levels and streamflow gaging, will continue through and beyond SPDSS implementation.
- Phase 2, expected to require approximately two years, will focus on water budget modeling, consumptive use modeling, enhancements groundwater model for the Denver Basin and Overlying Alluvium Region, and surface water modeling.
- Phase 3, the final phase, is expected to require approximately three years and will include final surface water modeling and development of a groundwater model for the Lower South Platte Alluvium Region.

As described above, Phase 1 allows basic water resource data to be developed reviewed and disseminated to the public before any modeling occurs. In addition, it allows cost effective, water administration activities to be implemented as quickly as possible. Phases 2 and 3 include the addition of various modeling tools that will utilize new and existing data in order to perform the complex water resource analyses identified as *Needs Assessment* in Chapter 2.

5.8 SUMMARY

Three alternatives for developing and implementing the SPDSS are described in this chapter. These alternatives consist of data collection activities and components that are summarized along with associated costs in Tables 5-1 and 5-2 below. Estimated capital costs and operations and maintenance costs during the SPDSS development and implementation phase are included in Table 5-1 for the three alternatives. Table 5-2 lists the estimated annual operation and maintenance costs after the SPDSS development and implementation period is completed.

Table 5-1. Summary of Estimated Costs During SPDSS Development for Alternatives 1, 2 and 3

	Total Cost		
	Alternative 1	**Alternative 2**	**Alternative 3**
Data Collection			
Surface Water	$682,000	$1,197,000	$6,336,000
Water Rights Administration and Accounting	$0	$0	$0
Groundwater	$1,605,000	$2,416,000	$8,434,000
Consumptive Use	$260,000	$415,000	$510,000
Water Budget	$50,000	$70,000	$70,000
System Integration	$0	$0	$0
GIS and Spatial Database Management System	$1,002,000	$1,552,000	$2,489,000
User Involvement and Training	$0	$0	$0
Subtotal: Data Collection	*$3,599,000*	*$5,650,000*	*$17,839,000*
Components			
Surface Water	$810,000	$1,645,000	$3,092,000
Water Rights Administration and Accounting	$195,000	$365,000	$455,000
Groundwater	$1,048,000	$1,948,000	$4,757,000
Consumptive Use	$180,000	$325,000	$425,000
Water Budget	$115,000	$260,000	$260,000
System Integration	$1,485,000	$1,790,000	$2,750,000
GIS and Spatial Database Management System	$160,000	$265,000	$725,000
User Involvement and Training	$333,000	$333,000	$582,000
Subtotal: Components	*$4,326,000*	*$6,931,000*	*$13,046,000*
Consultant Coordination and Management	$1,088,780	$1,106,060	$1,116,060
Project Management	$1,312,000	$1,312,000	$1,312,000
Total: Data Collection, Components, Coordination and Project Management	**$10,325,780**	**$14,999,060**	**$33,313,060**

Table 5-2. Summary of Estimated Annual Operations and Maintenance Costs for Alternatives 1, 2 and 3

Item	Total Cost and (FTE) Per Year					
	Alternative 1		Alternative 2		Alternative 3	
Modeler	$0	(0)	$90,000	(1)	$90,000	(1)
GIS & Modeler	$90,000	(1)	$90,000	(1)	$90,000	(1)
Ground Water and Technical Services	$75,000	(1)	$75,000	(1)	$150,000	(2)
Contract Programmer	$125,000	(N/A)	$125,000	(N/A)	$125,000	(N/A)
Other Costs	$30,000	(N/A)	$40,000	(N/A)	$60,000	(N/A)
Total: Data Collection	***$320,000***	***(2)***	***$420,000***	***(3)***	***$515,000***	***(4)***

CHAPTER 6

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APPENDIX A

LIST OF USER INTERVIEWS AND ADVISORY COMMITTEE MEMBERS

TABLE A-1
LIST OF COMPLETED SPDSS FEASIBILITY INTERVIEWS

User Group/Agency	Person	Number of Interviews
City of Aurora	Lisa Darling	1
Bijou Irrigation District	John Rusch	1
Cache La Poudre Water Users Association and Thompson Water District	Don Brown	1
Centennial Water and Sanitation District	Rick McCloud	1
	John Hendricks	1
Colorado Attorney General's Office	Wendy Weiss	1
	Steve Sims	1
	Matt Poznanovic	1
Colorado Division of Natural Resources	Kent Holsinger	1
Central Colorado Water Conservancy District	Forest Leaf	2
	Randy Ray	1
Colorado Division of Water Resources/SEO	Hal Simpson	1
	Jack Byers	2
	Ray Bennett	2
	Dick Wolfe	1
	Leah Lewis	1
	Doug Stenzel	1
	Don Wambold	1
	Bill Fronezak	1
	Kathleen Sullivan	1
	George Van Slyke	1
	Brian Ahrens	1
	Lori Torikai	1
Colorado Division of Water Resources – Div. 1	Dick Stenzel	1
	Jim Hall	2
	Dave Ellington	1
Colorado Division of Water Resources – Div. 5	Brian Romig	1
Colorado Division of Wildlife	Grady McNeil	1
Colorado River Water Conservation District	Dave Kanzer	1
Colorado Water Conservation Board	Rod Kuharich	1
	Randy Seaholm	1
	Ray Alvarado	2
	Andy Moore	1
	Brian Hyde	1
	Tom Browning	1
	Jeff Baessler	1
	Carolyn Fritz	1
Colorado Water Resources & Power Development Authority	Dan Law	1
Denver Water	Dave Little	1
	Bob Seger	1
	Mark Wagee	1
	Greg Bryant	1
City of Fort Collins	Dennis Bode	1
Ground Water Appropriators of South Platte (GASP)	Jack Odor	2
	Brent Nation	2
	Dave Robbins (Attorney)	1

User Group/Agency	**Person**	**Number of Interviews**
Jackson County Water Conservancy District	Kent Crowder	1
City of Loveland	Larry Howard	1
Lower South Platte Water Conservancy District	Bob Shot	1
Metro Wastewater Reclamation District	John Van Royen	1
Northern Colorado Water Conservancy District	Alan Berryman	2
	Jon Altenhofen	2
	Andy Pineda	2
	Val Flory	2
	Scott Bartling	2
North Poudre Irrigation Company	Steve Smith	1
North Sterling Irrigation District	James Yahn	1
Parker Water and Sanitation District	Frank Jaeger	1
	Bruce Lytle	1
Riverside Irrigation District	Don Chapman	1
South Metro Groundwater Users	Peter Binney	1
St. Vrain and Left Hand Water Conservancy District	Vernon Peppler	1
	Les Williams	1
City of Sterling	Joe Kielbasa	1
City of Thornton	Mark Koleber	1
Upper South Platte Water Conservancy District	Steve Spann	1
Urban Drainage and Flood Control District	Ben Urbonas	1
US Fish and Wildlife Service	George Smith	1
	Mark Butler	1
	Bob Waltermeyer	1
US Forest Service	Dave Park	1
City of Westminster	Ron Hellbusch	1

TABLE A-2
SPDSS ADVISORY COMMITTEE INVITED MEMBERS

Name	Water User Group/Agency
Greg Walcher	Colorado Department of Natural Resources
Eric Oppelt	Colorado Department of Health
Richard Griebling	Colorado Division of Oil and Gas
Vicki Cowart	Colorado Geological Survey
Dan McAuliffe	Colorado Water Conservation Board
Mary Halsted	Colorado Division of Wildlife
Dick Stenzel	Colorado Division of Water Resources
Hal Simpson	Colorado Division of Water Resources
Laurie Mathews	Colorado Division of Parks & Outdoors Recreation
Steve Sims	Colorado Attorney General's Office
Wendy Weiss	Colorado Attorney General's Office
Matt Poznanovic	Colorado Attorney General's Office
David Freeman	Colorado State University
Dan Law	Colorado Water Resources and Power Development Authority
John Hallahan	Badger Beaver Water Conservancy Dist.
Eric Kuhn	Colorado River Water Conservation District
Tom Cech	Central Colorado Water Conservancy District
Forrest Leaf	Central Colorado Water Conservancy District
Robert Walker	Groundwater Management Subdistrict for CCWCD
Patricia Wells	Denver Water
David Little	Denver Water
Jack Odor	GASP
Philip Mortensen	GASP
Brent Nation	GASP
Kent Crowder	Jackson County Water Conservancy District
Jim Powers	Lower South Platte Water Conservancy District
Newell Geer	Michigan River Water Conservancy District
Daniel Kaup	Michigan River Water Conservancy District
Eric Wilkinson	Northern Colorado Water Conservancy District
Val Flory	Northern Colorado Water Conservancy District
Vernon Peppler	Saint Vrain & Left Hand Water Conservancy District
Steve Spann	Upper South Platte Water Conservancy District
Ronald Hooper	Arikaree Ground Water Management District
Fred Hendrickson	Bancroft-Clover Water & Sanitation District
John Rusch	Bijou Irrigation District
Robert Steiben	Cache La Poudre Water Users Association
Ken Brown	Castlewood Water District c/o HCL Engineering
John Hendrick	Centennial Water and Sanitation District

Name	Water User Group/Agency
Marilyn Jorrie	Centennial Water Users' Assocation
James Miller	Central Weld County Water District
Dean Winfield	Central Yuma County Ground Water Management Dist.
Bill Cordon	Chambers Ditch Company
Stuart Loosley	Cherokee Metropolitan District
John Warford	Cherry Creek Valley Water & Sanitation Dist.
Wally Welton	Clear Creek Water Users Alliance
Bob Hastings	Colorado Rural Water Association
Walter Welton	Consolidated Mutual Water Company
Patrick Mulhern	Cottonwood Water & Sanitation District
Les Williams	District 6 Water Users Association
James Sullivan	Douglas County Water Resource Authority
Glenn Feyth	East Cheyenne Groundwater Management Dist.
Shawn Hobb	East Larimer County Water District
Webb Jorigs	East Larimer County Water District
Manuel Montoya	Farmers Reservoir and Irrigation Company
John Weitzel	Fort Collins-Loveland Water District
Tim Ortner	Frenchman Ground Water Management District
Lawrence Gerkin	Henrylyn Irrigation Company
George Beardsley	Inverness Water & Sanitation District
Robert Steiben	Larimer County Underground Water Users Association
Brian Burnett	Left Hand Water District
Jane Delling	Little Thompson Water District
James Brnak	Lost Creek Ground Water Management District
Robert Dickenson	Louden Ditch Company
Larry Frame	Julesburg Irrigation District
Paul Hahlweg	Marks Butte Ground Water Management District
Pamela Spivey	Medtropolitan Denver Water Authority
Richard Price	North Kiowa Bijou Ground Water Management Dist.
Gordon Schuppe	North Sterling Irrigation District
Ron Dvorak	North Washington Street Water & Sanitation District
Robert Fillingham	Parker Water & Sanitation District
Mike Bowman	Pioneer Irrigation District
Jack Dice	Platte Canyon Water & Sanitation District
Ann Azari	Platte River Power Authority
James May	Plains Ground Water Management District
E.L. Caneva	Riverside Irrigation District
William Stroh	Sandhills Ground Water Management District
Jim Jones	South Adams County Water & Sanitation District
Ron Cooper	Southgate Water District
Max Smith	Southern High Plains Ground Water Management District
David Bernhardt	Thompson Water Users Association
Donald Nickell	Upper Big Sandy Ground Water Management District

Name	Water User Group/Agency
Dean Goss	Upper Black Squirrel Creek Ground Water Management Dist.
Ben Urbonas	Urban Drainage and Flood Control District
Roy Smith	W. Y. Ground Water Management District
A.L. Anderson	Weld County Underground Water Users Association
Albert Cook, Jr.	Willows Water District
Robert Werner	Metro Wastewater Reclamation District
Lisa Darling	City of Aurora – Water Resources Division
Doug Kemper	City of Aurora
Cliff Deeds	City of Arvada
David Rhodes	City of Boulder - Public Works Director
Mike Bartleson	City of Broomfield
Stan Brown	City of Castle Rock
Kenneth Ross	City of Englewood
Earl Smith	City of Evans
Mike Smith	City of Fort Collins
Todd Williams	City of Greeley
Steve Bagley	City of Greeley
Richard Plastino	City of Lakewood
Charles Blosten	City of Littleton
Barbara Huner	City of Longmont
Thomas Phare	City of Louisville
Larry Howard	City of Loveland
Bruce Shipley	City of Northglenn
Joseph Kiolbasa	City of Sterling
Mary Hall	City of Thornton
Mark Russell	City of Walden
Ronald Hellbusch	City of Westminster
Terry Walker	City of Windsor
Randy Wells	City of Wray
William Easton	City of Yuma
Rob Coney	Adams County
Steve Ward	Arapahoe County
Graham Billingsley	Boulder County
Susan Pacek	Clear Creek County
Everett Wayne Johnson	Cheyenne County
Ed Tepe	Douglas County
Ken Wolf	Elbert County
Ken Eye	Gilpin County
Janet Bell	Long Range Plan Coordinator - Jefferson County
Jackson County Commissioners	Jackson County
Rick Dykstra	Kit Carson County
Marc Englemoen	Larimer County

Name	Water User Group/Agency
County Commissioners	Lincoln County
Kenneth Strohson	Logan County
Mark Arnhdt	Morgan County
County Commissioners	Park County
Robert Johnson	Sedgwick County
Quentin Vance	Washington County
Monica Mika-Daniels	Weld County
County Commissioners	Yuma County
Mark Arndt	Colorado Counties, Inc.
Ray Christensen	Colorado Farm Bureau
Lorraine Anderson	Colorado Municipal League
Polly Page	Denver Regional Council of Governments
Rick Minor	US Army Corps of Engineers - Omaha District
Alice Johns	US Bureau of Reclamation
Malcolm Wilson	US Bureau of Reclamation
Ann Morgan	Bureau of Land Management
Mark Alston	EPA Region VIII
Marcela Hutchinson	EPA Region VIII
Alan Wright	EPA Region VIII
LeRoy Carlson	US Fish & Wildlife Service
Lyle Laverty	U.S. Forest Service
Cathy Tate	USGS
Cass Vigil	USGS
Stephen Black	Natural Resoures Conservation Service, USDA
Ron Steinbach	Western Area Power Administration
Tom Wylie	National Park Service

APPENDIX B

INVENTORY OF AVAILABLE DATA

Table B-1. South Platte River Streamflow Data Inventory

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
South Platte Basin											
06759100	BIJOU CREEK NEAR FT. MORGAN, CO	USGS	40.28	-103.88	10190011	1	4,302	1,500.00	1976-87	12	6.9%
06759000	BIJOU CREEK NEAR WIGGINS, CO	USGS	40.25	-104.04	10190011	1	4,490	1,314.00	1950-56	7	4.0%
BOXHUDCO	BOX ELDER CREEK NEAR HUDSON, CO	DWR				1			1942-44	3	31.1%
06756500	CROW CREEK NEAR BARNSVILLE, CO	USGS	40.49	-104.44	10190009	1	4,670	1,324.00	1951-57	7	9.3%
06758300	KIOWA CREEK AT BENNETT, CO	USGS	39.75	-104.41	10190010	1	5,430	236.00	1960-64	5	5.2%
06758000	KIOWA CREEK AT ELBERT, CO	USGS	39.21	-104.53	10190010	1	6,740	28.60	1955-65	11	2.1%
06757600	KIOWA CREEK AT K-79 RES, NEAR EASTONVILLE, CO	USGS	39.07	-104.58	10190010	1	7,287	3.20	1954-65	12	52.4%
06758200	KIOWA CREEK AT KIOWA, CO	USGS	39.34	-104.47	10190010	1	6,350	111.00	1955-65	11	6.0%
06753400	LONETREE CREEK AT CARR, CO	DWR	40.90	-104.87	10190008	1	4,680	194.98	1993-95	3	12.6%
06753990	LONETREE CREEK NEAR GREELEY, CO	DWR	40.44	-104.59	10190008	1	4,630	571.43	1993-95	3	12.5%
06753500	LONETREE CREEK NEAR NUNN, CO	USGS	40.77	-104.79	10190008	1	5,320	199.00	1951-57	7	7.7%
06759910	SOUTH PLATTE RIVER AT COOPER BRIDGE, NR BALZAC,	DWR	40.41	-103.47	10190012	1	4,091	16,795.30	1980-98	19	2.1%
06759500	SOUTH PLATTE RIVER AT FORT MORGAN, CO	DWR	40.27	-103.80	10190012	1	4,254	14,810.00	1943-58	16	3.1%
06756995	SOUTH PLATTE RIVER AT MASTERS, CO	USGS	40.31	-104.24	10190003	1	4,450	12,175.00	1976-88	13	6.0%
06757000	SOUTH PLATTE RIVER AT SUBLETTE, CO	USGS	40.30	-104.18	10190003	1	4,419	12,170.00	1926-55	30	3.0%
06754000	SOUTH PLATTE RIVER NEAR KERSEY, CO	DWR	40.41	-104.56	10190003	1	4,576	9,654.00	1901-98	98	0.0%
06758500	SOUTH PLATTE RIVER NEAR WELDONA, CO	DWR	40.32	-103.92	10190003	1	4,308	13,245.00	1952-98	47	0.0%
06758100	WEST KIOWA CREEK AT ELBERT, CO	USGS	39.21	-104.54	10190010	1	6,740	35.90	1962-65	4	18.2%
395301105120800	ANTELOPE SPGS. CR. ABV. WOMAN CR. AT RFP	USGS	39.88	-105.20	10190003	2			1994-96	3	12.2%
06720990	BIG DRY CREEK AT MOUTH NEAR FORT LUPTON, CO	DWR	40.04	-104.85	10190003	2	4,900	107.00	1991-98	8	9.6%
06720820	BIG DRY CREEK AT WESTMINSTER, COLO	USGS	39.91	-105.03	10190003	2	5,215		1987-98	12	13.4%
EVANS2CO	EVANS # 2 DITCH	DWR	40.13	-104.81		2			1925-36	12	63.4%
06720490	FIRST CR AT HWY 2, NEAR ROCKY MTN ARSENAL, CO	USGS	39.88	-104.86	10190011	2			1992-94	3	31.1%
06720460	FIRST CR BEL BUCKLEY RD, AT ROCKY MTN ARSENAL, C	USGS	39.81	-104.79	10190011	2			1992-94	3	31.1%
06720330	GRANGE HALL C AT GRANT PARK, AT NORTHGLENN, CO	USGS	39.89	-104.98	10190003	2			1977-79	3	37.6%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
06720415	GRANGE HALL CREEK AT NORTHGLENN, CO	USGS	39.89	-104.96	10190003	2			1977-81	5	33.0%
06720417	GRANGE HALL CREEK BELOW NORTHGLENN, CO	USGS	39.89	-104.96	10190003	2	5,200		1981-82	2	28.9%
395331105134400	GRAVEL PIT AT ROCKY FLATS PLANT	USGS	39.89	-105.23	10190003	2			1994-96	3	17.0%
394845104494201	HIGHLINE LATERAL @ 6TH AVE @ RMA,CO	DWR	39.81	-104.83		2					
394616104455400	HIGHLINE LATERAL ABV TOWER RD NR COMMERCE CITY C	DWR	39.77	-104.77		2			-		
394807104485900	HIGHLINE LATERAL BLW PERIMETER RD @ RMA,CO	DWR	39.80	-104.82		2			-		
394845104494202	HIGHLINE LATERAL OVERFLOW TO UP DERBY LK @ RMA,C	DWR	39.81	-104.83		2					
394856104504603	LADORA DITCH BLW LADORA WEIR @ RMA,CO	DWR	39.82	-104.85		2					
394911104514400	LAKE MARY OVERFLOW TO EAST MOOSE POND @ RMA, CO	DWR	39.82	-104.86		2					
395253105095500	MOWER DITCH AT INDIANA ST. AT ROCKY FLATS PLANT	USGS	39.88	-105.17	10190003	2			1994-96	3	12.4%
394845104494204	NORTH UVALDA TO LOWER DERBY LK @ RMA,CO	DWR	39.81	-104.83		2					
395306105131700	NORTH WOMAN CR. AT W. BUFFER ZONE FENCE LN AT RF	USGS	39.88	-105.22	10190003	2			1994-96	3	12.9%
395310105113300	POND C-1 AT ROCKY FLATS PLANT	USGS	39.89	-105.19	10190003	2			1994-96	3	17.6%
395313105110500	S. INTERCEPTOR DITCH ABV. POND C-2 AT RFP	USGS	39.89	-105.18	10190003	2			1994-96	3	31.1%
395342105110800	S. WALNUT CR BELOW POND B-4 AT ROCKY FLATS PLANT	USGS	39.90	-105.18	10190003	2			1994-96	3	12.3%
395335105112700	S. WALNUT CR. ABOVE B-SERIES BYPASS AT RFP	DWR	39.89	-105.19	10190003	2					
395253105131700	S. WOMAN CR. AT W. BUFFER ZONE FENCE LINE AT RFP	USGS	39.88	-105.22	10190003	2			1994-96	3	21.5%
394856104504601	SAND CR LATERAL ABV LADORA WEIR @ RMA,CO	DWR	39.82	-104.85		2					
394856104504602	SAND CR LATERAL BLW LADORA WEIR @ RMA,CO	DWR	39.82	-104.85		2					
394839104570300	SAND CREEK AT MOUTH NR COMMERCE CITY,CO	USGS	39.81	-104.95	10190003	2	5,110	191.00	1992-98	7	1.6%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
06714220	SENAC CR AT N BORDER SLUDGE AREA, NR AURORA, CO	USGS	39.65	-104.68	10190003	2	5,705	7.81	1989-93	5	39.7%
395246105111800	SMART DITCH ABOVE POND D-1 AT ROCKY FLATS PLANT	USGS	39.88	-105.19	10190003	2			1994-95	2	41.6%
06721000	SOUTH PLATTE RIVER AT FORT LUPTON, CO	USGS	40.08	-104.82	10190003	2	4,889	5,010.00	1929-96	68	0.0%
06720500	SOUTH PLATTE RIVER AT HENDERSON, CO	DWR	39.92	-104.87	10190003	2	5,003	4,713.00	1926-98	73	0.0%
SPSCFLCO	SOUTH PLATTE SUPPLY CANAL AT 8 FT P.F.	DWR	40.08	-104.82		2			1954-98	45	2.4%
06720790	SOUTH WALNUT CREEK AT ROCKY FLATS PLANT, CO	USGS	39.90	-105.18	10190003	2		0.40	1972-74	3	19.1%
395332105124600	T-130 DITCH AT MCKAY BYPASS AT ROCKY FLATS PLANT	USGS	39.89	-105.21	10190003	2	6,047		1994-96	3	18.3%
394845104494203	UVALDA INTERCEPTOR TO UP DERBY LK @ RMA,CO	DWR	39.81	-104.83		2					
395347105120900	WALNUT CR. ABV.PORTAL 3 AT RFP	USGS	39.90	-105.20	10190003	2			1995-96	2	58.5%
395358105110500	WALNUT CR. BELOW POND A-3 AT ROCKY FLATS PLANT	USGS	39.90	-105.18	10190003	2			1994-95	2	17.9%
395403105104700	WALNUT CR. BELOW POND A-4 AT ROCKY FLATS PLANT	USGS	39.90	-105.18	10190003	2			1994-96	3	12.3%
395349105114900	WALNUT CR. BELOW PORTAL 3 AT ROCKY FLATS PLANT	USGS	39.90	-105.20	10190003	2			1994-96	3	12.8%
395407105095900	WALNUT CREEK AT INDIANA ST. AT ROCKY FLATS PLANT	USGS	39.90	-105.17	10190003	2			1994-96	3	14.8%
06720780	WALNUT CREEK AT ROCKY FLATS PLANT, CO	USGS	39.90	-105.18	10190003	2		1.09	1972-74	3	27.6%
395308105123100	WOMAN CR. ABOVE OLD LANDFILL AT ROCKY FLATS PLAN	USGS	39.88	-105.21	10190003	2			1994-95	2	41.8%
395309105114100	WOMAN CR. ABOVE POND C-1 AT ROCKY FLATS PLANT	USGS	39.89	-105.19	10190003	2			1994-95	2	37.7%
395304105105100	WOMAN CR. BELOW POND C-2 AT ROCKY FLATS PLANT	USGS	39.88	-105.18	10190003	2			1994-95	2	20.3%
395240105095500	WOMAN CREEK AT INDIANA ST. AT ROCKY FLATS PLANT	USGS	39.88	-105.16	10190003	2			1994-96	3	12.9%
06720700	WOMAN CREEK AT ROCKY FLATS PLANT, CO	USGS	39.89	-105.18	10190003	2		2.10	1972-73	2	52.6%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
06720690	WOMAN CREEK NEAR PLAINVIEW, CO	USGS	39.89	-105.20	10190003	2			1973-74	2	30.4%
06752000	CACHE LA POUDRE R A MO OF CN, NR FT COLLINS, CO	DWR	40.66	-105.22	10190007	3	5,220	1,056.00	1881-98	118	1.2%
06752280	CACHE LA POUDRE R AB BOXELDER C, NR TIMNATH, CO	USGS	40.55	-105.01	10190007	3	4,862	1,246.00	1979-98	20	1.8%
CLAKODCO	CACHE LA POUDRE R. AT KODAK NR. WINDSOR,	DWR	40.44	-104.88		3			1971-83	13	22.1%
06745000	CACHE LA POUDRE RIVER AB CHAMBERS LK OUTLET, CO	USGS	40.63	-105.81	10190007	3	8,420	89.70	1929-31	3	18.5%
06752260	CACHE LA POUDRE RIVER AT FORT COLLINS, CO	USGS	40.59	-105.07	10190007	3	4,940	1,129.00	1975-98	24	0.0%
06749000	CACHE LA POUDRE RIVER BELOW ELKHORN CREEK, CO	USGS	40.69	-105.43	10190007	3	6,448	409.00	1946-59	14	0.9%
06752500	CACHE LA POUDRE RIVER NEAR GREELEY, CO	DWR	40.42	-104.64	10190007	3	4,610	1,877.00	1903-98	96	12.6%
06748000	CACHE LA POUDRE RIVER NEAR LOG CABIN, CO	USGS	40.70	-105.57	10190007	3	7,090	234.00	1909-31	23	75.9%
06747500	CACHE LA POUDRE RIVER NEAR RUSTIC, CO	USGS	40.70	-105.69	10190007	3	7,610	198.00	1956-68	13	3.7%
06748200	FALL CREEK NEAR RUSTIC, CO	USGS	40.55	-105.63	10190007	3	9,765	3.59	1960-73	14	4.0%
CLACANCO	FT. COL. CA. AT CACHE LA POUDRE R. NR.	DWR	40.70	-105.25		3			1963-86	24	13.9%
HSCPVDCO	HANSEN SUPPLY CANAL AT 12 FT P.F. NR FT.	DWR	40.66	-105.21		3			1953-98	46	0.0%
HSCCLPCO	HANSEN SUPPLY CANAL AT 20' P.F. NR FT.	DWR	40.66	-105.21		3			1951-98	48	0.0%
06748510	LITTLE BEAVER CREEK NEAR IDYLWILDE, CO	DWR	40.64	-105.66	10190007	3	10,000	0.88	1960-73	14	4.0%
06748530	LITTLE BEAVER CREEK NEAR RUSTIC, CO	DWR	40.62	-105.56	10190007	3	8,350	12.30	1960-73	14	4.0%
MUNCANCO	MUNROE CANAL	DWR	40.69	-105.25		3			1952-98	47	0.0%
06751500	N FORK CACHE LA POUDRE RIVER NEAR LIVERMORE, CO	USGS	40.70	-105.23	10190007	3	5,380	567.00	1929-65	37	43.1%
NOPCANCO	N. POUDRE CA. AT CACHE LA POUDRE R. NR.	DWR	40.83	-105.28		3			1966-86	21	6.5%
06751150	NORTH FORK CACHE LA POUDRE BELOW HALLIGAN RES. N	USGS	40.88	-105.34		3			1998-98	1	43.3%
06751490	NORTH FORK CACHE LA POUDRE R. AT LIVERMORE, CO	USGS	40.79	-105.25	10190007	3	5,715	539.00	1986-98	13	4.6%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
POVCANCO	POUDRE VAL. CA. AT CACHE LA POUDRE R.	DWR	40.67	-105.22		3			1966-86	21	6.5%
06748500	SOUTH FORK CACHE LA POUDRE RIVER NR EGGERS, CO	USGS	40.62	-105.52	10190007	3	7,900	70.60	1929-31	3	18.8%
06748600	SOUTH FORK CACHE LA POUDRE RIVER NR RUSTIC, CO	USGS	40.65	-105.49	10190007	3	7,597	92.40	1956-79	24	0.0%
	ADAMS TUNNEL AT EAST PORTAL-COMPUTED FLOW	DWR				4			1996-98	3	31.1%
401723105400000	ANDREWS CREEK-LOCH VALE-RMNP	DWR	40.29	-105.67		4	10,540				
06732300	BEAVER BROOK NEAR ESTES PARK, CO	USGS	40.37	-105.62	10190006	4	8,590	1.49	1968-70	3	12.4%
402114105350101	BIG THOMPSON BL MORAINE PARK NR ESTES PARK, CO	USGS	40.35	-105.58		4			1995-97	3	31.1%
06738000	BIG THOMPSON R AT MOUTH OF CANYON, NR DRAKE, CO	DWR	40.42	-105.23	10190006	4	5,297	305.00	1927-98	72	8.2%
06733000	BIG THOMPSON RIVER AT ESTES PARK, CO	DWR	40.38	-105.51	10190006	4	7,493	137.00	1946-98	53	0.0%
06741510	BIG THOMPSON RIVER AT LOVELAND, CO	USGS	40.38	-105.06	10190006	4	4,906	535.00	1979-98	20	0.6%
06744000	BIG THOMPSON RIVER AT MOUTH, NEAR LA SALLE, CO	DWR	40.35	-104.78	10190006	4	4,680	830.00	1914-98	85	11.3%
06736500	BIG THOMPSON RIVER BL POWERHOUSE, NR DRAKE, CO	DWR	40.42	-105.28	10190006	4	5,600	278.00	1917-85	69	2.6%
06735500	BIG THOMPSON RIVER NEAR ESTES PARK, CO	DWR	40.38	-105.49	10190006	4	7,423	155.00	1930-98	69	0.0%
06741500	BIG THOMPSON RIVER NEAR LOVELAND, CO	USGS	40.40	-105.11	10190006	4	4,970	505.00	1947-55	9	9.8%
06731800	BOULDER BROOK NEAR ESTES PARK, CO	USGS	40.32	-105.62	10190006	4	8,850	3.83	1968-70	3	18.2%
06739500	BUCKHORN CREEK NEAR MASONVILLE, CO	DWR	40.43	-105.18	10190006	4	5,200	134.00	1947-98	52	38.2%
HFCBBSCO	CHARLES HANSEN FEEDER CANAL BELOW BIG	DWR	40.42	-105.23		4			1950-98	49	0.0%
HFCPPLCO	CHARLES HANSEN FEEDER CANAL POWER PLANT	DWR	40.42	-105.23		4			1990-96	7	11.4%
06738100	CHARLES HANSEN FEEDER CANAL WASTEWAY TO	DWR	40.42	-105.23		4			1953-98	46	23.6%
06741000	COTTONWOOD CREEK NEAR PINEWOOD, CO	USGS	40.38	-105.24	10190006	4	5,650	14.70	1947-53	7	4.4%
DILTUNCO	DILLE TUNNEL NEAR DRAKE, CO	DWR	40.42	-105.25		4			1950-98	49	0.0%
06740000	DRY CREEK NEAR PINEWOOD, CO	USGS	40.37	-105.23	10190006	4	5,420	7.11	1950-52	3	10.9%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
06734500	FISH CREEK NEAR ESTES PARK, CO	DWR	40.37	-105.49	10190006	4	7,476	15.80	1947-98	52	1.1%
06732000	GLACIER CREEK NEAR ESTES PARK, CO	USGS	40.34	-105.58	10190006	4	7,980	20.80	1941-70	30	36.4%
HFCCCRCO	HANSEN FEEDER CANAL AT T.O. TO	DWR	40.38	-104.86		4			1953-98	46	0.0%
401707105395000	ICY BROOK-LOCH VALE-RMNP	DWR	40.29	-105.66		4	10,430				
LTCANYCO	LITTLE THOMPSON CANYON	DWR	40.26	-105.21		4			1961-98	38	67.9%
06743500	LITTLE THOMPSON RIVER AT MILLIKEN, CO	DWR	40.34	-104.86	10190006	4	4,735	199.00	1951-68	18	17.2%
06742000	LITTLE THOMPSON RIVER NEAR BERTHOUD, CO	USGS	40.26	-105.20	10190006	4	5,220	100.00	1929-61	33	53.7%
06736000	NORTH FORK BIG THOMPSON RIVER AT DRAKE, CO	DWR	40.43	-105.34	10190006	4	6,170	85.10	1947-98	52	41.6%
06734900	OLYMPUS TUNNEL (ESTES FOOTHILLS CANAL)	DWR	40.38	-105.49		4			1952-98	47	22.1%
SVSLT1CO	ST VRAIN SUPPLY CAN. T.O. TO L. THOMPSON	DWR	40.26	-105.21		4			1953-98	46	1.2%
SVSLT2CO	ST VRAIN SUPPLY CAN. T.O. TO L. THOMPSON	DWR	40.26	-105.21		4			1953-98	46	3.4%
SVSHERCO	ST.VRAIN SUPPLY CANAL T.0. TO HERTHA	DWR	40.33	-105.21		4			1954-98	45	2.8%
BTPPMCCO	USBR POWER PLANT AT BIG THOMPSON CANYON MOUTH	DWR	40.42	-105.22		4			1996-98	3	31.1%
LTCELKCO	W. FK. LIT. THOM. R. B. BIG ELK MEAD.	DWR	40.26	-105.45		4			1955-63	9	8.1%
WINDESCO	WIND RIVER NEAR ESTES PARK, CO	DWR	40.33	-105.58		4			1949-98	50	28.9%
BEAVERCO	BEAVER CREEK ABOVE BEAVER RESERVOIR NEAR	DWR	40.12	-105.52		5			1991-98	8	59.5%
BFCLYOCO	BOULDER FEEDER CANAL AT 10 FT P.F. NR	DWR	40.22	-105.26		5			1953-98	46	0.9%
BFCLHCCO	BOULDER FEEDER CANAL AT 4 FT P.F. TO	DWR	40.10	-105.22		5			1953-98	46	2.1%
DRYCRKCO	DRY CREEK TURNOUT NEAR NIWOT, CO	DWR	40.08	-105.21		5			1954-98	45	12.7%
06725000	LEFT HAND CREEK AT MOUTH, AT LONGMONT, CO	USGS	40.15	-105.10	10190005	5	4,940	72.00	1927-55	29	36.0%
06724500	LEFT HAND CREEK NEAR BOULDER, CO	DWR	40.13	-105.30	10190005	5	5,710	52.00	1929-80	52	69.9%
LEFTHDCO	LEFT HAND DIVERSION NEAR WARD COL	DWR	40.09	-105.51		5			1991-98	8	59.5%
MIDSTECO	MIDDLE SAINT VRAIN AT PEACEFUL VALLEY	DWR	40.13	-105.52		5			1997-98	2	80.3%
06722900	MIDDLE ST. VRAIN CREEK NEAR RAYMOND, CO	USGS	40.13	-105.52	10190005	5	8,680	16.80	1956-58	3	29.2%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
06722000	N ST. VRAIN CREEK AT LONGMONT DAM, NR LYONS, CO	USGS	40.22	-105.36	10190005	5	6,050	106.00	1925-53	29	0.2%
06721500	NORTH ST. VRAIN CREEK NEAR ALLENS PARK, CO	USGS	40.22	-105.53	10190005	5	8,290	32.60	1925-97	73	77.3%
06723400	SOUTH ST. VRAIN CREEK ABOVE LYONS, CO	USGS	40.21	-105.28	10190005	5	5,355	81.40	1976-80	5	16.8%
06722500	SOUTH ST. VRAIN CREEK NEAR WARD, CO	DWR	40.09	-105.51	10190005	5	9,372	14.40	1925-98	74	61.7%
06724000	ST. VRAIN CREEK AT LYONS, CO	DWR	40.22	-105.26	10190005	5	5,292	212.00	1895-98	104	0.0%
06731000	ST. VRAIN CREEK AT MOUTH, NEAR PLATTEVILLE, CO	DWR	40.26	-104.88	10190005	5	4,740	976.00	1927-98	72	0.0%
06725450	ST. VRAIN CREEK BELOW LONGMONT, CO	USGS	40.16	-105.01	10190005	5	4,850	424.00	1976-98	23	9.4%
06725100	ST. VRAIN CREEK NEAR LONGMONT, CO	USGS	40.16	-105.01	10190005	5	4,890	370.00	1964-68	5	17.3%
SVSLYOCO	ST. VRAIN SUPPLY CANAL AT 15 FT. P.F. NR	DWR	40.22	-105.26		5			1953-98	46	0.0%
LYODIVCO	TOWN OF LYON'S DIVERSION	DWR	40.25	-105.30		5			1996-98	3	61.2%
06730200	BOULDER CR AT NORTH 75TH ST NR BOULDER	USGS	40.05	-105.18	10190005	6		304.00	1986-98	13	4.6%
400118105134600	BOULDER CREEK AT COTTONWOOD GROVE NR BOULDER CO	DWR	40.02	-105.23	10190005	6	5,210				
06730500	BOULDER CREEK AT MOUTH, NEAR LONGMONT, CO	USGS	40.15	-105.01	10190005	6	4,880	439.00	1927-98	72	34.0%
06727000	BOULDER CREEK NEAR ORODELL, CO	DWR	40.01	-105.33	10190005	6	5,826	102.00	1906-98	93	0.0%
BCSCBCCO	BOULDER CREEK SUPPLY CANAL AT 10 FT P.F.	DWR	40.05	-105.19		6			1954-98	45	0.0%
BOSDELCO	BOULDER CREEK, SOUTH DIVERSION NR	DWR	39.93	-105.30		6			1958-98	41	15.1%
06726900	BUMMERS GULCH NEAR EL VADO, CO	USGS	40.01	-105.35	10190005	6	4		1983-95	13	7.1%
06730400	COAL CREEK NEAR LOUISVILLE CO	USGS				6			1997-98	2	35.3%
06730300	COAL CREEK NEAR PLAINVIEW, CO	DWR	39.87	-105.28	10190005	6	6,540	15.10	1959-98	40	7.4%
06727500	FOURMILE CREEK AT ORODELL, CO	USGS	40.02	-105.33	10190005	6	5,750	24.10	1947-95	49	61.7%
BODITLCO	LOWER BOULDER DITCH NEAR BOULDER, CO	DWR	40.05	-105.13		6			1962-90	29	11.5%
06725500	MIDDLE BOULDER CREEK AT NEDERLAND, CO	DWR	39.96	-105.50	10190005	6	8,186	36.20	1907-98	92	0.0%
06726000	NORTH BOULDER CREEK AT SILVER LAKE, CO	USGS	40.03	-105.57	10190005	6		8.70	1913-32	20	16.4%
NOBOLACO	NORTH BOULDER CREEK BELOW LAKEWOOD RES.	DWR	39.99	-105.49		6			1971-84	14	4.0%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
06726500	NORTH BOULDER CREEK NEAR NEDERLAND, CO	USGS	39.99	-105.50	10190005	6	8,135	30.40	1929-31	3	21.4%
395452105113800	ROCK CREEK AT HWY 128 AT ROCKY FLATS PLANT	USGS	39.92	-105.19	10190005	6			1995-96	2	48.2%
SOBOELCO	S. BOULDER CK. AB. D.W.B. DIV. NR	DWR	39.93	-105.31		6			1969-82	14	10.7%
06729450	S. BOULDER CK. B. GROSS RES. NR. COAL	DWR	39.94	-105.35		6			1967-98	32	0.0%
06729300	SOUTH BOULDER CREEK AT PINECLIFFE, CO	USGS	39.93	-105.42	10190005	6	7,930	72.70	1979-80	2	28.6%
BOCELSCO	SOUTH BOULDER CREEK NEAR ELDORADO	DWR	39.93	-105.30		6			1990-98	9	8.1%
06729500	SOUTH BOULDER CREEK NEAR ELDORADO SPRINGS, CO	USGS	39.93	-105.30	10190005	6	6,080	109.00	1896-95	100	0.5%
06729000	SOUTH BOULDER CREEK NEAR ROLLINSVILLE, CO	USGS	39.91	-105.50	10190005	6	8,380	42.70	1911-49	39	70.8%
394433105302100	ARGO TUNNEL AT IDAHO SPRINGS, CO	DWR	39.74	-105.51	10190004	7					
06717400	CHICAGO CREEK BLW DEVILS CANYON NR IDAHO SPRGS C	USGS	39.72	-105.57	10190004	7	8,040	43.70	1994-98	5	17.3%
394308105413800	CLEAR CR. ABV. GEORGETOWN LAKE NR GEORGETOWN, CO	USGS	39.72	-105.69		7	8,460	80.00	1997-98	2	35.6%
394359105411900	CLEAR CR. BLW. GEORGETOWN LAKE NR GEORGETOWN, CO	USGS	39.73	-105.69		7	8,450	82.40	1997-98	2	36.4%
06718300	CLEAR CREEK ABV JOHNSON GULCH NR IDAHO SPRINGS,	USGS	39.75	-105.44	10190004	7	7,210	267.00	1994-98	5	17.3%
06715000	CLEAR CREEK ABV WEST FORK CLEAR CREEK NR EMPIRE	USGS	39.75	-105.66	10190004	7	8,260	86.10	1994-98	5	17.3%
06719000	CLEAR CREEK AT FORKS CREEK, CO	USGS	39.75	-105.40	10190004	7	6,870	339.00	1899-12	14	0.0%
06719505	CLEAR CREEK AT GOLDEN, CO	USGS	39.75	-105.23	10190004	7	5,695	400.00	1974-98	25	0.8%
06717500	CLEAR CREEK AT IDAHO SPRINGS, CO	USGS	39.74	-105.51	10190004	7	7,510	242.00	1910-12	3	31.2%
06720000	CLEAR CREEK AT MOUTH, NEAR DERBY, CO	DWR	39.83	-104.96	10190004	7	5,110	575.00	1914-98	85	12.1%
06719526	CLEAR CREEK AT TABOR STREET, AT WHEATRIDGE, CO	USGS	39.77	-105.13	10190004	7	5,400		1981-83	3	26.4%
06718000	CLEAR CREEK BELOW IDAHO SPRINGS, CO	USGS	39.74	-105.50	10190004	7	7,450	259.00	1951-55	5	17.3%
06719500	CLEAR CREEK NEAR GOLDEN, CO	DWR	39.75	-105.25	10190004	7	5,735	399.00	1909-79	71	0.0%
06716500	CLEAR CREEK NEAR LAWSON, CO	DWR	39.77	-105.63	10190004	7	8,080	147.00	1946-98	53	0.9%
394115105525600	CLEAR CREEK NEAR LOVELAND PASS, CO	USGS	39.69	-105.88		7	10,615	5.86	1995-96	2	52.5%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
06717000	FALL RIVER NEAR IDAHO SPRINGS, CO	USGS	39.76	-105.56	10190004	7	7,715	23.50	1930-38	9	2.4%
394634105465800	HOOP CREEK AT MOUTH NR BERTHOUD FALLS, CO	USGS	39.78	-105.78		7	9,595		1997-98	2	47.8%
06714800	LEAVENWORTH CREEK @ MOUTH NR GEORGETOWN, CO	USGS	39.69	-105.70		7	9,290	12.00	1994-98	5	17.3%
06718550	NORTH CLEAR CREEK ABOVE MOUTH NR BLACKHAWK, CO	USGS	39.75	-105.40	10190004	7	6,910	59.40	1994-98	5	17.3%
06718500	NORTH CLEAR CREEK NEAR BLACK HAWK, CO	USGS	39.76	-105.43	10190004	7	7,220	52.20	1951-55	5	17.3%
06719735	RALSTON C BL SHWARTZWLDER MINE NR PLAINVIEW, CO	USGS	39.84	-105.28	10190004	7	6,515		1983-83	1	34.2%
06719740	RALSTON CREEK AB RALSTON RES, NR PLAINVIEW, CO	USGS	39.82	-105.26	10190004	7	6,065		1983-83	1	35.6%
06719725	RALSTON CREEK NEAR PLAINVIEW, CO	USGS	39.85	-105.30	10190004	7	6,765		1983-83	1	39.5%
SOCLACCO	S. CLEAR CREEK ABOVE CABIN CREEK RES.,	DWR	39.66	-105.71		7			1965-68	4	69.7%
CABCRECO	S. CLEAR CREEK AT CABIN CREEK OUTLET, CO	DWR	39.65	-105.71		7			1967-68	2	48.2%
06714400	SOUTH CLEAR CREEK ABV LOWER CABIN CREEK RESERVOI	USGS	39.65	-105.71	00000010	7	9,290	11.80	1994-97	4	22.5%
393647105425317	SOUTH CLEAR CREEK ABV NAYLOR CREEK NR GEORGETOWN	USGS	39.61	-105.71	10190004	7	10,710	2.19	1996-97	2	26.7%
06714600	SOUTH CLEAR CRK ABV LEAVENWORTH CRK NR GEORGETWN	USGS	39.69	-105.70	00000010	7	9,280	16.00	1994-97	4	22.5%
06715500	WEST FORK CLEAR CREEK ABOVE EMPIRE, CO	USGS	39.76	-105.70	10190004	7	8,605	40.50	1942-46	5	14.2%
06716100	WEST FORK CLEAR CREEK ABV MOUTH NR EMPIRE, CO	USGS	39.76	-105.66	10190004	7	8,235	57.60	1994-98	5	17.3%
06716000	WEST FORK CLEAR CREEK NEAR EMPIRE, CO	USGS	39.76	-105.66	10190004	7	8,271	58.20	1929-31	3	19.6%
AURAM2CO	AUR RAM INTAKE @ 10" VENTURI AB AUR	DWR	39.45	-105.07		8			1967-68	2	48.2%
AURRAMCO	AURORA RAMPART RESERVOIR	DWR	39.45	-105.07		8			1967-68	2	48.2%
06713500	CHERRY CREEK AT DENVER, CO	USGS	39.75	-105.00	10190003	8	5,175	409.00	1942-98	57	21.5%
06713300	CHERRY CREEK AT GLENDALE, CO	USGS	39.71	-104.94	10190003	8	5,320		1985-98	14	0.0%
06713000	CHERRY CREEK BELOW CHERRY CREEK LAKE, CO	USGS	39.65	-104.86	10190003	8	5,491	385.00	1950-98	49	0.0%
06712000	CHERRY CREEK NEAR FRANKTOWN, CO	USGS	39.36	-104.76	10190003	8	6,150	169.00	1939-98	60	0.0%
06712500	CHERRY CREEK NEAR MELVIN, CO	USGS	39.60	-104.82	10190003	8	5,608	360.00	1939-84	46	31.9%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
393109104464500	CHERRY CREEK NEAR PARKER, CO	USGS	39.52	-104.78	10190003	8	5,805		1991-98	8	9.6%
06712855	CHERRY CREEK TRIBUTARY NO. 1 NEAR AURORA, CO	DWR	39.63	-104.83	10190003	8	5,615				
06712960	COTTONWOOD CREEK ABOVE CHERRY CREEK LAKE, CO	DWR	39.62	-104.85	10190003	8	5,550				
06708750	EAST PLUM CR AT CASTLE ROCK, COLO.	USGS	39.38	-104.86	10190002	8			1985-89	5	13.9%
06711545	LITTLE DRY CREEK AT GREENWOOD VILLAGE, CO	USGS	39.62	-104.95	10190002	8	5,427	14.40	1994-97	4	15.3%
394302105063400	MCINTYRE GULCH AB KIPLING ST @ DFC @ LAKEWOOD CO	DWR	39.72	-105.11		8					
06709530	PLUM CREEK AT TITAN RD NR LOUVIERS, CO	USGS	39.51	-105.02	10190002	8	5,535		1984-98	15	0.7%
06709500	PLUM CREEK NEAR LOUVIERS, CO	USGS	39.51	-105.02	10190002	8	5,585	302.00	1947-90	44	0.0%
06709000	PLUM CREEK NEAR SEDALIA, CO	USGS	39.44	-104.98	10190002	8	5,723	274.00	1942-98	57	75.6%
06712860	QUINCY AVE STORM DRAIN NR AURORA, CO	DWR	39.63	-104.83	10190003	8	5,660				
06707501	S. PLATTE RIVER BELOW STRONTIA SPRINGS	DWR	39.44	-105.12		8			1982-98	17	2.7%
06714215	SOUTH PLATTE R AT 64TH AVE. COMMERCE CITY, CO	USGS	39.81	-104.96	10190003	8	5,105	3,884.00	1982-98	17	0.0%
06714130	SOUTH PLATTE RIVER AT 50TH AVENUE AT DENVER, CO	USGS	39.79	-104.97	10190003	8	5,133		1980-81	2	4.7%
06714000	SOUTH PLATTE RIVER AT DENVER, CO	DWR	39.76	-105.00	10190003	8	5,158	3,861.00	1895-98	104	0.0%
06711565	SOUTH PLATTE RIVER AT ENGLEWOOD, CO	USGS	39.63	-105.02	10190002	8	5,251		1983-98	16	0.0%
06711590	SOUTH PLATTE RIVER AT FLORIDA AVE AT DENVER, CO	USGS	39.69	-105.00	10190002	8	5,230		1981-81	1	18.4%
06710000	SOUTH PLATTE RIVER AT LITTLETON, CO	USGS	39.62	-105.02	10190002	8	5,304	3,069.00	1941-86	46	0.0%
06707500	SOUTH PLATTE RIVER AT SOUTH PLATTE, CO	DWR	39.41	-105.17	10190002	8	6,078	2,579.00	1896-98	103	0.0%
06710245	SOUTH PLATTE RIVER AT UNION AVE AT ENGLEWOOD, CO	USGS	39.67	-105.00	10190002	8	5,292	3,093.00	1989-96	8	13.5%
06708000	SOUTH PLATTE RIVER AT WATERTON, CO	DWR	39.49	-105.09	10190002	8	5,484	2,621.00	1926-98	73	0.0%
PLACHACO	SOUTH PLATTE RIVER BELOW CHATFIELD	DWR	39.56	-105.06		8			1985-98	14	10.1%
06710247	SOUTH PLATTE RIVER BELOW UNION AVE, AT ENGLEWOOD	USGS	39.63	-105.01	10190002	8		3,043.00	1996-98	3	8.9%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
06701970	SPRING CR ABOVE MOUTH NR SOUTH PLATTE CO	USGS				8			1997-98	2	45.9%
06714100	THIRTY-SIXTH STREET STORM SEWER AT DENVER, CO	USGS	39.77	-104.98	10190003	8			1975-77	3	43.8%
06710605	BEAR CREEK ABOVE BEAR CREEK LAKE NEAR MORRISON,	USGS	39.65	-105.17	10190002	9	5,645	176.00	1986-98	13	1.3%
06710385	BEAR CREEK ABOVE EVERGREEN, CO	USGS	39.63	-105.33	10190002	9	7,076		1984-98	15	2.4%
06710500	BEAR CREEK AT MORRISON, CO	DWR	39.65	-105.20	10190002	9	5,780	164.00	1900-98	99	15.9%
06711500	BEAR CREEK AT MOUTH, AT SHERIDAN, CO	DWR	39.65	-105.03	10190002	9	5,295	260.00	1927-98	72	0.0%
06710995	TURKEY CR. AT MOUTH OF CANYON, NR. MORRISON, CO	USGS				9			1998-98	1	48.2%
06711040	TURKEY CREEK ABOVE BEAR CREEK LAKE NEAR MORRISON	USGS	39.64	-105.16	10190002	9	5,635	50.60	1986-89	4	11.2%
06694700	FOURMILE CREEK NEAR FAIRPLAY, CO	USGS	39.18	-106.06	10190001	23	10,250	12.00	1978-80	3	17.4%
06697200	FRENCH CREEK NEAR JEFFERSON,COLORADO	USGS	39.39	-105.64	10190001	23		4.63	1986-90	5	48.1%
06698000	JEFFERSON CREEK NEAR JEFFERSON, CO	USGS	39.39	-105.81	10190001	23	9,600	11.80	1978-86	9	4.0%
06697450	MICHIGAN CREEK ABOVE JEFFERSON, CO	USGS	39.33	-105.84	10190001	23	9,521	23.10	1978-86	9	4.3%
06693980	MIDDLE FORK SOUTH PLATTE RIVER AB FAIRPLAY, CO	USGS	39.24	-106.03	10190001	23	10,050	62.20	1978-80	3	13.5%
06694100	MIDDLE FORK SOUTH PLATTE RIVER NR HARTSEL, CO	USGS	39.02	-105.76	10190001	23	8,796	250.00	1978-80	3	14.7%
06699000	ROCK CREEK NEAR JEFFERSON, COLORADO	USGS	39.29	-105.70	10190001	23			1986-90	5	48.1%
06695000	S PLATTE R AB 11-MILE CANYON RE, NR HARTSEL, CO	DWR	38.97	-105.58	10190001	23	8,613	880.00	1939-98	60	0.0%
06694400	SOUTH FORK SOUTH PLATTE RIVER AB FAIRPLAY, CO	USGS	39.08	-106.05	10190001	23	9,470	50.30	1978-80	3	11.5%
PLAANTCO	SOUTH PLATTE RIVE BELOW ANTERO RESERVOIR	DWR	38.99	-105.89		23			1975-98	24	0.9%
06694920	SOUTH PLATTE RIVER ABOVE SPINNEY	DWR	38.99	-105.68		23			1982-98	17	10.1%
06696200	SOUTH PLATTE RIVER AT LAKE GEORGE, CO	USGS	38.99	-105.36	10190001	23		1,084.00	1911-29	19	5.7%
06696000	SOUTH PLATTE RIVER NEAR LAKE GEORGE, CO	DWR	38.91	-105.49	10190001	23	8,458	963.00	1929-98	70	0.0%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
06696980	TARRYALL CREEK AT UPPER STATION, NEAR COMO, CO	USGS	39.33	-105.87	10190001	23	9,930	23.70	1978-86	9	4.3%
06697100	TARRYALL CREEK BELOW PARK GULCH NR. COMO, COLORA	USGS	39.28	-105.79		23			1997-98	2	27.9%
	TARRYALL CREEK BELOW TARRYALL RESERVOIR	DWR	39.22	-105.61		23			1974-80	7	56.3%
06698500	TARRYALL CREEK NEAR JEFFERSON, CO	USGS	39.29	-105.72	10190001	23	9,050	183.00	1912-81	70	85.9%
06699500	TARRYALL CREEK NEAR LAKE GEORGE, CO	USGS	39.08	-105.42	10190001	23	8,250	434.00	1943-55	13	44.3%
06763990	S. PLATTE R. AT JULESBURG, COLO. (CHAN. 2)	DWR	40.98	-102.25	10190018	64			1980-98	19	45.6%
06763980	S. PLATTE R. AT JULESBURG, COLO. (CHAN. 4)	DWR	40.98	-102.25	10190018	64			1980-98	19	45.6%
06760000	SOUTH PLATTE RIVER AT BALZAC, CO	USGS	40.41	-103.47	10190012	64	4,091	16,852.00	1917-80	64	0.0%
06764000	SOUTH PLATTE RIVER AT JULESBURG, CO	DWR	40.98	-102.25	10190018	64	3,447	23,193.00	1902-98	97	3.7%
ONEJURCO	SOUTH PLATTE RIVER AT JULESBURG-CHANNEL 1	DWR	40.97	-102.25		64			1995-98	4	42.1%
06760500	SOUTH PLATTE RIVER NEAR CROOK, CO	USGS	40.84	-102.81	10190012	64	3,705	19,238.00	1953-58	6	12.2%
06706800	BUFFALO CR AT MOUTH AT BUFFALO CREEK,CO	USGS	39.39	-105.27		80			1997-98	2	52.5%
393040105340400	DEER CREEK NR. BAILEY, CO	USGS	39.51	-105.57	10190002	80	9,280	13.40	1996-97	2	14.0%
06704500	DUCK CREEK NEAR GRANT COLORADO	USGS	39.53	-105.73	10190002	80	9,770	7.78	1994-97	4	22.5%
06705500	GENEVA CREEK AT GRANT, CO	USGS	39.47	-105.68	10190002	80	8,760	74.60	1908-97	90	88.0%
06700500	GOOSE CREEK ABOVE CHEESMAN LAKE, CO	DWR	39.21	-105.30	10190002	80	6,910	86.60	1924-85	62	7.1%
06706000	NF SOUTH PLATTE R BELOW GENEVA C, AT GRANT, CO	USGS	39.46	-105.66	10190002	80	8,561	127.00	1909-98	90	29.8%
06707000	NF SOUTH PLATTE RIVER AT SOUTH PLATTE, CO	USGS	39.41	-105.18	10190002	80	6,091	479.00	1909-82	74	1.2%
PLAGRACO	NO. FORK SO. PLATTE RIVER AT GRANT,	DWR	39.46	-105.66		80			1990-98	9	8.1%
06702500	NORTH FORK SOUTH PLATTE RIVER AT GRANT, CO	USGS	39.46	-105.66	10190002	80	8,576	49.00	1910-18	9	14.2%
06706500	NORTH FORK SOUTH PLATTE RIVER AT PINE, CO	USGS	39.41	-105.32	10190002	80	6,710	374.00	1942-46	5	12.1%
06702000	S PLATTE R AB NORTH FORK AT SOUTH PLATTE, CO	USGS	39.41	-105.17	10190002	80	6,080	2,098.00	1905-12	8	8.7%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
06700000	SOUTH PLATTE RIVER ABOVE CHEESMAN LAKE, CO	USGS	39.16	-105.31	10190002	80	6,846	1,628.00	1924-43	20	22.0%
06701500	SOUTH PLATTE RIVER BELOW CHEESMAN LAKE, CO	DWR	39.21	-105.27	10190002	80	6,609	1,752.00	1924-98	75	0.0%
06699005	TARRYALL CREEK BELOW ROCK CREEK NEAR JEFFERSON,	USGS	39.29	-105.70	10190001	80		230.00	1983-97	15	0.5%
North Platte Basin											
06611000	COLORADO CREEK NEAR SPICER, CO	USGS	40.44	-106.50	10180001	47	8,381	25.80	1950-56	7	22.5%
06611100	GRIZZLY CREEK NEAR SPICER, CO	USGS	40.49	-106.45	10180001	47	8,234	118.00	1976-79	4	21.5%
06611200	BUFFALO CREEK NEAR HEBRON, CO	USGS	40.52	-106.37	10180001	47	8,190	56.30	1976-80	5	17.3%
06611300	GRIZZLY CREEK NEAR HEBRON, CO	USGS	40.56	-106.39	10180001	47	8,130	223.00	1976-80	5	17.3%
06611500	GRIZZLY CREEK NEAR WALDEN, CO	USGS	40.64	-106.40	10180001	47	8,060	258.00	1905-47	43	49.7%
06611700	LITTLE GRIZZLY CREEK NEAR COALMONT, CO	USGS	40.55	-106.62	10180001	47	8,625	10.10	1967-73	7	11.4%
06611800	LITTLE GRIZZLY CREEK ABOVE COALMONT, CO	USGS	40.57	-106.51	10180001	47	8,200	35.40	1976-79	4	21.3%
06611900	LITTLE GRIZZLY CREEK ABOVE HEBRON, CO	USGS	40.58	-106.45	10180001	47	8,120	52.20	1976-80	5	17.3%
06612000	LITTLE GRIZZLY CREEK NEAR HEBRON, CO	USGS	40.63	-106.40	10180001	47	8,070	98.60	1904-45	42	61.4%
06612500	ROARING FORK NEAR WALDEN, CO	USGS	40.68	-106.46	10180001	47	8,037	79.10	1904-47	44	41.9%
06613000	NORTH PLATTE RIVER NEAR WALDEN, CO	USGS	40.70	-106.42	10180001	47	8,000	469.00	1904-47	44	40.3%
06614000	NORTH FORK NORTH PLATTE RIVER NEAR WALDEN, CO	USGS	40.73	-106.41	10180001	47	7,972	160.00	1923-45	23	37.1%
06614800	MICHIGAN RIVER NEAR CAMERON PASS, CO	USGS	40.50	-105.86	10180001	47	10,390	1.53	1973-98	26	0.6%
06615000	SOUTH FORK MICHIGAN RIVER NEAR GOULD, CO	USGS	40.46	-106.01	10180001	47	9,274	11.40	1950-58	9	8.1%
06615500	MICHIGAN RIVER NEAR LINDLAND, CO	USGS	40.55	-106.04	10180001	47	8,734	60.90	1931-41	11	6.0%
06616000	NORTH FORK MICHIGAN RIVER NEAR GOULD, CO	USGS	40.55	-106.02	10180001	47	8,793	20.50	1950-82	33	0.0%
06617100	MICHIGAN RIVER AT WALDEN, CO	USGS	40.74	-106.28	10180001	47	8,045	182.00	1904-47	44	40.7%
06617500	ILLINOIS CREEK NEAR RAND, CO	DWR	40.46	-106.18	10180001	47	8,551	70.60	1931-98	68	78.4%
06618000	WILLOW CREEK NEAR RAND, CO	USGS	40.47	-106.22	10180001	47	8,600	55.90	1931-40	10	4.6%
06618500	ILLINOIS CREEK AT WALDEN, CO	USGS	40.73	-106.29	10180001	47	8,039	259.00	1923-47	25	0.0%
06619000	MICHIGAN RIVER NEAR COWDREY, CO	USGS	40.86	-106.34	10180001	47	7,878	478.00	1904-47	44	73.4%
06619400	CANADIAN RIVER NEAR LINDLAND, CO	USGS	40.70	-106.07	10180001	47	8,150	44.00	1978-83	6	5.8%

Table B-1. South Platte River Streamflow Data Inventory (continued)

STATION ID	STATION NAME	Source	Lat	Long	USGS Hydrologic Unit	Water District	Elevation (feet)	Drainage (sq. mi.)	Period of Record	# of Years	Percent Missing
06619415	BUSH DRAW NEAR WALDEN, CO	USGS	40.74	-106.10	10180001	47	8,070	4.10	1981-83	3	48.2%
06619420	WILLIAMS DRAW NEAR WALDEN, CO	USGS	40.74	-106.11	10180001	47	8,110	3.95	1979-83	5	56.8%
06619450	CANADIAN RIVER NEAR BROWNLEE, CO	USGS	40.81	-106.24	10180001	47	7,930	158.00	1978-83	6	5.5%
06619500	CANADIAN RIVER AT COWDREY, CO	USGS	40.86	-106.31	10180001	47	7,870	181.00	1904-47	44	67.3%
06620000	NORTH PLATTE RIVER NEAR NORTHGATE, CO	USGS	40.94	-106.34	10180001	47	7,810	1,431.00	1904-96	93	9.1%
404301106081101	UPPER WILLIAMS DRAW PRECIP. GAUGE NR STA 06619420	DWR	40.72	-106.14	10180001	47	8,330	0.00			
MICGOUCO	MICHIGAN RIVER NEAR GOULD, COLORADO	DWR	40.58	-106.06		47			1993-95	3	31.1%
Laramie Basin											
06657500	LARAMIE RIVER NEAR GLENDEVEY, CO	USGS	40.80	-105.88	10180010	48	8,230	101.00	1904-82	79	6.6%
06746095	JOE WRIGHT CREEK ABOVE JOE WRIGHT RESERVOIR, CO	USGS	40.54	-105.88	10190007	48	9,990	3.01	1978-98	21	1.6%
06746100	JOE WRIGHT CREEK NEAR CAMERON PASS, CO	USGS	40.54	-105.88	10190007	48	9,910	5.05	1973-78	6	23.8%
06746110	JOE WRIGHT CREEK BELOW JOE WRIGHT RESERVOIR, CO	USGS	40.56	-105.87	10190007	48	9,710	6.90	1978-98	21	0.3%
06659580	SAND CREEK AT COLORADO-WYOMING STATE LINE	USGS	40.99	-105.76	10180010	76	7,580	29.20	1968-96	29	44.4%
06750500	WILSON SUPPLY CANAL NEAR EATON	DWR	40.91	-105.78		76			1932-98	67	33.1%

Notes:

1) Blank fields - data not available from source.
2) Source: CDSS HydroBase database for Division 1

Table B-2. Assessment of Diversion Data

Basin	Water District	Approximate Number of Structures with Average Annual Diversions (acre-feet) as Categorized						
		Infrequent Data	0 – 999	1,000 – 1,999	2,000 – 4,999	5,000 – 9,999	Greater than 10,000	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
South Platte								
	1	428	16	8	11	4	12	479
	2	222	30	11	11	7	21	302
	3	719	43	9	5	7	17	800
	4	472	68	5	10	7	11	573
	5	503	47	13	17	4	3	587
	6	552	49	18	13	9	5	646
	7	539	58	13	10	10	7	637
	8	585	150	10	7	2	8	762
	9	669	26	3	4	0	0	702
	23	617	334	28	13	4	2	998
	64	222	14	7	11	5	6	265
	80	235	133	1	0	0	1	370
Subtotal		5,763	968	126	112	59	93	7,121
Republican								
	49	35	5	0	2	0	0	42
	65	51	21	2	2	2	3	81
Subtotal		86	26	2	4	2	3	123
North Platte								
	47	286	386	69	44	9	2	796
Subtotal		286	386	69	44	9	2	796
Laramie								
	48	67	52	5	0	0	0	124
	76	10	1	0	0	0	0	11
Subtotal		77	53	5	0	0	0	135
Total		6,212	1,433	202	160	70	98	8,175
Total of Average Diversions (ac-ft/yr)		N/A	440,509	286,251	493,342	500,204	3,013,982	4,734,288

Note:
1) Average calculated from the available data within the CDSS HydroBase database.
2) Infrequent data represents that no annual data was summarized for that structure in the CDSS HydroBase database.
3) Structures for the purpose of this table were identified as headgates within the structure table in the CDSS HydroBase database.
4) Republican River diversions will not be included in SPDSS.

Table B-3. Transbasin Streamflow Inventory

Station ID	Station Name	Source	Basin Diverted From	Basin Diverted To	Period of Record	# of Years	Percent Missing
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
09013000	ALVA B ADAMS TUN AT E PORTAL, NR ESTES PARK, CO	DWR	Colorado	South Platte	1947-98	52	1.5%
07086300	AURORA HOMESTAKE PIPELINE ABOVE ELEVENMILE RESERVOIR	DWR	Colorado	South Platte	1980-82	3	33.3%
09021500	BERTHOUD PASS DITCH AT BERTHOUD PASS, CO	DWR	Colorado	South Platte	1931-98	68	17.6%
09046000	BOREAS PASS DITCH AT BOREAS PASS NR	DWR	Colorado	South Platte	1932-98	67	49.0%
09012000	EUREKA DITCH	DWR	Colorado	South Platte	1943-96	54	27.2%
09010000	GRAND RIVER DITCH AT LA POUDRE PASS, CO	DWR	Colorado	South Platte	1928-98	71	23.1%
09022500	MOFFAT WATER TUNNEL AT EAST PORTAL, CO	DWR	Colorado	South Platte	1936-98	63	16.3%
09050590	ROBERTS TUNNEL AT EAST PORTAL NEAR	DWR	Colorado	South Platte	1974-98	25	0.8%
STCTUNCO	STRAIGHT CR. TUNNEL AT EAST PORTAL OF EISENHOWER	DWR	Colorado	South Platte	1994-98	5	0.0%
09047300	VIDLER TUNNEL NEAR ARGENTINE PASS, CO	DWR	Colorado	South Platte	1970-98	29	0.2%
APGTUNCO	AUGUST P. GUMLICK TUNNEL NEAR JONES	DWR	Colorado	South Platte	1939-98	60	20.1%
CAPDCPCO	CAMERON PASS DITCH NEAR CAMERON PASS	DWR	North Platte	South Platte	1930-98	69	49.4%
06746000	MICHIGAN DITCH AT CAMERON PASS,COLORADO	DWR	North Platte	South Platte	1931-98	68	44.6%
BOBGLNCO	BOBCREEK DITCH NEAR DEADMAN MTN., NEAR GLENDEVEY	DWR	Laramie	South Platte	1939-98	60	95.0%
DEADDPCO	DEADMAN DITCH NEAR DEADMAN PARK, CO	DWR	Laramie	South Platte	1934-98	65	3.4%
06747000	LARAMIE POUDRE TUNNEL	DWR	Laramie	South Platte	1931-98	68	30.2%
SKYDCLCO	SKYLINE DITCH AT CHAMBERS LAKE, CO	DWR	Laramie	South Platte	1922-98	77	41.1%
WSDEARCO	WILSON SUPPLY CANAL NEAR EATON	DWR	Laramie	South Platte	1932-98	67	32.3%
06750000	COLUMBINE DITCH AT DEADMAN HILL	DWR	Laramie	South Platte	1939-56	18	91.2%

Note:
1) Sources for Division of Water Resources Stream Flow Data, CDSS HydroBase, and cross referenced with USGS Water Resource Data Reports.
2) Hoosier Pass Tunnel diversions are not shown because this system diverts water from the Colorado to the South Platte and then to the Arkansas.

Table B-4. Assessment of Reservoirs Structures

Basin	Water District	Approximate Number of Reservoirs with Maximum Annual Storage as Categorized							
		No Storage Record	0 - 999	1,000 - 4,999	5,000 - 9,999	10,000 - 19,999	20,000 - 49,999	Greater than 50,000	Total
South Platte									
	1	342	10	3	1	1	4	3	364
	2	89	91	9	4	0	3	1	197
	3	235	52	29	24	2	2	4	348
	4	178	10	7	11	0	2	2	210
	5	223	46	18	4	0	1	1	293
	6	228	28	10	9	0	2	1	278
	7	144	127	25	9	1	4	2	312
	8	232	30	3	4	2	1	2	274
	9	151	22	6	2	1	0	0	182
	23	155	35	1	0	0	0	5	196
	64	110	0	0	1	0	1	2	114
	80	114	2	1	0	0	0	0	117
Subtotal		2,201	453	112	69	7	20	23	2,885
North Platte									
	47	107	122	4	4	0	0	0	237
Subtotal		107	122	4	4	0	0	0	237
Laramie									
	48	25	0	0	0	0	0	0	25
	76	0	0	0	0	0	0	0	0
Subtotal		25	0	0	0	0	0	0	25
Total		2,333	575	116	73	7	21	23	3,147

Note:
1) Source: Structures identified as reservoirs in the CDSS HydroBase database.
2) No storage record indicates reservoir structures with no storage record available from CDSS HydroBase database. Some of these structures appear to be reservoir outlet works.
3) Cheesman Reservoir, Prewitt Reservoir, and Horsetooth Reservoir storage is recorded twice within the CDSS HydroBase database. Only one record is accounted for in the above table.

Table B-5. Assessment of Water Rights

Basin	Water District	Ground Water 2) Absolute No. Entries	Ground Water 2) Absolute Net Amount (cfs)	Ground Water 2) Other / Conditional No. Entries	Ground Water 2) Other / Conditional Net Amount (cfs)	Ditch Absolute No. Entries	Ditch Absolute Net Amount (cfs)	Ditch Other / Conditional No. Entries	Ditch Other / Conditional Net Amount (cfs)	Reservoir Absolute No. Entries	Reservoir Absolute Net Amount (cfs)	Reservoir Other / Conditional No. Entries	Reservoir Other / Conditional Net Amount (cfs)	Other 3) Absolute No. Entries	Other 3) Absolute Net Amount (cfs)	Other 3) Other / Conditional No. Entries	Other 3) Other / Conditional Net Amount (cfs)	Total No. Entries
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
South Platte																		
	1	4,532	32,604	773	2,338	291	24,033	91	9,167	208	473,824	138	1,379,546	29	224	6	415	6,068
	2	4,340	60,093	664	2,180	150	10,668	147	3,383	115	142,937	117	61,988	21	140	125	1,458	5,679
	3	2,091	2,205	83	334	338	7,652	320	14,374	305	316,878	393	404,784	121	502	75	28,146	3,726
	4	800	132	43	138	177	7,004	172	1,325	170	206,489	56	17,063	131	1,047	62	307	1,611
	5	605	416	53	243	265	3,379	147	2,354	292	200,224	154	230,550	163	403	71	333	1,750
	6	1,252	1,328	30	68	293	8,594	310	2,982	238	173,972	312	74,247	117	1,175	127	2,462	2,679
	7	985	2,849	40	41	364	12,565	380	13,294	228	76,815	337	675,851	136	1,369	67	490	2,537
	8	5,298	175,893	775	18,757	191	882	161	2,547	161	92,893	504	503,291	99	1,643	246	11,575	7,435
	9	1,092	4,128	172	31	224	1,540	70	201	142	13,282	185	34,066	112	135	47	55	2,044
	23	1,048	504	52	9	152	1,934	17	510	192	433,239	288	333,759	241	836	28	38	2,018
	64	1,559	2,592	240	6,194	146	5,609	66	362	59	131,244	30	26,349	11	17	8	4,037	2,119
	80	622	29	91	5	144	255	55	120	99	165,030	75	16,818	63	72	27	7	1,176
Subtotal		24,224	282,775	3,016	30,335	2,735	84,115	1,936	50,619	2,209	2,426,825	2,589	3,758,311	1,244	7,563	889	49,324	38,842
Republican																		
North Platte																		
	47	267	68	24	0	912	8,598	58	98	171	74,736	28	11,668	67	183	1	0	1,528
Subtotal		267	68	24	0	912	8,598	58	98	171	74,736	28	11,668	67	183	1	0	1,528
Laramie																		
	48	48	2	4	0	152	4,394	28	59	46	48,425	8	89,072	40	22	2	0	328
	76	2	0	1	0	8	58	0	0	0	0	0	0	0	0	1	6	12
Subtotal		50	2	5	0	160	4,452	28	59	46	48,425	8	89,072	40	22	3	6	340
Total		24,541	282,845	3,045	30,335	3,807	97,165	2,022	50,776	2,426	2,549,986	2,625	3,859,051	1,351	7,768	893	49,330	40,710

Note:

1) Source: CDSS HydroBase database.

2) Includes categories of seep, springs, and wells.

3) Includes categories of pipeline, mine, other, pump, and power plant.

4) If a given structure has more than one category, only the first category is counted.

5) If a given structure has an absolute and conditional water right for one entry, only the absolute water right is counted and summed

Table B-6. Summary of Division 1 Groundwater Rights[1]

Water District	Number of Wells by Flow Rate (gpm) < 15	15-50	50-100	100-200	200-500	500-1000	1000-2000	>2000	Total number Of Wells	Percent of Wells Per District
1		626	258	287	719	963	1052	72	3977	15.8
2		854	555	662	548	890	532	60	4101	16.2
3		291	51	136	359	355	132	4	1328	5.3
4		85	24	22	35	27	7	10	210	0.8
5		117	16	10	13	31	10	0	197	0.8
6		392	41	17	27	18	1	2	498	2.0
7		202	62	62	56	4	2	0	388	1.5
8		1372	875	619	492	302	182	108	3950	15.6
9		120	19	24	3	2	4	7	179	0.7
23		105	7	23	8	0	1	0	144	0.6
48		2	0	0	0	0	0	0	2	0.0
49		1	0	1	0	7	4	1	14	0.1
64		224	28	43	122	309	426	178	1330	5.3
65		0	0	0	0	3	11	0	14	0.1
80		74	3	1	3	0	0	0	81	0.3
North Platte		19	1	0	4	0	1	0	66	0.3
Total Number of Wells by Flow	8,811	4,484	1,940	1,907	2,389	2,911	2,365	442	25,249	
Percent of Wells	34.9	17.8	7.7	7.6	9.5	11.5	9.4	1.8		
Total Flow	69,295	139,330	143,768	264,722	847,447	2,265,380	3,222,776	5,459,288	12,412,006	
Percent of Total Flow	0.6	1.1	1.2	2.1	6.8	18.3	26.0	44.0	100.0	

[1]Source: CDSS HydroBase database

Table B-7. Summary of Geologic Structure and Aquifer Properties

Author	Title	Source	Date	WL	Fmn elevs	Logs	K, b, T, S	Maps	Notes
Bryant, B., McGrew, L.W., and Wobus, R.A	Geologic Map of the Denver 1 X 2 Quadrangle, North-Central Colorado	USGS Misc. Investig. Series Map I-1163	1981					x	S Denver area 106x39 to 108x40
Buckles, D.R. and Watts, K.R.	Geohydrology, Water Quality, and Preliminary Simulations of Ground-Water /flow of the Alluvial Aquifer in the Upper Black Squirrel Creek Basin, El Paso County, Colorado.	USGS WRI 88-4017	1988		x		x	x	Upper Black Squirrel basin
Chase, G.H, and McConaghy, J.A.	Generalized Surficial Geologic Map of the Denver Area, Colorado	USGS Misc. Geol. Investig. Map I-731	1972					x	Castle Rock to Brighton
CO DWR	Ground Water Resources of the upper Black Squirrel Creek Basin - El Paso County, CO	SEO or CWCB	1967		x			x	
CO SEO	Denver Basin and South Platte River Basin Technical Study (SB-74)	SB-74 (web site)	2000						
CSU	Eval of Water Resources in Kiowa & Bijou Creek Basins, CO	SEO or CWCB	1966		x			x	
CWCB & USGS	Geology and Ground Water Resources of Parts of Lincoln, Elbert and El Paso Counties, CO	SEO or CWCB	1946		x			x	Upper Big Sandy Designated Basin
Hiller, D.E., and Schneider, P.A., Jr.	Depth to the Water Table (1976-77) in the Boulder-Fort Collins-Greeley Area, Front Range Urban Corridor, Colorado	USGS Misc Invest Map I-855-I	1979	x				x	WL's from 1976-77
Hiller, D.E., Brogden, R.E. and Schneider, P.A., Jr.	Hydrology of the Arapahoe Aquifer in the Englewood-Castel Rock Area, South of Denver, Denver Basin, Colorado	USGS Misc Invest Map I-1043	1978	x	x			x	South Denver & Castle Rock
Hiller, D.E., Schneider, P.A., Jr., and Hutchinson, E.C.	Well Yields and Chemical Quality of Water from Water-Table Aquifers in the Greater Denver Area, Front Range Urban Corridor, Colorado	USGS Misc Investig Series Map I-856-J	1983					x	
Hiller, D.E., Schneider, P.A., Jr., and Hutchinson, E.C.	Depth to the Water Table (1976-77) in the Greater Denver Area, Front Range Urban Corridor, Colorado	USGS Misc Investig Series Map I-856-K	1983	x				x	WL's from 1976-77

Table B-7. Summary of Geologic Structure and Aquifer Properties (continued)

Hunt, C.B.	Pleistocene & Recent Deposits in the Denver Area, Colorado	USGS Bulletin 996-C	1954					x	40 mi^2 around Denver Profiles & X-secs of S Platte & surf geol map
Hurr, R.T., and Schneider, P.A.	Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Brush Reach of the South Platte River Valley, Colorado	USGS Open-File Report 73-123	1972	x	x		x	x	S Platte - Brush reach 1968 WL data & SDF's
Hurr, R.T., and Schneider, P.A.	Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Greeley Reach of the South Platte River Valley, Colorado	USGS Open-File Report 73-124	1972	x	x		x	x	S Platte - Greeley reach 1968 WL data & SDF's
Hurr, R.T., and Schneider, P.A.	Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Julesburg Reach of the South Platte River Valley, Colorado	USGS Open-File Report 73-125	1972	x	x		x	x	S Platte - Julesburg reach 1968 WL data & SDF's
Hurr, R.T., and Schneider, P.A.	Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Sterling Reach of the South Platte River Valley, Colorado	USGS Open-File Report 73-126	1972	x	x		x	x	S Platte - Sterling reach 1968 WL data & SDF's
Hurr, R.T., and Schneider, P.A.	Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Weldona Reach of the South Platte River Valley, Colorado	USGS Open-File Report 73-127	1972	x	x		x	x	S Platte - Weldona reach 1968 WL data & SDF's
Hurr, R.T., Schneider, P.A., Jr., and Minges, D.R.	Hydrology of the South Platte River Valley, Northeastern, Colorado	CWCB Circular 28	1975	x	x		x	x	NE Colo,not Repub. R Maps of gain/loss, bdrk, b, T; Figs of divs, ET
Hurr, R.T., Schneider, P.A., Jr., et al.	Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Brighton Reach of the South Platte River Valley, Colorado	USGS Open-File Report 72-332	1972	x	x		x	x	S Platte - Brighton reach 1968 WL data & SDF's
Jenkins, E.D.	Records and Logs of Selected Wells and Test Holes, and Chemical and Radiometric Analyses of Ground Water in the Boulder Area, Colorado	CWCB Basic Data Report 5	1961	x	x	x		x	Boulder Co WL's '58-59; well yield & locs
Kirkham, R. and Rold, J	Water Resources of Upper Crow Creek, CO	CO GS	1986		x			x	
Lindvall, R.M.	Geologic Map of the Fort Logan Quadrangle, Jefferson, Denver & Adams Counties, Colorado	USGS Quadrangle Map GQ 1427	1980					x	W-SW of Denver General surficial geology
McConaghy, J.A., Chase, G.H, Boettcher, A.J., and Major, T.J.	Hydrogeologic Data of the Denver Basin, Colorado	CWCB Basic Data Report 15	1964	x	x	x	x	x	parts of Blder, Adams, Den, Doug & JeffCo 55-62 WLs; well use & locs, T values

Table B-7. Summary of Geologic Structure and Aquifer Properties (continued)

Nelson, Haley, Patterson & Quirk, Inc	Ground Water Resources of the Lost Creek Drainage Basin - Weld, Adams & Arapahoe Counties, CO	SEO or CWCB	1967		x			x	
Nelson, Haley, Patterson & Quirk, Inc	Ground Water Resources of Northwest Washington County, CO	SEO or CWCB	1967		x			x	Camp Creek Designated Basin
Robson, S.G, Romero, J.C. and Zawistowski, S.	Geologic Structure, Hydrology and Water Quality of the Arapahoe Aquifer in the Denver Basin, Colorado	USGS Hydrologic Investigations Atlas HA-647	1981	x	x			x	Arapahoe aquifer
Robson, S.G, Wacinski, A., Zawistowski, S. and Romero, J.C	Geologic Structure, Hydrology and Water Quality of the laramie-Fox Hills Aquifer in the Denver Basin, Colorado	USGS Hydrologic Investigations Atlas HA-650	1981	x	x			x	Laramie-Fox Hills aquifer
Robson, S.G.	Alluvial and Bedrock Aquifers of the Denver Basin--Eastern Colorado's Dual Ground-Water Resource	USGS Water-Supply Paper 2302	1988				x	x	DB & SP aq's General text descr; alluvial maps N of Denver
Robson, S.G.	Bedrock Aquifers in the Denver Basin, Colorado--A Quantitative Water-resources Appraisal	USGS Professional Paper 1257	1987	x	x		x	x	Denver basin 1978 WL data; pumping estimates
Robson, S.G.	Hydraulic Characteristics of the Principal Bedrock Aqufiers in the Denver Basin., Colorado	USGS Hydrologic Investigations Atlas HA-659	1983				x	x	
Robson, S.G.	Geohydrology of the Shallow Aquifers in the Denver Metropolitan Area, Colorado	USGS Hydrologic Invest Atlas HA-736	1996	x	x			x	Denver area
Robson, S.G. and E.R. Banta	Data from Core Analyses, Aquifer Testing and Geophysical Logging of Denver Basin Bedrock Aquifers at Castle Pines, Colorado	USGS Open-File Report 93-442	1993			x		x	South Denver
Robson, S.G. and G. Graham	Geohydrology of the North Park Area, Jackson County, Colorado	USGS WRI 96-4166	1996	x	x		x	x	Jackson County
Robson, S.G., J.S. Heiny and L.R. Arnold, ,	Geohydrology of the shallow aquifers in the Fort Lupton-Gilcrest area, Colorado	USGS Hydrologic Investigations Atlas HA-646.	2000	x				x	
Robson, S.G. and Romero, J.C.	Geologic Structure, Hydrology and Water Quality of the Dawson Aquifer in the Denver Basin, Colorado	USGS Hydrologic Investigations Atlas HA-643	1981	x	x			x	Dawson aquifer
Robson, S.G. and Romero, J.C.	Geologic Structure, Hydrology and Water Quality of the Denver Aquifer in the Denver Basin, Colorado	USGS Hydrologic Investigations Atlas HA-646	1981	x	x			x	Denver aquifer
Robson, S.G., Van Slyke, G, and Graham, G.	Structure, Outcrop and Subcrop of the Bedrock Aquifers along the Western Margin of the Denver Basin, Colorado	USGS Hydrologic Investigations Atlas HA-742	1998		x			x	Front range area

Table B-7. Summary of Geologic Structure and Aquifer Properties (continued)

Romero, J.C, and Hampton, E.R.	Maps showing the approximate configuration and depth to the top of the Laramie-Fox Hills Aquifer, Denver Basin, Colorado	USGS Misc Invest Map I-791-I	1972		x			x	Laramie-Fox Hills aquifer
Romero, J.C.	Ground Water Resources of the Bedrock Aquifers of the Denver Basin Colorado	CO SEO	1976				x		Denver Basin Detailed hydrogeol & quality descr
Ruddy, B.C.	Streamflow Gain-and-Loss and Suspended-Sediment Characteristics of the South Platte River and Three Irrigation Canals near Fort Morgan, Colorado	USGS WRI 84-4220	1984						Fort Morgan area
Schneider, P.A., Jr.	Records and Logs of Selected Wells and Test Holes, and Chemical Analyses of Ground Water in the South Platte River Basin in Western Adams and Southwestern Weld Counties, Colorado	CWCB Basic Data Report 9	1962	x	x	x		x	Adams & Weld Co 55-57 WLs, well depths, locations
Schneider, P.A., Jr.	Shallow Ground water in the Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colorado, 1975-77	USGS WRI 83-4058	1983	x				x	S Platte, Bldr & St Vrain Ck alluvium WL map from 1975-77
Smith, R.O, Schneider, P.A., Jr., and Petri, L.R.	Ground-Water Resources of the South Platte River Basin in Western Adams and Southwestern Weld Counties Colorado	USGS Water-Supply Paper 1658	1964	x	x		x	x	Henderson to Kersey (S Platte, Beebe Draw, Box Elder Ck) Water Resources descr; underflow calcs on SP
Trimble, D.E. and Machette, M.N.	Geologic Map of the Greater Denver Area, Front Range Urban Corridor, Colorado	USGS Misc. Investig. Series Map I-856-H	1979					x	General geology
USDA, Soil Conservation Service	Soil Survey of Adams County, Colorado	USDA	1974					x	Adams Co Surficial soils maps
USGS	Geologic Map of the Boulder-Fort Collins-Greeley area, Colorado	USGS Misc Invest Series Map I-855-G	1985					x	General surface geology; Pub date unk
Van Slyke, G	Aquifer Data from Geophysical Logs Denver Basin, Colorado	CO SEO	1997		x				Denver Basin Access file w >3900 wells
Van Slyke, G., J. Romero, G. Moravec, and A. Wacinski	Geologic Structure, Sandstone/Siltstone Isolith, and Location of Nontributary Ground Water for the Dawson Aquifer, Denver Basin, Colorado	CWCB Atlas DBA-1	1988		x			x	
Van Slyke, G., J. Romero, G. Moravec, and A. Wacinski	Geologic Structure, Sandstone/Siltstone Isolith, and Location of Nontributary Ground Water for the Denver Aquifer, Denver Basin, Colorado	CWCB Atlas DBA-2	1988		x			x	
Watts, K.R.	Hydrogeology and Simulation of Flow betweenthe Alluvial and Bedrock Aquifers in the Upper Black Squirrel Creek Basin, El Paso County, Colorado	USGS WRI 94-4238	1995	x	x	x	x	x	Upper Black Squirrel basin

Table B-8. Water Level Data Summary (from SEO Records)

Region	Number of Wells	Period of Record
Denver Basin and overlying aquifers region	316	1960-1999
Lower South Platte alluvial aquifer region	35	1988-1999
Designated Groundwater Basins region	10	Mid 1970s then 1980 to 2000
North and South Park region	0	Not Available

Table B-9. National Climatic Data Center Climate Stations[1]

Station ID	Station name	Lat	Long	Elev	Temp	Prec	Evap	Snow	Start Year	End Year	WD	Temp % Comp.	Prec % Comp.	Evap % Comp.
0092	AGATE 3 SW	39.450	-103.933	5480	x	x			1948	1953	1	na	98	
0109	AKRON 4 E	40.150	-103.150	4540	x	x	x	x	1948	2000	65	98	52	54
0114	AKRON 1 N	40.167	-103.217	4590	x	x		x	1947	2000	65	48	98	
0183	ALLENSPARK 2 NNW	40.217	-105.533	8500	x	x		x	1948	2000	5	58	86	
0185	ALLENSPARK 1 NW	40.200	-105.533	8620	x	x		x	1994	2000	5	92	98	
0258	ANTERO JUNCTION 3 NN	38.967	-105.950	9040	x	x		x	1966	1968	23	na	100	
0263	ANTERO RESERVOIR	39.000	-105.900	8940	x	x		x	1961	2000	23	96	98	
0304	ARAPAHOE	38.850	-102.183	4010		x		x	1948	2000	49	92	12	
0348	ARRIBA	40.033	-105.267	5370	x	x		x	1948	2000	6	61	74	
0454	BAILEY	39.400	-105.483	7740	x	x		x	1948	2000	80	85	97	
0571	BEAVER RESERVOIR	40.117	-105.517	9160	x	x	x	x	1966	1974	6	na	na	
0620	BENNETT	39.750	-104.417	5670	x	x		x	1974	2000	1	na	57	
0674	BERTHOUD PASS	39.800	-105.783	11310	x	x		x	1950	1987	7	61	61	
0686	BETHUNE	39.300	-102.433	4200	x	x		x	1949	1953	49	na	69	
0834	BONNY DAM 2 NE	39.650	-102.117	3650	x	x	x	x	1949	2000	49	81	95	40
0843	BOULDER #2	40.033	-105.267	5400	x	x		x	1948	2000	6	na	89	
0848	BOULDER	40.000	-105.267	5400	x	x		x	1948	2000	6	95	95	
0862	BOVINA	39.317	-103.367	5280	x	x		x	1948	1963	65	na	82	
0945	BRIGGSDALE	40.633	-104.317	4880	x	x		x	1948	2000	1	70	65	
0950	BRIGHTON 1 NE	39.950	-104.833	4980	x	x		x	1973	2000	2	97	97	
1060	BUCKHORN MTN 1 E	40.617	-105.283	7400	x	x		x	1988	2000	4	94	58	
1121	BURLINGTON 4 S	39.250	-102.283	4170	x	x		x	1948	2000	49	82	92	
1126	BURLINGTON 12 NNE	39.483	-102.167	4230	x	x		x	1948	1978	49	na	94	
1131	BURLINGTON 8 SE	39.250	-102.150	4240	x	x		x	1948	1955	49	na	94	
1179	BYERS 5 ENE	39.733	-104.133	5200	x	x		x	1948	2000	1	91	98	
1186	CABIN CREEK	39.650	-105.700	10030	x	x		x	1968	2000	7	93	90	
1342	CARIBOU RANCH	40.000	-105.517	8370	x	x			1962	1970	6	49	79	
1401	CASTLE ROCK	39.367	-104.867	6250	x	x		x	1948	2000	8	81	68	
1528	CHEESMAN	39.217	-105.283	6890	x	x		x	1948	2000	80	98	98	
1547	CHERRY CREEK DAM	39.650	-104.833	5650	x	x		x	1951	2000	8	83	90	

Table B-9. National Climatic Data Center Climate Stations (continued)

Station ID	Station name	Lat	Long	Elev	Temp	Prec	Evap	Snow	Start Year	End Year	WD	Temp % Comp.	Prec % Comp.	Evap % Comp.
1564	CHEYENNE WELLS	38.817	-102.367	4250	x	x		x	1918	2000	49	79	91	
1681	COAL CREEK CANYON	39.883	-105.383	8950	x	x		x	1993	2000	6	98	100	
1809	COMO 4 SE	39.283	-105.833	9518	x	x		x	1998	2000	23	na	na	
1826	CONIFER	39.533	-105.367	7780		x		x	1965	1981	9		na	
1996	CROOK	40.867	-102.800	3616	x	x		x	1995	2000	64	100	96	
2162	DEER TRAIL	39.633	-104.050	5180		x		x	1948	2000	1		10	
2211	DENVER INTL AP	39.833	-104.650	5414	x	x		x	1995	2000	1	92	100	
2220	DENVER WSFO AP	39.767	-104.867	5300	x	x		x	1947	2000	8	99	99	
2223	DENVER WATER DEPT	39.733	-105.000	5228	x	x		x	1997	2000	2	na	na	
2225	DENVER WSO CITY	39.750	-104.983	5290	x	x		x	1948	1975	8	99	100	
2494	EASTONVILLE 2 NNW	39.117	-104.600	7240		x		x	1956	2000	1		98	
2496	EASTONVILLE 2 NNE	39.083	-104.550	7270		x		x	1956	1966	1		94	
2535	ECKLEY	40.117	-102.483	3890		x		x	1948	2000	65		83	
2538	ECKLEY 14N	40.333	-102.533	3890		x		x	1998	2000	65		100	
2557	EDGEWATER	39.750	-105.083	5450	x	x		x	1948	1962	8	77	94	
2593	ELBERT	39.217	-104.550	6790	x	x		x	1962	1980	1	92	99	
2595	ELBERT 2 WNW	39.250	-104.583	7030	x	x		x	1956	1966	1	na	82	
2597	ELBERT 3 SE	39.200	-104.500	6760	x	x		x	1956	1966	1	na	97	
2598	ELBERT 4 SSW	39.167	-104.567	7220	x	x		x	1956	1966	1	na	99	
2601	ELBERT 5 SW	39.167	-104.600	7060	x	x		x	1956	1966	1	na	90	
2603	ELBERT 8 SW	39.117	-104.617	7210	x	x		x	1956	1966	1	na	99	
2631	ELIZABETH 2 ENE	39.367	-104.567	6590	x	x		x	1996	2000	1	100	92	
2633	ELK CREEK	39.483	-105.367	8450	x	x		x	1948	1965	80	na	97	
2731	ERIE	40.050	-105.050	5030	x	x		x	1948	1977	6	na	100	
2759	ESTES PARK	40.383	-105.517	7760	x	x	x	x	1948	2000	4	95	96	40
2790	EVERGREEN	39.633	-105.317	7000	x	x		x	1961	2000	9	89	94	
2795	EVERGREEN 2 SW	39.617	-105.350	7310	x	x		x	1948	1968	9	na	83	
2814	FAIRPLAY	39.233	-106.000	10010	x	x		x	1948	1970	23	na	90	
2819	FAIRPLAY 2	39.217	-106.000	9960	x	x		x	1964	1968	23	na	na	
2932	FLAGLER 2 NW	39.333	-103.100	5000	x	x		x	1949	2000	49	93	96	

Table B-9. National Climatic Data Center Climate Stations (continued)

Station									Start	End		Temp %	Prec %	Evap %
ID	Station name	Lat	Long	Elev	Temp	Prec	Evap	Snow	Year	Year	WD	Comp.	Comp.	Comp.
2934	FLATIRON 8 WSW	40.367	-105.233	5504		x		x	1996	2000	4	na	92	
2944	FLEMING	40.683	-102.833	4250	x	x		x	1948	2000	65	na	97	
2965	FLORISSANT FOSSIL BE	38.917	-105.283	8410	x	x		x	1974	2000	23	90	75	
3005	FORT COLLINS	40.583	-105.083	5010	x	x	x	x	1900	2000	3	97	97	51
3027	FORT LUPTON 2 SE	40.067	-104.783	4910	x	x		x	1948	1976	2	76	95	
3038	FORT MORGAN	40.267	-103.800	4320	x	x		x	1948	2000	1	97	96	
3258	GENOA	39.283	-103.500	5600	x	x		x	1948	2000	65	28	90	
3261	GEORGETOWN	39.700	-105.700	8580	x	x		x	1948	1980	7	40	65	
3331	GLEN COMFORT	40.383	-105.450	7350	x	x		x	1995	1999	4	na	72	
3340	GLENDEVEY	40.800	-105.883	8310	x	x		x	1949	1958	48	na	86	
3386	GOLDEN 3 NW	39.783	-105.317	7120	x	x		x	1976	2000	7	na	na	
3530	GRANT	39.467	-105.683	8690	x	x		x	1963	2000	80	98	98	
3546	GREELEY	40.417	-104.683	4650	x	x		x	1948	1985	3	79	94	
3553	GREELEY UNC	40.400	-104.700	4650	x	x		x	1959	2000	3	99	99	
3570	GREENLAND	39.183	-104.850	6880	x	x		x	1966	1981	8	na	100	
3579	GREENLAND 9 SE	39.100	-104.733	7390	x	x		x	1948	2000	8	na	94	
3584	GREENLAND 6 NE	39.200	-104.733	6650	x	x		x	1948	2000	8	na	94	
3629	GROSS RESERVOIR	39.933	-105.350	7960	x	x		x	1968	2000	6	17	99	
3643	GROVER 10 W	40.867	-104.417	5080	x	x		x	1948	1975	1	82	96	
3811	HARTSEL	39.033	-105.800	8880	x	x		x	1948	1966	23	na	93	
3850	HAWTHORNE	39.933	-105.283	5930	x	x		x	1948	1978	6	na	93	
4054	HOHNHOLZ RANCH	40.967	-106.000	7760	x	x		x	1985	2000	48	95	94	
4082	HOLYOKE	40.583	-102.300	3730	x	x		x	1948	2000	65	96	98	
4135	HOURGLASS RESERVOIR	40.633	-105.600	9520	x	x		x	1988	2000	3	98	97	
4155	HOYT	40.000	-104.083	5000	x	x		x	1948	2000	1	na	94	
4234	IDAHO SPRINGS	39.750	-105.517	7570	x	x		x	1948	1976	7	80	92	
4242	IDALIA	39.700	-102.300	3960	x	x		x	1948	2000	65	85	83	
4293	INTER CANYON	39.567	-105.217	7040		x		x	1966	2000	9		92	
4380	JOES 2 SE	39.633	-102.650	4200	x	x		x	1948	2000	65	75	34	
4397	JONES PASS 2 E	39.767	-105.850	10330	x	x		x	1961	1973	7	64	93	

Table B-9. National Climatic Data Center Climate Stations (continued)

Station ID	Station name	Lat	Long	Elev	Temp	Prec	Evap	Snow	Start Year	End Year	WD	Temp % Comp.	Prec % Comp.	Evap % Comp.
4413	JULESBURG	40.983	-102.267	3470	x	x		x	1948	2000	64	83	90	
4452	KASSLER	39.500	-105.100	5500	x	x		x	1948	2000	8	94	98	
4460	KAUFFMAN 4 SSE	40.850	-103.900	5250	x	x		x	1948	1987	64	93	97	
4584	KIOWA 5 SE	39.283	-104.433	6400	x	x		x	1956	1966	1	na	80	
4585	KIOWA 4 SW	39.300	-104.517	6560	x	x		x	1956	1966	1	na	100	
4592	KIRK	39.617	-102.583	4000	x	x		x	1949	1953	65	na	56	
4603	KIT CARSON	38.767	-102.783	4280	x	x		x	1948	2000	49	na	na	
4742	LAKE GEORGE 8 SW	38.900	-105.467	8510	x	x	x	x	1948	2000	23	98	81	10
4762	LAKEWOOD	39.750	-105.117	5640	x	x		x	1900	2000	7	85	95	
4825	LARKSPUR 4 NW	39.283	-104.917	8110	x	x		x	1996	2000	8	100	92	
4856	LAST CHANCE	39.750	-103.600	4790	x	x		x	1964	1965	1	na	na	
4945	LEROY 5 WSW	40.517	-103.000	4390	x	x		x	1948	2000	65	79	97	
5025	LINDON 4 S	39.683	-103.417	4890	x	x		x	1988	2000	1	100	98	
5056	LITTLETON	39.617	-105.017	5360	x	x		x	1955	2000	8	97	94	
5116	LONGMONT 2 ESE	40.167	-105.067	4950	x	x		x	1948	2000	5	95	97	
5121	LONGMONT 6 NW	40.250	-105.150	5000	x	x		x	1948	2000	5	na	100	
5236	LOVELAND NCWCD	40.400	-105.117	5040	x	x		x	1989	2000	4	100	99	
5402	MARSTON FILTER PLANT	39.633	-105.067	5540	x	x		x	1966	2000	9	na	89	
5573	MILDRED	39.833	-102.467	4100	x	x		x	1952	1953	65	na	na	
5797	MT EVANS RES STATION	39.650	-105.600	10630	x	x		x	1983	2000	9	96	90	
5805	MORRISON 1 SW	39.650	-105.233	6000	x	x		x	1948	1957	7	na	97	
5878	NEDERLAND 2 NNE	39.983	-105.500	8240	x	x		x	1970	1989	6	92	97	
5922	NEW RAYMER	40.600	-103.850	4950	x	x		x	1948	2000	64	93	69	
5934	NEW RAYMER 21 N	40.933	-103.767	5180	x	x		x	1987	2000	64	100	100	
5984	NORTHGLENN	39.900	-105.017	5370	x	x		x	1984	2000	2	79	91	
6023	NUNN	40.700	-104.783	5190	x	x		x	1948	2000	1	99	39	
6192	OTIS 11 NE	40.267	-102.833	4260	x	x		x	1948	1989	65	na	91	
6225	OVID	40.967	-102.383	3530	x	x		x	1948	1978	64	na	98	
6299	PAOLI	40.617	-102.467	3900	x	x		x	1900	1977	65	na	94	
6323	PARKER 2 N	39.533	-104.750	6310	x	x		x	1995	2000	8	83	83	

Table B-9. National Climatic Data Center Climate Stations (continued)

Station									Start	End		Temp %	Prec %	Evap %
ID	Station name	Lat	Long	Elev	Temp	Prec	Evap	Snow	Year	Year	WD	Comp.	Comp.	Comp.
6326	PARKER 6 E	39.533	-104.650	6310	x	x		x	1948	2000	2	97	97	
6430	PERRY PARK	39.267	-104.967	6310	x	x		x	1966	1987	8	na	90	
6816	RALSTON RESERVOIR	39.833	-105.233	5910	x	x		x	1968	2000	7	8	97	
6842	RAWHIDE RESERVOIR	40.867	-105.017	5710	x	x		x	1984	1985	3	17	54	
6921	RED FEATHER LAKES	40.800	-105.583	3750	x	x		x	1991	1997	3	97	95	
6925	RED FEATHER LKS 2 SE	40.783	-105.550	8370	x	x		x	1948	1990	3	64	85	
6930	RED FEATHER LAKES 6	40.733	-105.517	7610	x	x		x	1959	1962	3	96	92	
7187	ROGGEN 2 S	40.150	-104.383	4730	x	x	x	x	1955	1960	1	95	95	45
7249	ROXBOROUGH STATE PAR	39.433	-105.067	6117	x	x		x	1995	2000	8	97	67	
7296	RUSTIC 9 WSW	40.700	-105.717	7700	x	x		x	1991	2000	3	100	92	
7510	SEDALIA 4 SSE	39.400	-104.950	6110		x		x	1956	2000	8		89	
7513	SEDGWICK	40.933	-102.517	3580	x	x		x	1948	1958	64	87	90	
7515	SEDGWICK 5 S	40.867	-102.517	3990	x	x		x	1958	2000	64	86	90	
7519	SEIBERT	39.300	-102.867	4800	x	x		x	1949	2000	49	na	94	
7557	SHAW 2 E	39.550	-103.350	5180	x	x		x	1948	2000	65	90	27	
7560	SHAW 4 ENE	39.567	-103.300	5180	x	x		x	1997	2000	65	100	83	
7648	SILVER LAKE	40.033	-105.583	10210	x	x		x	1948	2000	6	na	29	
7682	SKY RNCH LUTHRN CMP	40.583	-105.600	9100	x	x		x	1985	1988	3	50	96	
7816	SOUTH PLATTE	39.400	-105.183	6090	x	x		x	1966	2000	80	na	95	
7881	SQUAW MOUNTAIN	39.683	-105.500	11510	x	x		x	1964	1981	7	2	96	
7950	STERLING	40.617	-103.217	3940	x	x		x	1948	2000	64	93	96	
8008	STRATTON	39.300	-102.600	4400	x	x		x	1948	2000	49	83	88	
8022	STRONTIA SPRINGS DAM	39.433	-105.117	5840	x	x		x	1984	2000	8	100	98	
8260	THURMAN 3 ENE	39.617	-103.183	4550	x	x		x	1949	1953	65	na	97	
8614	VERNON 4 SW	39.917	-102.383	3900		x		x	1998	2000	65		na	
8690	VIRGINIA DALE 7 ENE	40.967	-105.217	7015	x	x		x	1995	2000	3	100	100	
8722	VONA	39.300	-102.733	4500	x	x		x	1948	1984	49	na	100	
8756	WALDEN	40.733	-106.283	8120	x	x		x	1948	2000	47	na	97	
8839	WATERDALE	40.433	-105.200	5200	x	x		x	1948	2000	4	95	na	
8896	WELDONA 2 SE	40.333	-103.933	4350	x	x		x	1974	2000	1	na	na	

Table B-9. National Climatic Data Center Climate Stations (continued)

Station ID	Station name	Lat	Long	Elev	Temp	Prec	Evap	Snow	Start Year	End Year	WD	Temp % Comp.	Prec % Comp.	Evap % Comp.
8907	WELLINGTON 5 WNW	40.733	-105.117	5260	x	x		x	1995	1999	3	86	94	
8939	WESTCREEK	39.133	-105.117	7810	x	x		x	1948	1959	8	na	97	
8995	WHEAT RIDGE 2	39.750	-105.083	5430	x	x		x	1981	2000	8	97	97	
9025	WIGGINS 7 SW	40.150	-104.183	4710	x	x	x	x	1960	1974	1	98	98	55
9147	WINDSOR	40.467	-104.900	4700	x	x		x	1948	1990	3	na	96	
9210	WOODLAND PARK 8 NNW	39.100	-105.083	7810	x	x		x	1948	2000	8	na	92	
9213	WOODROW 6 NNE	40.067	-103.567	4374		x		x	1993	2000	1		100	
9243	WRAY 2 E	40.083	-102.183	3510	x	x		x	1918	2000	65	82	88	
9295	YUMA	40.117	-102.717	4130	x	x		x	1948	2000	65	80	88	
9297	YUMA 10 NW	40.217	-102.817	4110		x		x	1989	2000	65		94	

Lat=latitude, Long=longitude, Elev=elevation, Temp=temperature, Prec=precipitation, Evap=evaporation, WD=water district,
% Comp=percent of period record with data "na" = information not available

[1]Source: National Climatic Data Center

Table B-10. COAgMet Climate Stations[1]

Station ID	Station name	Lat	Long	Elev	Temp	Prec	Evap	Snow	VP	Solar	Wind	Soil T.	Start Year	End Year	WD
akr02	Akron USDA GPRC	40.1552	-103.142	4550	x	x			x				1995	1998	65
alt01	Ault Station	40.5717	-104.732	4910	x	x			x	x	x	x	1992	2000	1
brl01	Burlington North	39.4998	-102.074	3900	x	x			x	x	x	x	1992	2000	49
br102	BurlingtonNo. 2	39.2652	-102.11	4170	x	x			x	x	x	x	1991	2000	49
ftc01	Fort Collins AERC	40.5947	-105.138	5120	x	x			x	x	x	x	1992	2000	3
ftc03	Fort Collins ARDEC	40.6523	-104.996	5110	x	x			x	x	x	x	1992	2000	3
ft101	Fort Lupton	40.0007	-104.849	5055	x	x			x	x	x	x	1992	2000	2
ftm01	Fort Morgan	40.2585	-103.954	4320	x	x			x	x	x	x	1995	2000	1
gly03	Greeley	40.4393	-104.647	4680	x	x			x	x	x	x	1992	2000	3
hxt01	Haxton	40.6722	-102.647	4040	x	x			x	x	x	x	1997	2000	65
hyk02	Holyoke	40.4913	-102.089	3735	x	x			x	x	x	x	1991	2000	65
id101	Idalia	39.7312	-102.089	3975	x	x			x	x	x	x	1991	2000	49
krk01	Kirk	na	Na	na	x	x			x	x	x	x	1996	2000	65
ksy01	Kersey	40.3773	-104.532	4625	x	x			x	x	x	x	1992	2000	1
lcn01	Lucerne	40.4753	-104.708	4750	x	x			x	x	x	x	1992	2000	3
pkh01	Peckham	40.3128	-104.727	4710	x	x			x	x	x	x	1992	2000	2
wry01	Wray	na	Na	na	x	x			x	x	x	x	1996	2000	65
yum02	Yuma #2	40.15	-102.724	4000	x	x			x	x	x	x	1996	2000	65

Lat=latitude, Long=longitude, Elev=elevation, Temp=temperature, Prec=precipitation, Evap=evaporation, VP=vapor pressure, Wind = wind speed, Soil T.=soil temperature
WD=water district, "na" = information not available

[1]Source: Colorado State University's COAgMet records

Table B-11. Northern Colorado Water Conservancy District Climate Stations[1]

Station name	Lat	Long	Elev	Temp	Precip	Evap	Snow	VP	Solar	Wind	Soil T.	Start Year	End Year	WD
Brush	40.6069	-104.9936	5005	x	x			x	x	x	x	1987	2000	3
Crook	40.8439	-102.8544	3735	x	x			x	x	x	x	1971	2000	64
Eaton	40.5556	-104.7575	4900	x	x			x	x	x	x	1993	2000	3
Ft. Collins	40.6069	-104.9936	5005	x	x			x	x	x	x	1986	2000	3
Gilcrest	40.2883	-104.8119	4755	x	x			x	x	x	x	1993	2000	2
Greeley East	40.4667	-104.6414	4670	x	x			x	x	x	x	1978	1993	3
Greeley West	40.4119	-104.7844	4798	x	x			x	x	x	x	1997	2000	3
Johnson's Corner	40.3650	-104.9794	4965	x	x			x	x	x	x	1993	2000	4
Longmont South	40.0733	-105.0944	5085	x	x			x	x	x	x	1987	2000	5
Longmont West	40.1878	-105.1269	5055	x	x			x	x	x	x	1997	2000	5
Loveland	40.4048	-105.0944	5085	x	x			x	x	x	x	1982	2000	4
Mountain Vista	40.6069	-104.9936	5005	x	x			x	x	x	x	1995	1998	3
Ovid	40.9700	-102.4525	3575	x	x			x	x	x	x	1992	2000	64
Sterling	40.5833	-103.2386	3950	x	x			x	x	x	x	1987	2000	64
Wiggins	40.3144	-104.0583	4485	x	x			x	x	x	x	1989	2000	1
Windsor	40.4750	-104.95833	4960	x	x			x	x	x	x	1995	2000	3

Lat=latitude, Long=longitude, Elev=elevation, Temp=temperature, Prec=precipitation, Evap=evaporation, VP=vapor pressure, Wind = wind speed, Soil T.=soil temperature WD=water district, "na" = information not available

[1]Source: NCWCD Records

Table B-12. Other (Non-NOAA) Evaporation Stations

Reservoir name	Lat	Long	Elev	Start Year	End Year	% Complete	WD	Source/Agency
Cherry Creek Dam	na	na	na	1959	1989	na	8	Corps of Engineers
Ralston Reservoir	na	na	na	1972	1980	na	7	Denver Water Board
Cheesman Reservoir	na	na	na	1967	1980	na	80	Denver Water Board
Antero Reservoir	na	na	na	1967 1977	1971 1980	na	23	Denver Water Board
ElevenMile Canyon Reservoir	na	na	na	1974	1980	na	23	Denver Water Board
Gross Reservoir	na	na	na	1974	1980	na	6	Denver Water Board

Lat=latitude, Long=longitude, Elev=elevation, % Complete=percent of period record with data, WD=water district, "na" = information not available

Table B-13. SNOTEL Sites[1]

Site ID	Site Name	Lat	Long	Elev	Start	End	Tributary
BLKC2	Bear Lake	40.317	-105.650	9500	1981	2000	Big Thompson
BTSC2	Berthoud Summit	39.800	-105.783	11,300	1979	2000	Clear Creek
COLC2	Columbine	40.400	-106.600	9,160	1980	2000	North Platte
COPC2	Copeland Lake	40.200	-105.567	8,600	1981	2000	St. Vrain
DDMC2	Deadmen Hill	40.800	-105.767	10,220	1979	2000	Poudre
GZPC2	Grizzly Peak	39.650	-105.867	11,100	1980	2000	Clear Creek
HOOC2	Hoosier Pass	39.367	-106.067	11,400	1980	2000	South Platte
JWRC2	Joe Wright	40.533	-105.883	10,120	1979	2000	Poudre
LELC2	Lake Eldora	39.933	-105.583	9,700	1979	2000	Boulder
LKIC2	Lake Irene	40.417	-105.817	10,700	1979	2000	Poudre
LBAC2	Loveland Basin	39.667	-105.900	11,400	1992	2000	Clear Creek
NIWC2	Niwot	40.033	-105.550	9,910	1981	2000	Boulder
ROAC2	Roach	40.867	-106.050	9,700	1981	2000	Laramie
TOWC2	Tower	40.533	-106.683	10,500	1979	2000	North Platte
UVCC2	University Camp	40.033	-105.567	10,300	1979	2000	Boulder
WLLC2	Willow Creek	40.350	-106.100	9,540	1979	2000	North Platte
WPRC2	Willow Park	40.433	-105.733	10,700	1980	2000	Poudre

[1]Source: NWS and NRCS Records

Table B-14. Assessment of Data Applicable for Current and Historic Land Use Classification and for Irrigation Water Service Areas

Data Type	Source	Main Application: Current land use	Main Application: Historic land use	Main Application: Service Area	Format, data description	Spatial Coverage	Temporal Coverage	Main Use	Main Limitation	Overall Utility
Maps of irrigated lands	NCWCD	*			30m raster, derived from satellite imagery	NCWCD	1997	Extent of irrigation	Crop types not identified, not field verified, year 1997, covers NCWCD	Mod
Regional water demand study	NCWCD	*			Vector files, derived from land use maps, satellite imagery	NCWCD	1990s	General land use categories	Does not discriminate irrigated lands, year 1996, covers NCWCD east to Kersey	Low
National Land Cover Date (NLCD)	USGS	*			30m raster, derived from satellite imagery	Entire study area when complete	2000	Land use and land cover	Not available until 2005	V Low
Colorado agricultural statistics	State	*	*		Tabular data, summarized by county	County-side for entire study area	Annual	Summary data for comparison	Not mapped to parcel level, aggregate data	Low
Farm Service Agency reports and maps	Farm Service Agency (formerly ASCS)	*	*		Data reported by producers, mapped on NHAP photography, unrectified, mostly from 1980s	About half of procedures in study area	Annual	Input for classification, verification	About 50% of irrig crops reported, not verified, not geo-referenced	Mod
Multi-resolution Land Characterization (MRLC)	USGS		*		30m Raster data, derived from satellite imagery	Entire study area	One season during the period 1988-94	Generalized land use and land cover	Acquired over a period of 6 years, not yet field verified, irrigated areas not explicitly segregated	Low
Land Use and Land Cover	USGS, Water Res. Div.		*		Vector format, derived from aerial photo interpretation and satellite imagery, 1;250,000 scale	Entire study area	Late 1970s	Generalized land use and land cover	Irrigated areas not segregated from other agriculture	V Low

Table B-14. Assessment of Data Applicable for Current and Historic Land Use Classification and for Irrigation Water Service Areas (Cont.)

Data Type	Source	Main Application			Format, data description	Spatial Coverage	Temporal Coverage	Main Use	Main Limitation	Overall Utility
		Current land use	Historic land use	Service Area						
Historic land use	USGS Front Range Infrastruc-ture Resources Project		*		Interpretations of digital scanned aerial photos, raster format, various resolutions	Western portion of study area, Fort Collins to South Denver	1937-9, 1950s, 1970s, 1990s	General land use	Available in early 2001, limited Front Range part of SP basin	Mod
National Hydrography Data (NHD), 1:24, 000 scale	USGS contract to Colo. Div. Of Wildlife			*	Digitized all hydrography features from USGS quads	Entire study area when complete	Various, mostly 1970s-1980s	Includes locations of major canals, ditches, structures	About 60% basin not complete until end 2001; base information is dated, service are not mapped	Low
Diversion and structure location	State			*	Point data	Entire study area	Assumed to be current	Assists identification of canals	Point data, location is only approximate, service areas not mapped	V Low
Maps of ditches, easements	Cache La Poudre Water Users Association			*	Maps traced on hardcopy maps, unknown scale	Poudre River	Data from 1990s	Locations of canals, major ditches	No complete, possibly substandard result, includes Poudre River only, service area not mapped	Low
Division 1 well location data	State			*		Division 1	Data assumed current	Mapping location and service areas	Only 20% of wells GPS located, inconsistencies in data esp. location, service area not mapped	Mod
Data from users	GASP, Central, ditch companies, SPMAP, etc.			*		Each source covers specific area within basin	Various dates, stages of completion	Some data directly usable and reliable, other serve as basis	Only 20% of wells GPS located, inconsistencies in data esp. location, service area not mapped	Mod

Table B-15. Landsat 7 TM Satellite Imagery, Maximum 10% Cloud Cover, Available for South Platte Basin from April-September, 2000[1]

Date	WRS Path	WRS Row	Cloud Cover
16-Apr-00	32	32	2
2-May-00	32	32	0
3-Jun-00	32	32	1
5-Jul-00	32	32	1
21-Jul-00	32	32	10
6-Aug-00	32	32	0
22-Aug-00	32	32	8
7-Sep-00	32	32	0
16-Apr-00	32	33	0
2-May-00	32	33	0
3-Jun-00	32	33	1
19-Jun-00	32	33	2
5-Jul-00	32	33	0
21-Jul-00	32	33	0
6-Aug-00	32	33	1
7-Sep-00	32	33	0
19-Feb-00	33	32	2
7-Apr-00	33	32	8
25-May-00	33	32	10
10-Jun-00	33	32	0
12-Jul-00	33	32	7
28-Jul-00	33	32	1
13-Aug-00	33	32	0
14-Sep-00	33	32	0
3-Feb-00	33	33	0
19-Feb-00	33	33	7
9-May-00	33	33	4
10-Jun-00	33	33	2
13-Aug-00	33	33	2
14-Sep-00	33	33	0
30-Sep-00	33	33	10
16-May-00	34	32	2

Table B-15. Landsat 7 TM Satellite Imagery, Maximum 10% Cloud Cover, Available for South Platte Basin from April-September, 2000 (continued)

1-Jun-00	34	32	0
9-Jul-00	34	32	5
26-Feb-00	34	33	2
13-Mar-00	34	33	6
1-Jun-00	34	33	2
19-Jul-00	34	33	1

[1]Sources of Data listed in Table B-14

Table B-16. GIS Data for Use in SPDSS

Category	Data Type	Source	Format, data description	Spatial Coverage Available	Quality Overall	Notes
Boundaries	Water Division/District Bdy	State	Arc/Info polygons	Study area	Good	
	County Boundaries	ESRI Maps	DLG from 1:100,000 maps	Study area	Fair	
	State HUC	USGS	DLG from 1:250,000 maps	Study area	Fair	
Other	Highways	USGS	DLG from 1:100,000 maps	Study area	Fair	
	Digital Elevation Model (DEM)	USGS – National Elevation Data (NED)	DEM, 30m pixel from 1:24,000 maps, seamless coverage	Study area	Good	$550 ($1/quad)
	Public land survey system (PLSS)	USGS	DLG, from 1:100,000 maps	Study area	Fair	Public domain data
	Public land survey system (PLSS)	State (proprietary)	DLG, from 1:24,000 USGS maps (?)	Study area	Good	Proprietary, cannot be distributed
	Soils, STATSGO	NRCS	Soil survey and interpretations, vector format	Study area	Fair	
	Wetlands, national wetland inventory	US Fish and Wildlife	National Wetlands Inventory (NWI) data available in vector format	Study area	Fair	
	Digital Raster Graphics (DRG)	USGS	Raster data, scanned 1:24,000 quad maps	Study area	Good	
	Land use, historic and current	Various	Various	Various		To be developed under SPDSS, described Ch. 13
River system and water distribution	Hydrography, general	USGS	DLG, from 1:100,000 scale maps	Study area	Fair	
	National Hydrography Data (NHD) incl. rivers, major canals, major drains, reservoirs, tunnels, major siphons	USGS contract to Colo Div of Wildlife	Digitized alignments and names as appear on 1:24,000 scale USGS quads,	Partial, 40% of study area	Good	Study area completed in late 2001
	Diversion and structure location	State	Point data	Study area	Fair	Location of structures is approximate
	Reservoir/Dam Locations	State	Point	Study area	Fair	
	Stream Gauge Locations	State, USGS	Point data	Study area	Fair	

Table B-16. GIS Data for Use in SPDSS (Cont.)

Category	Data Type	Source	Format, data description	Spatial Coverage Available	Quality Overall	Notes
	Digital orthophotos and x-sections of S. Platte	CWCB	Raster data (orthos) and vector (x-sections)	S. Platte Chatfield Res. to State line	Good	Digital orthos avail, x-sections by end-2000
	SDF maps of South Platte River	USGS/NCWCD	Vector data	NCWCD area available in SPMAP	Good	Availability of USGS data from other reaches needs to be determined
	Irrigation service areas	Various	Various	Various		To be developed as GIS data under SPDSS, described in Ch. 13
	Data from users	GASP, Central, ditch companies, SPMAP, etc.	Various	Each source covers specific areas within basin	Various	Various dates, stages of completion
Local gov't	Relevant data from counties	e.g. Weld, Larimer, Jackson	Various	Each source covers specific areas within basin	Various	Various dates, stages of completion
	Relevant data from municipalities	e.g. Denver, Greeley	Various	Each source covers specific areas within basin	Various	Various dates, stages of completion
Climate	Temp, precip, evaporation, vapor press, solar, soil temp	NOAA/NWS, CSU, NCWCD, USACE, DWD	Point data	Point data throughout Div 1	Acceptable overall	Data, described in Ch 11, will be brought into GIS format
	Snow depth and snow water equivalent	NWS, NRCS	Point data	17 locations	Good	Data, described in Ch. 12, will be brought into GIS format

APPENDIX C

COST TABLES

Table C-1. Estimated Costs During SPDSS Implementation for Surface Water Alternatives

Surface Water Resources Planning	Alternative 1 Description	Reference Section	Total Cost	Alternative 2 Description	Reference Section	Total Cost	Alternative 3 Description	Reference Section	Total Cost
Data Collection									
Research/identify appropriate study period	Complete task (costs assume a 1950-present study period)	5.2	$9,000	Nothing added (costs assume a 1950-present study period)	n/a	$9,000	Nothing added (costs assume a 1950-present study period)	n/a	$9,000
Identify key streamflow gages and estimate streamflows for missing records	Records at least 70 % complete throughout study period (approx. 63 gages)	5.3.1.1.1	$47,000	Nothing added	n/a	$47,000	Nothing added	n/a	$47,000
Identify key diversion structures, QA/QC diversion data, and fill missing data for 25% of structures	Structures comprising more than an average annual diversion of 5,000 ac-ft (approximately 163 structures or 75% of annual diversions); fill monthly data for 41 diversions	5.3.1.1.2	$121,000	Structures comprising more than an average annual diversion of 2000 ac-ft (total of approximately 319 structures or 85 percent of annual diversions); fill daily data for 80 diversions	5.4.1.1.2	$273,000	Nothing added	n/a	$273,000
Identify key transmountain diversion structures and fill/resolve conflicting records (19 total structures)	19 transbasin structures	5.3.1.1.2	$54,000	Nothing added	n/a	$54,000	Nothing added	n/a	$54,000
Identify key storage elements and fill missing records	50 greater than 10,000 ac-ft & 9 smaller than 10,000 ac-ft (approx. 85% of total storage); fill missing monthly records	5.3.1.1.2	$118,000	Fill missing records on a daily basis for 59 storage elements	5.4.1.1.2	$149,000	Nothing added	n/a	$149,000
River call data collection	Not included	n/a	$0	Collect and evaluate river call data	5.4.1.1.3	$56,000	Nothing added	n/a	$56,000
Augmentation plan, substitute supply plan, and transfer decree data	Not included	n/a	$0	Data for 10 largest plans/transfers	5.4.1.1.3	$64,000	Data for 40 largest plans/transfers	5.5.1.1	$259,000
Field Work Plan development	Develop plan for Alternative 1 field activities	5.3.1.1	$9,000	Develop plan for Alternative 2 field activities	n/a	$14,000	Develop plan for Alternative 3 field activities	n/a	$56,000
Point flow investigations per SB-74 recommendations to support groundwater modeling of Denver Basin alluvium	Monitoring 2 times/year for 2 years at 25 sites overlying the Denver Basin	5.3.1.1.3	$218,000	Nothing added	n/a	$218,000	Nothing added	n/a	$218,000
Point flow investigations per Division 1 need for improved administration	Monitoring 4 times over 2 years along the Lower South Platte from St. Vrain River to Julesburg (conducted by DWR)	5.3.1.1.3	$106,000	Nothing added	n/a	$106,000	Monitoring 6 times over 2 years along the Lower South Platte from St. Vrain River to Julesburg (conducted by DWR)	5.5.1.1	$134,000
Flow routing data collection	Not included	n/a	$0	Not included	n/a	$0	Collect flow routing & channel characteristics data	5.5.1.1	$167,000
Install new satellite monitoring systems on existing diversion structures	Not included	n/a	$0	Satellite monitoring systems on 6 diversion structures (non-transmountain) and 2 transmountain diversion structures	5.4.1.1.4	$135,000	Satellite monitoring systems on 10 diversion structures (non-transmountain) and 2 transmountain diversion structures	5.5.1.1	$203,000
Install new standard stream gages	Not included	n/a	$0	1 new stream gage on S Platte R below Julesburg (installed by DWR)	5.4.1.1.4	$19,000	Not included	n/a	$0
Install new standard stream gages	Not included	n/a	$0	1 new stream gages on S Platte R at Atwood (installed by Consultant)	5.4.1.1.4	$53,000	8 new stream gages on S Platte R and tributaries (installed by Consultant)	5.5.1.1	$431,000
Conceptual Design Investigation (CDI) for rated controlled section gage	Not included	n/a	$0	Not included	n/a	$0	Conduct CDI and develop recommendations	5.5.1.1	$95,000
Install new stream gages with rated controlled section gages	Not included	n/a	$0	Not included	n/a	$0	3 rated control sections and gages	5.5.1.1	$3,967,000
Operate and maintain diversion structure gages	Not included	n/a	$0	DWR Satellite Monitoring Program responsibility	5.4.1.1.4	$0	Nothing added	n/a	$0
Rate, operate, and maintain new standard stream gages	Not included	n/a	$0	DWR Division 1 Engineer responsibility	5.4.1.1.4	$0	Conduct for duration of SPDSS implemention (5 years)	5.5.1.1	$218,000
Rate, operate, and maintain rated control section gages	Not included	n/a	$0	Not included	n/a	$0	DWR Division 1 Engineer responsibility	5.5.1.1	$0
Subtotal: Data Collection			***$682,000***			***$1,197,000***			***$6,336,000***

Table C-1. Estimated Costs During SPDSS Implementation for Surface Water Alternatives

Surface Water Resources Planning	Alternative 1 Description	Reference Section	Total Cost	Alternative 2 Description	Reference Section	Total Cost	Alternative 3 Description	Reference Section	Total Cost
Components									
Modeling time step	Monthly (1950-present)	5.3.2.1	N/A	Monthly & Daily (1950-present)	5.4.2.1	N/A	Monthly & Daily (1950-present)	n/a	N/A
Develop Models	S. Platte (excluding Republican), N. Platte, & Laramie	5.3.2.1	N/A	S. Platte (excluding Republican), N. Platte, & Laramie	5.4.2.1	N/A	S. Platte (excluding Republican), N. Platte, & Laramie	5.5.2.1	N/A
StateMod logic refinements	Not included	n/a	$0	Reporting of river call environment by node and time step	5.4.2.1	$47,000	Nothing added	n/a	$47,000
StateMod logic refinements	Not included	n/a	$0	Not included	n/a	$0	Implement flow routing	5.5.2.1	$473,000
StateMod logic refinements	Not included	n/a	$0	Not included	n/a	$0	Interactive information flow with groundwater model	5.5.2.1	$270,000
StateMod logic refinements	Not included	n/a	$0	Not included	n/a	$0	Interactive information flow for transmountain diversion with other DSS products	5.5.2.1	$112,000
StateMod logic refinements	Not included	n/a	$0	Not included	n/a	$0	Refine StateMod input to integrate point-flow gain/loss evaluation	5.5.2.1	$116,000
StateMod GUI Enhancements	Minimum level	5.3.2.1	$21,000	Intermediate Level	5.4.2.1	$60,000	Expanded Level	5.5.2.1	$119,000
Meet with key structure operators and Division 1 personnel to review prior studies, develop understanding of operations, and develop operational/admininstration memoranda	163 diversion structures, 19 transbasin structures, 59 storage elements	5.3.2.1	$208,000	319 diversion structures, 19 transbasin structures, 59 storage elements	5.4.2.1	$415,000	Nothing added	n/a	$415,000
Develop return flow factors, delay tables, and other ground water parameters	Based on Alt. 1 level of gages and structures	5.3.2.1	$49,000	Nothing added	n/a	$49,000	Nothing added	n/a	$49,000
Construct StateMod input files (stream network, key structures and rights, non-key aggregated structures and rights, aggregated well supplies, operating rules, demands, storage, water use/return flows)	Monthly model, 70-100% complete gages, 163 diversion structures, 19 transbasin structures, 59 storage elements	5.3.2.1	$207,000	Monthly & daily model, 70-100% complete gages, 319 diversion structures, 19 transbasin structures, 59 storage elements	5.4.2.1	$445,000	Monthly & daily model, 70-100% complete gages, 319 diversion structures, 19 transbasin structures, 59 storage elements plus flow routing data sets	5.5.2.1	$634,000
Generate baseflows	Based on Alt. 1 level of gages and structures and monthly modeling	5.3.2.1	$47,000	Based on Alt. 2 level of gages and structures and monthly & daily modeling	5.4.2.1	$88,000	Based on Alt. 3 level of gages & structures, point flow data, flow routing, and monthly & daily modeling	5.5.2.1	$107,000
Calibrate model	Based on Alt. 1 level of gages and structures and monthly modeling	5.3.2.1	$118,000	Based on Alt. 2 level of gages and structures and monthly & daily modeling	5.4.2.1	$204,000	Based on Alt. 3 level of gages & structures, point flow data, flow routing, and monthly & daily modeling	5.5.2.1	$261,000
Develop typical application	Not included	n/a	$0	Complete task	5.4.2.1	$70,000	Nothing added	n/a	$70,000
Comparison of modeling results with Users' modeling results	Not included	n/a	$0	Not included	n/a	$0	Compare to Denver and NCWCD	5.5.2.1	$56,000
Update return flow factors and delay tables from ground water modeling results	Not included	n/a	$0	Complete task	5.4.2.1	$48,000	Nothing added	n/a	$48,000
Document basin model for alternative	Based on Alt. 1 level of modeling	5.3.2.1	$160,000	Based on Alt. 2 level of modeling	5.4.2.1	$219,000	Based on Alt. 3 level of modeling	5.5.2.1	$315,000
Subtotal: Components			***$810,000***			***$1,645,000***			***$3,092,000***
Coordination with Consultant team	7 yrs, 12 mon/yr, 1 dy/mon	n/a	$92,000	Nothing added	n/a	$92,000	Nothing added	n/a	$92,000
User Coordination	6 yrs, 2 mtg/yr, 12 hrs/mtg, 2 staff/mtg	n/a	$56,000	Nothing added	n/a	$56,000	Nothing added	n/a	$56,000
Technical Subcommittee Meetings	3 mtgs, 16 hrs/mtg (prepare & attend), 2 staff/mtg	n/a	$14,000	Nothing added	n/a	$14,000	Nothing added	n/a	$14,000
Project Management	6 yrs, 12 mon/yr, 10 hrs/mon	n/a	$109,000	Nothing added	n/a	$109,000	Nothing added	n/a	$109,000
Total: Data Collection, Components, Coordination, and Project Management			**$1,763,000**			**$3,113,000**			**$9,699,000**

Table C-2. Estimated Costs Costs During SPDSS Implementation for Water Rights Administration and Accounting Alternatives

Water Rights Administration and Accounting	Alternative 1 Description	Reference Section	Total Cost	Alternative 2 Description	Reference Section	Total Cost	Alternative 3 Description	Reference Section	Total Cost
Data Collection									
See Surface Water Tables	See Surface Water Tables			See Surface Water Tables			See Surface Water Tables		
Subtotal: Data Collection			***$0***			***$0***			***$0***
Components									
Display more than 1 day admin data	Alternative 1 effort	5.3.2.2	$5,000	Nothing added	n/a	$5,000	Nothing added	n/a	$5,000
Export provisional admin data	Alternative 1 effort	5.3.2.2	$5,000	Nothing added	n/a	$5,000	Nothing added	n/a	$5,000
Update to use new stream network data	Alternative 1 effort	5.3.2.2	$20,000	Nothing added	n/a	$20,000	Nothing added	n/a	$20,000
Create straight line diagrams	Alternative 1 effort	5.3.2.2	$20,000	Nothing added	n/a	$20,000	Nothing added	n/a	$20,000
Curtailment analysis (if have stream network)	Alternative 1 effort	5.3.2.2	$20,000	Nothing added	n/a	$20,000	Nothing added	n/a	$20,000
Enhance real-time data performance	Alternative 1 effort	5.3.2.2	$25,000	Nothing added	n/a	$25,000	Nothing added	n/a	$25,000
Enhance data sharing by use of XML technology	Replace current special project email submission process with	5.3.2.2	$25,000	Develop general data sharing procedure for SPDSS external	5.4.2.2	$45,000	Nothing added	n/a	$45,000
PCs for water commissioners	PCs for water commissioners	5.3.2.2	$50,000	Nothing added	n/a	$50,000	Nothing added	n/a	$50,000
Data entry tool for HydroBase	Alternative 1 effort	5.3.2.2	State	Nothing added	n/a	State	Nothing added	n/a	State
Historic statistics associated with real-time data	Alternative 1 effort	5.3.2.2	$15,000	Nothing added	n/a	$15,000	Nothing added	n/a	$15,000
Provide access to additional real-time data (snow, etc)	Alternative 1 effort	5.3.2.2	$10,000	Nothing added	n/a	$10,000	from other sites customizing	5.5.2.2	$30,000
Admin data entry (e.g., water user)	Not Included	n/a	$0	Admin data entry	5.4.2.2	$50,000	Nothing added	n/a	$50,000
Check admin data against decrees	Not Included	n/a	$0	Check admin data against decrees	5.4.2.2	$50,000	Nothing added	n/a	$50,000
Stream loss as an input to WIS	Not Included	n/a	$0	Stream loss as an input	5.4.2.2	$20,000	Nothing added	n/a	$20,000
Update displays for historic call data in HydroBase	Not Included	n/a	$0	Nothing added	n/a	$10,000	Nothing added	n/a	$10,000
Bulk analysis of real-time or historic data (e.g., analyze point flow for low-flow)	Not Included	n/a	$0	Analyze key structures.	5.4.2.2	$20,000	General procedure for real-time data.	5.5.2.2	$40,000
Provide access to agency forecast information	Not Included	n/a	$0	Nothing added	n/a	$0	Provide access to agency forecasts	5.5.2.2	$10,000
Access to scanned images of water commissioner field books (displays)	Not Included	n/a	$0	Nothing added	n/a	$0	Access to scanned images of water commissioner field books (displays)	5.5.2.2	$20,000
Automated call notification	Not Included	n/a	$0	Not Included	n/a	$0	Automated call notification	5.5.2.2	$20,000
SubTotal: Components			***$195,000***			***$365,000***			***$455,000***
Project management and coordination	see table C-6			see table C-6			see table C-6		
Technical Subcommittee Meetings	2 meetings/year	n/a	$17,280	4 meetings/year	n/a	$34,560	Nothing added	n/a	$34,560
Total: Data Collection, Components			**$212,280**			**$399,560**			**$489,560**

Table C-3. Estimated Costs During SPDSS Implementation for Groundwater Alternatives

Groundwater	Alternative 1 Description	Reference Section	Total Cost	Alternative 2 Description	Reference Section	Total Cost	Alternative 3 Description	Reference Section	Total Cost
Data Collection									
Groundwater Pumping									
Feasibility Study for pumping estimate	2 months LOE[1]	5.3.1.3.1	$40,000	nothing added	n/a	$40,000	3 months LOE	n/a	$55,000
Collect historic pumping data	2 months LOE	5.3.1.3.1	$41,000	4 months LOE	5.4.1.3.1	$81,000	6 months LOE	5.5.1.3.1	$115,000
Collect historic power data	Not included	n/a	$0	Not included	n/a	$0	150 high-capacity wells	5.5.1.3.1	$550,000
Perform well rating tests	Not included	n/a	$0	Not included	n/a	$0	150 high-capacity wells	5.5.1.3.1	$385,000
Geologic Structure and Aquifer Properties									
Collect aquifer configuration data	2 months LOE	5.3.1.3.2	$35,000	4 months LOE	5.4.1.3.2	$69,000	12 months LOE	5.5.1.3.2.	$207,000
Collect historic aquifer property data	2 month LOE	5.3.1.3.2	$35,000	3 months LOE	5.4.1.3.2	$52,000	5 months LOE	5.5.1.3.2.	$87,000
Workplan Development	1.5 months LOE	n/a	$30,000	2 months LOE	n/a	$40,000	3 months LOE	n/a	$60,000
Streambed conductance testing	40 sites + 5 paired staff gag	5.3.1.3.2	$133,000	nothing added	n/a	$133,000	80 sites + 10 paired staff gage	5.5.1.3.2.	$265,000
Construct alluvial wells + testing[2]	40 wells	5.3.1.3.2	$454,000	60 wells	5.4.1.3.2	$680,000	220 wells	5.5.1.3.2.	$2,493,000
Construct bedrock wells + testing[2]	4 wells	5.3.1.3.2	$321,000	6 wells	5.4.1.3.2	$477,000	25 wells	5.5.1.3.2.	$2,600,000
Conduct pumping tests (incl constr of obs wells)	4 tests (all in bedrock)	5.3.1.3.2	$260,000	8 tests (3 alluvial, 5 bedrock)	5.4.1.3.2	$402,000	16 tests (6 alluvial, 10 bedrock)	5.5.1.3.2.	$819,000
Groundwater Level Data									
Collect historic water level data	2 months LOE	5.3.1.3.3	$35,000	3 months LOE	5.4.1.3.3	$52,000	8 months LOE	5.5.1.3.3	$138,000
Collect water levels, once per year for 4 years	180 existing/40 new	5.3.1.3.3	$161,000	270 existing/60 new/10 convert	5.4.1.3.3	$300,000	270 existing/240 new/20 conve	5.5.1.3.3	$540,000
ID abandoned wells for conversion to monitoring	1 month/yr for 4 years	5.3.1.3.3	$60,000	1.5 months/yr for 4 years	5.4.1.3.3	$90,000	2 months/yr for 4 years	5.5.1.3.3	$120,000
Data Collection Subtotal			***$1,605,000***			***$2,416,000***			***$8,434,000***
Components									
Data Analysis & Mapping (using new and historical data)									
Pumping estimates	4 months LOE	5.3.2.3	$80,000	8 months LOE	5.4.2.3	$160,000	12 months LOE	5.5.2.3	$240,000
Aquifer properties	3 months LOE	5.3.2.3	$60,000	6 months LOE	5.4.2.3	$120,000	11 months LOE	5.5.2.3	$220,000
Aquifer mapping	6 months LOE	5.3.2.3	$120,000	11 months LOE	5.4.2.3	$220,000	20 months LOE	5.5.2.3	$400,000
Water level data analyses	3 months LOE	5.3.2.3	$60,000	7 months LOE	5.4.2.3	$140,000	10 months LOE	5.5.2.3	$200,000
Underflow estimates	1 month LOE	5.3.2.3	$20,000	3 months LOE	5.4.2.3	$60,000	5 months LOE	5.5.2.3	$100,000
Stream gain/loss estimates	2 month LOE	5.3.2.3	$40,000	4 months LOE	5.4.2.3	$80,000	6 months LOE	5.5.2.3	$120,000
Modeling									
Denver Basin and Overlying Alluvium region	Add alluvium, revise pumping, K's to SB-96-74	5.3.2.3	$464,000	Refine URFs, revise aquifer properties, add Stream	5.4.2.3	$672,000	Add low-K layers and direct gain/loss output	5.5.2.3	$986,000
Lower South Platte Alluvium region	Use SDF's & extend where nonexistent	5.3.2.3	$204,000	use Modflow & develop URFs	5.4.2.3	$496,000	Add direct gain/loss output	5.5.2.3	$641,000
North & South Park, Other Designated GW Basins	Not Included	n/a	$0	Not Included	n/a	$0	Modflow for 4 Basins	5.5.2.3	$1,100,000
Dynamic MODFLOW-StateMod linkage	Not Included	n/a	$0	Not Included	n/a	$0	Denver Basin, Lower South Pla	5.5.2.3	$750,000
Subtotal: Components			***$1,048,000***			***$1,948,000***			***$4,757,000***
Support Services									
User Coordination + Tech Subcommittee Mtgs	2 AC mtgs/year + 5 TSC	n/a	$60,000	Nothing added	n/a	$60,000	Nothing added	n/a	$60,000
Coordination with consultant team	7 yrs at 8 hrs/mo	n/a	$83,000	Nothing added	n/a	$83,000	Nothing added	n/a	$83,000
Project Mangement	7 yrs, 12 mon/yr, 10 hrs/mon (Cost Savings w SW)	n/a	$114,000	Nothing added	n/a	$114,000	Nothing added	n/a	$114,000
Total: Data Collection, Components, Coordination, and Project Management			**$2,910,000**			**$4,621,000**			**$13,448,000**

[1]LOE = Level of Effort

[2]Well costs include the cost of permitting and access

Table C-4. Estimated Costs During SPDSS Implementation for Consumptive Use Alternatives

Consumptive Use	Alternative 1 Description	Reference Section	Total Cost	Alternative 2 Description	Reference Section	Total Cost	Alternative 3 Description	Reference Section	Total Cost
Data Collection									
Provide Technical Guidance and Review for of GIS Land Classification and Attributes	Current Coverage Only	5.3.1.4	$30,000	Historic Coverages (3)	n/a	$40,000	Additional Historic Coverages	n/a	$80,000
Climate Data	Collect and fill NWCD data (40 stations) and evap data	5.3.1.4	$50,000	Collect and fill NCWCD, CoAgMet data (20 stations)	5.4.1.4	$65,000	No additional effort	n/a	$65,000
Agricultural Statistics Collection	CAS Collection/Digitization	5.3.1.4	$10,000	No additional effort	n/a	$10,000	No additional effort	n/a	$10,000
Provide Technical Guidance and Review for selection of Key Structures, Diversion Records, User Questions)	Alternative 1 SW effort	5.3.1.4	$30,000	Alternative 2 SW effort	n/a	$50,000	No additional effort	n/a	$50,000
Conveyance and application Efficiency Estimates	Estimate from User Interviews	5.3.1.4	$15,000	Efficiencies based on South Platte Info	5.4.1.4	$30,000	No additional effort	n/a	$30,000
Soil water holding capacity estimates	Based on STATSGO mapping	5.3.1.4	$15,000	No additional effort	n/a	$15,000	No additional effort	n/a	$15,000
Review previous estimates of pcu	Minimum Review	5.3.1.4	$5,000	Extensive Review	n/a	$15,000	No additional effort	n/a	$15,000
Collect Lysimeter Data	Not Included	n/a	$0	Collect/Summarize	5.4.1.4	$15,000	No additional effort	n/a	$15,000
Local calibrated and High Altitude crop coefficient data	Based on Existing Studies	n/a	$15,000	High altitude coefficient information	5.4.1.4	$20,000	High altitude adjustment methodologies	5.5.1.4	$25,000
NCWCD's Kimberly Penman information	Not Included	n/a	$0	Collect/Summarize	5.4.1.4	$5,000	No additional effort	n/a	$5,000
SPMAP Documentation	Not Included	n/a	$0	Review	5.4.1.4	$10,000	No additional effort	n/a	$10,000
Crop Yield Statistics	Not Included	n/a	$0	Not Included	n/a	$0	Collect/Summarize	5.5.1.4	$20,000
Published Information on precipitation recharge	Collect and summarize, provide estimates	5.3.1.4	$20,000	No additional effort	n/a	$20,000	No additional effort	n/a	$20,000
Published Information on gw use of native vegetation	Collect and summarize, provide estimates	5.3.1.4	$30,000	No additional effort	n/a	$30,000	No additional effort	n/a	$30,000
Municipal use or population estimates	Based on per capita CU	5.3.1.4	$10,000	Based on Data from cities	5.4.1.4	$30,000	No additional effort	n/a	$30,000
Outdoor Municipal use data	Not included	n/a	$0	Based on Existing Studies	5.4.1.4	$30,000	No additional effort	n/a	$30,000
Livestock counts	CAS Collection/Digitization	5.3.1.4	$5,000	No additional effort	n/a	$5,000	No additional effort	n/a	$5,000
Reservoir Evaporation	EOM contents, evap rates	5.3.1.4	$5,000	No additional effort	n/a	$5,000	No additional effort	n/a	$5,000
Wildlife area use data	Based on Existing Studies and User Information	5.3.1.4	$20,000	No additional effort	n/a	$20,000	Detailed Mapping	5.5.1.4	$50,000
Subtotal: Data Collection			***$260,000***			***$415,000***			***$510,000***
Components									
Estimate acreage using Ag. Statistics	Develop method and fill missing gaps in irrigated acreage (1 coverage)	5.3.2.4	$20,000	(3 coverages)	n/a	$20,000	No additional effort	n/a	$20,000
ID key weather stations/tie to irrigated acreage	40 Stations	5.3.2.4	$20,000	No additional effort	n/a	$20,000	No additional effort	n/a	$20,000
Blaney-Criddle Calibration	Existing calibrated parameters	5.3.2.4	$5,000	Calibration based on lysimeter and Kimberly Penman, High altitude studies	5.4.2.4	$25,000	No additional effort	n/a	$25,000
Blaney-Criddle historical analysis	Structures used in SW effort, StateCU existing capabilities	5.3.2.4	$25,000	Additional structures used in SW effort, StateCU enhanced features	5.4.2.4	$55,000	No additional effort	n/a	$55,000
Documentation	Historic Crop Cu Report	5.3.2.4	$20,000	Additional documentation consistent with additional modeling effort	5.4.2.4	$35,000	No additional effort	n/a	$35,000
StateCU enhancements	Simplified Use through GUI	5.3.2.4	$40,000	Enhancements include Kimberly-Penman method, other SPMAP CU features	5.4.2.4	$80,000	Enhancements include lake evaporation calcs, application depth nomographs, Penman-Monteith thru GUI	5.5.2.4	$120,000
Provide technical guidance and review of groundwater pumping based on shortages	Comparison to CU-based estimates	5.3.2.4	$20,000	No additional effort	n/a	$30,000	No additional effort	n/a	$30,000
Crop Yield Investigation	Not included	n/a	$0	Not included	n/a	$0	Investigate crop yeild relationships	5.5.2.4	$60,000
SPMAP input files/ analysis	Not included	n/a	$0	Develop SPMAP CU input files/ Run Historic CU	5.4.2.4	$30,000	No additional effort	n/a	$30,000
CU & Losses Summary (indoor and outdoor municipal, industrial, reservoir evap, livestock wildlife use)	Summary for SP, NP, Laramie basins	5.3.2.4	$30,000	No additional effort	n/a	$30,000	No additional effort	n/a	$30,000
Subtotal: Components			***$180,000***			***$325,000***			***$425,000***
User Coordination (CU and WB work = 4 out of 6 years)	8 Advisory Meetings, 4 TAC Meetings	n/a	$30,000	No additional effort	n/a	$30,000	No additional effort	n/a	$30,000
Coordination with consultant team	3 hrs/week for 4 years	n/a	$65,000	No additional effort	n/a	$65,000	No additional effort	n/a	$75,000
Project Management	Meetings/Progress Reports/Invoices 42 months	n/a	$60,000	No additional effort	n/a	$60,000	No additional effort	n/a	$60,000
Total: Data Collection, Components, Coordination, and Project Management			**$595,000**			**$895,000**			**$1,100,000**

Table C-5. Estimated Costs During SPDSS Implementation for Water Budget Alternatives									
Water Budget	**Alternative 1 Description**	**Reference Section**	**Total Cost**	**Alternative 2 Description**	**Reference Section**	**Total Cost**	**Alternative 3 Description**	**Reference Section**	**Total Cost**
Data Collection									
Review published reports on water budgets	Review minimum published to create initial water budget	5.3.1.5	$50,000	More extensive research into published documents	5.4.1.5	$70,000	No additional effort	n/a	$70,000
Subtotal: Data Collection			***$50,000***			***$70,000***			***$70,000***
Components									
Initial water budgets	Overall basins, South Platte, North Platte, and Laramie	5.3.2.5	$30,000	Overall basins plus sub-basins and ground water model areas	5.4.2.5	$70,000	No additional effort	n/a	$70,000
Intermediate water budgets (3 updates)	Overall basins, South Platte, North Platte, and Laramie	5.3.2.5	$10,000	Overall basins plus sub-basins and ground water model areas	5.4.2.5	$20,000	No additional effort	n/a	$20,000
Final water budgets	Overall basins, South Platte, North Platte, and Laramie	5.3.2.5	$50,000	Overall basins plus sub-basins and ground water model areas	5.4.2.5	$100,000	No additional effort	n/a	$100,000
Native Vegetation Comparisons	Compare StateWB native vegetation CU estimates to published	5.3.2.5	$25,000	Compare StateWB native vegetation CU estimates to published, on-going work	5.4.2.5	$30,000	No additional effort	n/a	$30,000
StateWB refinements	Not included	n/a	$0	StateWB Refinements identified during RGDSS and updated Documentation	5.4.2.5	$40,000	No additional effort	n/a	$40,000
Subtotal: Components			***$115,000***			***$260,000***			***$260,000***
Project Management/Coordination	Included in Table C-4			Included in Table C-4			Included in Table C-4		
Total: Data Collection, Components, Coordination, and Project Management			**$165,000**			**$330,000**			**$330,000**

Table C-6. Estimated Costs During SPDSS Implementation for System Integration

Data Centered System Integration	Alternative 1 Description	Reference Section	Total Cost	Alternative 2 Description	Reference Section	Total Cost	Alternative 3 Description	Reference Section	Total Cost
Data Collection									
No Data Collection for System Integration	No Data Collection for System Integration			No Data Collection for System Integration			No Data Collection for System Integration		
Subtotal: Data Collection			***$0***			***$0***			***$0***
Components									
Relational Databse Management System									
Store CWCB ISF database in HydroBase	Alternative 1 effort	5.3.2.6.1.	$40,000	Nothing added	n/a	$40,000	Nothing added	n/a	$40,000
Transfer of provisional data to historic archive	Alternative 1 effort	5.3.2.6.1.	$50,000	Nothing added	n/a	$50,000	Nothing added	n/a	$50,000
Data exchange enhancements using XML	Special projects	5.3.2.6.1.	$20,000	Nothing added	n/a	$20,000	Nothing added	n/a	$20,000
Match well permits with decrees	Using State/RGDSS/HDR Software	5.3.2.6.1.	$30,000	Nothing added	n/a	$30,000	Nothing added	n/a	$30,000
Store pumping records	Alternative 1 effort	5.3.2.6.1.	$5,000	Nothing added	n/a	$5,000	Nothing added	n/a	$5,000
Store other groundwater data	Alternative 1 effort	5.3.2.6.1.	$20,000	Nothing added	n/a	$20,000	Nothing added	n/a	$20,000
Eval and enhance storage of groundwater and well data (ensure relational integrity and coordination with State)	Alternative 1 effort	5.3.2.6.1.	$30,000	Nothing added	n/a	$30,000	Nothing added	n/a	$30,000
Store stream network data	Alternative 1 effort	5.3.2.6.1.	$15,000	Nothing added	n/a	$15,000	Nothing added	n/a	$15,000
Enhance storage of irrigated acreage data - add derived table for crop acreage by structure.	Alternative 1 effort	5.3.2.6.1.	$20,000	Nothing added	n/a	$20,000	Nothing added	n/a	$20,000
Store additional data for aug plans and exchanges	Not Included	n/a	$0	Store additional data for aug plans and exchanges	5.4.2.6.1	$20,000	Nothing added	n/a	$20,000
Store additional real-time data in HydroBase	Not Included	n/a	$0	Store additional real-time data in HydroBase	5.4.2.6.1	$10,000	Nothing added	n/a	$10,000
Store transit loss data	Not Included	n/a	$0	Store transit loss data	5.4.2.6.1	$5,000	Nothing added	n/a	$5,000
Store water commissioner field book images	Not Included	n/a	$0	Not Included	n/a	$0	Alternative 3 effort	5.5.2.6.1	$500,000
System Integration Tools									
Makenet	SPDSS enhancements	5.3.2.6.3	$20,000	Add a GUI to help users run the DMI and prompt users for input	5.4.2.6.3	$40,000	Nothing added	n/a	$40,000
Watright	SPDSS enhancements	5.3.2.6.3	$20,000	Add a GUI to help users run the DMI and prompt users for input	5.4.2.6.3	$55,000	Nothing added	n/a	$55,000
Demandts	SPDSS enhancements	5.3.2.6.3	$20,000	Add GUI or phase out and add the functionationalty to other DMIs	5.4.2.6.3	$40,000	Nothing added	n/a	$40,000
Tstool	SPDSS enhancements	5.3.2.6.3	$20,000	Add map interface.	5.4.2.6.3	$40,000	Nothing added	n/a	$40,000
PreCU	SPDSS enhancements	5.3.2.6.3	$20,000	Nothing added	n/a	$20,000	Nothing added	n/a	$20,000
StateGWP	SPDSS enhancements	5.3.2.6.3	$10,000	Upgrade ArcView, additional data/output viewing	5.4.2.6.3	$20,000	Nothing added	n/a	$20,000
Model database evaluation / prototype	Surface water	5.3.2.6.3	$200,000	Nothing Added	n/a	$200,000	Expand to groundwater and consumptive use model	5.5.2.6.3	$600,000
Integrate animation tool with model database	Real-time data displays	5.3.2.6.3	$25,000	Add historic data display	5.4.2.6.3	$50,000	Nothing added	n/a	$50,000

Table C-6. Estimated Costs During SPDSS Implementation for System Integration									
Data Centered System Integration	**Alternative 1**	**Reference**		**Alternative 2**	**Reference**		**Alternative 3**	**Reference**	
	Description	**Section**	**Total Cost**	**Description**	**Section**	**Total Cost**	**Description**	**Section**	**Total Cost**
Product Documentation and Access									
Upgrade servers	State already has	5.3.2.6.4	$0	Nothing added	n/a	$0	Nothing added	n/a	$0
State' web portal guidelines	Cost dependent on State's standards	5.3.2.6.4	$20,000	Nothing added	n/a	$20,000	Nothing added	n/a	$20,000
Additional documentation to clarify data reports	Alternative 1 effort	5.3.2.6.4	$10,000	Nothing added	n/a	$10,000	Nothing added	n/a	$10,000
Advanced web server features	Rework of web site to use Active Server Pages	5.3.2.6.4	$30,000	Nothing added	n/a	$30,000	Nothing added	n/a	$30,000
More graphics in web displays	Add static maps for lookups, basic hydrographs.	5.3.2.6.4	$40,000	Plus additional graph types.	5.4.2.6.4	$60,000	Plus IMS.	5.5.2.6.4	$100,000
Use web to provide summary of current conditions	Summary of real-time conditions.	5.3.2.6.4	$20,000	Plus summary of calls.	5.4.2.6.4	$40,000	Plus additional optimization of labeling, zooming.	5.5.2.6.4	$60,000
CDSS products on CD	Alternative 1 effort	5.3.2.6.4	$20,000	Nothing added	n/a	$20,000	Nothing added	n/a	$20,000
Maintenance and User Involvement									
Data flow diagram and documentation	Alternative 1 effort	5.3.2.7	$30,000	Nothing added	n/a	$30,000	Nothing added	n/a	$30,000
Stored procedures for all queries	Minimal	5.3.2.7	$50,000	Recommended	5.4.2.7	$150,000	Nothing added	n/a	$150,000
CDSS maintenance (6 Years)	Alternative 1 effort	5.3.2.7	$600,000	Nothing added	n/a	$600,000	Nothing added	n/a	$600,000
Infrastructure upgrade (e.g., Windows 2000)	Alternative 1 effort	5.3.2.7	$100,000	Nothing added	n/a	$100,000	Nothing added	n/a	$100,000
Subtotal: Components			***$1,485,000***			***$1,790,000***			***$2,750,000***
User Coordination	12 Advisory Meetings, 8 TAC Meetings	n/a	$41,000	Nothing added	n/a	$41,000	Nothing added	n/a	$41,000
Coordination with Consultant Team	3 hrs/week	n/a	$95,000	Nothing added	n/a	$95,000	Nothing added	n/a	$95,000
RTi Project Management	Meetings/Progress Reports/Invoices	n/a	$90,000	Nothing added	n/a	$90,000	Nothing added	n/a	$90,000
Total: Data Collection, Components, Coordination, and Project Management			**$1,711,000**			**$2,016,000**			**$2,976,000**

Table C-7. Estimated Costs During SPDSS Implementation for Land Use, Irrigation Service Areas and Geospatial Data Alternatives

GIS and Spatial Database Management	Alternative 1	Reference		Alternative 2	Reference		Alternative 3	Reference	
	Description	Section	Total Cost	Description	Section	Total Cost	Description	Section	Total Cost
Data Collection									
Mapping of current land use	Irrigated areas, crop types using satellite imagery and GIS	5.3.1.6	$195,000	Nothing added	n/a	$195,000	Additional field work for more accurate mapping	5.5.1.6	$240,000
Orthophoto and satellite image base map development	Digital, seamless image base	5.3.1.6	$180,000	Nothing added	n/a	$180,000	Substitute high resolution (1m) IKONOS imagery for most irrigated areas (6000km2)	5.5.1.6	$450,000
Mapping wells, irrigation systems, irrigation service areas	Utilize GIS analysis with input from State, water users	5.3.1.6	$515,000	Nothing added	n/a	$515,000	Nothing added	n/a	$515,000
Survey wells with GPS (Div 1), additional field work to refine service areas	Not included	n/a	$0	Div 1 well location program, 3 FTE's for 2 years	5.4.1.6	$374,000	Div 1 well location program plus mapping and field work to specify well service areas	5.5.1.6	$834,000
Mapping historic land use of 1950s, 1970s, late-1980s	Use ag statistics for estimating historic consumptive use	5.3.1.6	$10,000	Use satellite image analysis and ag statistics	5.4.1.6	$186,000	More detailed analysis on aerial photographs from 1950s and 1970s	5.5.1.6	$264,000
GIS database development	Full GIS database for use throughout SPDSS	5.3.1.6	$102,000	Nothing added	n/a	$102,000	Locate all key diversion structures (500) with GPS	5.5.1.6	$186,000
Subtotal: GIS and Related Data Collection			***$1,002,000***			***$1,552,000***			***$2,489,000***
Components									
Spatial Database Mangement System									
Enhanced interface between Hydrobase and GIS data	Enhance locational attributes	5.3.2.6.2	$44,000	Nothing added	n/a	$44,000	Nothing added	n/a	$44,000
GIS network of surface water hydrology, structures and water distribution system	For key structures (500), QA/QC locations, hydro network	5.3.2.6.2	$61,000	Develop to include 1500 structures	5.4.2.6.2	$94,000	Nothing added	n/a	$94,000
Develop tools for full web-enablement of spatial data	Not Included	n/a	$0	Not Included	n/a	$0	Map Server, includes software and hardware, fully developed map interfaces and options	5.5.2.6.2	$109,000
Mapping, visualization and presentation tools	Not Included	n/a	$0	Develop templates and techniques for maps, 3-D, animations and other presentations	5.4.2.6.2	$45,000	Develop applications and presentations for State and other users	5.5.2.6.2	$86,000
GIS support and data maintenance (4 years)	Update GIS databases, develop applications, incorporate results	5.3.2.6.2	$55,000	Nothing added	n/a	$55,000	Additional GIS databases and applications	5.5.2.6.2	$255,000
Mapping, visualization, presentation and Internet mapping tools maintenance (4 years)	Not Included	n/a	$0	Support mapping and visualization applications, incorporate new products	5.4.2.6.2	$27,000	ArcIMS applications, databases, edit/updates, incorporate new products	5.5.2.6.2	$137,000
Subtotal: Components			***$160,000***			***$265,000***			***$725,000***
User Coordination	8 Advisory Meetings, 4 TAC Meetings	n/a	$34,500	Nothing added	n/a	$34,500	Nothing added	n/a	$34,500
Coordination with Consultant Team	Av. 3 hr/week, 4 years	n/a	$74,000	Nothing added	n/a	$74,000	Nothing added	n/a	$74,000
RTi Project Management	Meetings/Progress Reports/Invoices	n/a	$54,000	Nothing added	n/a	$54,000	Nothing added	n/a	$54,000
Total: Data Collection, Components, Coordination, and Project Management			**$1,324,500**			**$1,979,500**			**$3,376,500**

Table C-8. Estimated Capital Costs for Groundwater Alternatives in Response to SB 96-74

Groundwater	Alternative 1		Alternative 2		Alternative 3	
	Description	Response to SB-74 Total	Description	Response to SB-74 Total	Description	Response to SB-74 Total
Data Collection						
Groundwater Pumping						
FS for pumping estimate	1.5 months LOE	$30,000	Nothing added	$30,000	2 months LOE	$40,000
Collect historic pumping data	1.5 months LOE	$31,000	3 months LOE	$61,000	Nothing added	$0
Collect historic power data	Not included	$0		$0	2 yrs LOE	$275,000
Perform well rating tests	Not included	$0		$0	1 yrs LOE	$192,500
Geologic Structure and Aquifer Properties						
Collect aquifer configuration data	1.5 months LOE	$26,000	Nothing added	$26,000	2 months LOE	$34,500
Collect historic aquifer property data	1.5 months LOE	$26,000	Nothing added	$26,000	2 months LOE	$34,800
Workplan Development	1.5 months LOE	$30,000	Nothing added	$30,000	2 months LOE	$40,000
Streambed conductance testing	30 sites	$100,000	30 sites	$100,000	60 sites	$265,000
Construct alluvial wells + testing	30 wells	$341,000	45 wells	$510,000	145 wells	$1,643,000
Construct bedrock wells + testing	4 wells	$321,000	6 wells	$477,000	25 wells	$2,600,000
Conduct pumping tests (includes constr of obs well)	4 tests (all in bedrock)	$260,000	6 tests (1 alluvial, 5 bedrock)	$351,000	13 tests (3 alluvial, 10 bedrock)	$741,000
Groundwater Level Data						
Collect historic water level data	1.5 months LOE	$26,000	Nothing added	$26,000	2 months LOE	$34,500
Collect water levels, once per year for 4 years	136 existing/34 new	$125,000	230 existing/51 new/9 converted	$264,000	240 existing/170 new/10 converted	$432,000
ID abandoned wells for conversion to monitoring wells	1 month/yr for 4 years	$60,000	Nothing added	$60,000	Nothing added	$60,000
Stream Gain/Loss Studies						
Workplan development	0.5 month LOE	$9,000	0.5 month LOE	$9,000	0.5 month LOE	$9,000
Point-Flow stream gaging program	25 sites, 2 times/year for 2 years	$218,000	25 sites, 2 times/year for 2 years	$218,000	25 sites, 2 times/year for 2 years	$218,000
Data Collection Subtotal		***$1,603,000***		***$2,188,000***		***$6,619,300***
Components						
Data Analysis & Mapping						
Pumping estimates	4 months LOE	$80,000	Nothing added	$80,000	14 months LOE	$98,000
Aquifer properties	2.5 months LOE	$50,000	3.5 months LOE	$70,000	20 months LOE	$220,000
Aquifer mapping	5 months LOE	$100,000	6 months LOE	$120,000	30 months LOE	$300,000
Water level data analyses	2.5 months LOE	$50,000	4.5 months LOE	$90,000	10 months LOE	$100,000
Underflow estimates at locations w/out transects	1 month LOE	$20,000	Nothing added	$20,000	5 months LOE	$53,000
Stream gain/loss estimates	2 month LOE	$40,000	Nothing added	$40,000	6 months LOE	$60,000
Modeling						
Denver Basin region	Add alluvium, revise pumping, K's to SB-96-74 MODFLOW	$464,000	refine URFs, revise aquifer properties, add Stream package	$672,000	add low-K layers and direct gain/loss output	$800,000
Lower South Platte region	Use SDF's & extend where nonexistent	$0	Use MODFLOW & develop URFs	$0	Alternative 2 plus add direct gain/loss output	$0
North and South Park and other Designated GW Basins regions	Not Inluded	$0	Spreadsheet models	$0	Modflow for 4 Basins	$0
Dynamic MODFLOW-StateMod linkage	Not Inluded	$0	Not Included	$0	Denver Basin, Lower South Platte	$600,000
StateMod refinements, development, & calibration	Not Inluded	$0	Not Inluded	$0	Integration of point-flow gaging program over Denver Basin alluvium	$274,000
Subtotal: Components		***$804,000***		***$1,092,000***		***$2,505,000***
Support Services						
User Coordination + Tech Subcommittee Mtgs	2 AC mtgs/year + 5 TSC mtgs	$60,000	60% of total	$36,000	Nothing added	$36,000
Coordination with Consultant Team	7 yrs at 8 hrs/mo	$83,000	60% of total	$49,800	Nothing added	$49,800
Project Mangement	7 yrs, 12 mon/yr, 10 hrs/mon (Cost Savings w SW)	$114,000	60% of total	$68,400	65% of total	$74,100
Total: Data Collection, Components, Coordination, and Project Management		**$2,664,000**		**$3,434,200**		**$9,284,200**

Table C-9. Estimated Capital Costs During SPDSS Implementation for User Involvement and Training Alternatives

Water Budget	Alternative 1 Description	Reference Section	Total Cost	Alternative 2 Description	Reference Section	Total Cost	Alternative 3 Description	Reference Section	Total Cost
Data Collection									
Not Applicable	Not Applicable			Not Applicable			Not Applicable		
Subtotal: Data Collection			***$0***			***$0***			***$0***
Components									
User Involvement									
Create and Maintain database of contacts of users	40 hrs to create, 2 hr/mo to maintain	5.3.2.8	$17,000	Nothing added	n/a	$17,000	Nothing added	n/a	$17,000
Quarterly newsletter	16 hrs/letter, 4X/year (does not include postage)	5.3.2.8	$46,000	Nothing added	n/a	$46,000	Nothing added	n/a	$46,000
SPDSS Advisory Committee Meetings	found in individual subs costs	5.3.2.8	$0	Nothing added	n/a	$0	Nothing added	n/a	$0
SPDSS Core Group meetings	included in project mgmt costs	5.3.2.8	$0	Nothing added	n/a	$0	Nothing added	n/a	$0
User Group meetings	4X/year, 16hr/mtg, 4 staff/mtg	5.3.2.8	$70,000	Nothing added	n/a	$70,000	Nothing added	n/a	$70,000
Outreach program	Not included	n/a	$0	Not included	n/a	$0	Grassroots communication	5.5.2.8	$180,000
Training									
Online web-based training modules for HydroBase and StateView	development and implementation	5.3.2.9	$40,000	Nothing added	n/a	$40,000	Nothing added	n/a	$40,000
Online web-based training modules for CWRAT	development and implementation	5.3.2.9	$20,000	Nothing added	n/a	$20,000	Nothing added	n/a	$20,000
Online web-based training modules for GIS tools (specific to CDSS)	development and implementation	5.3.2.9	$20,000	Nothing added	n/a	$20,000	Nothing added	n/a	$20,000
Online web-based training modules for StateMod and StateMod GUI	development and implementation	5.3.2.9	$40,000	Nothing added	n/a	$40,000	Nothing added	n/a	$40,000
Online web-based training modules for StateCU	development and implementation	5.3.2.9	$40,000	Nothing added	n/a	$40,000	Nothing added	n/a	$40,000
Online web-based training modules for GW Models	development and implementation	5.3.2.9	$40,000	Nothing added	n/a	$40,000	Nothing added	n/a	$40,000
Half-Day Training sessions	Not included	n/a	$0	Not included	n/a	$0	4X/year	5.5.2.9	$69,000
Subtotal: Components			***$333,000***			***$333,000***			***$582,000***
Total: Data Collection & Components			**$333,000**			**$333,000**			**$582,000**

APPENDIX D

COMMENTS TO DRAFT FEASIBILITY STUDY (SUBMITTED JUNE 2001) AND RESPONSE TO COMMENTS

COLORADO R VER WATER
CONSERVATION DISTRICT

Protecting Western Colorado Water Since 1937

August 30, 2001

Mr. Ray Bennett
Division of Water Resources
1313 Sherman Street, Room 818
Denver, CO 80203

Dear Ray

The Colorado River Water Conservation District is providing the following comments on the Draft South Platte Decision Support System Feasibility Study (SPDSS) dated June 1, 2001. In general, the River District agrees with the overall direction and approach the CWCB and the State are taking in the development of the SPDSS. It is our feeling that the selected alternative, while somewhat expensive, will provide the water users and the State with a useful and robust tool for water resource administration and planning. The following provides our general comments on the Draft Feasibility Study.

Of fundamental importance to the River District is the ability of the tool and the data to accurately define historical "baseline" conditions in the South Platte Basin. For us, this means conditions of flow in the South Platte River prior to the introduction of transmountain diversions (TMDs) from the Colorado River Basin to the South Platte Basin. An accurate baseline is necessary for understanding basic questions regarding water use and reuse in the South Platte. We encourage the study team to spend the time and resources necessary to adequately address this primary issue.

It is our desire that the SPDSS have the ability to track transmountain water from the source to the beneficial use including successive re-uses. The data and tools developed under the SPDSS must be able to quantify the initial use of TMDs and the amount and timing of the reusable return flows. We realize that there are many administrative and contractual details involved with the source-to-use issue and that the SPDSS may simply not have the resolution to define all of them. However, we believe that the basic hydrologic and administrative data are available to sufficiently define the important aspects of source-to-use with respect to the TMDs.

There may be opportunities to build on the work of the South Metro Water Supply Study investigations regarding updating of the SB-74 groundwater model of the Denver Basin aquifers.

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We encourage the SPDSS study team to maintain communications with this and other outside organizations to coordinate overlapping work efforts to the extent practicable.

Thank you for the opportunity to comment on the draft study. The District appreciates being involved in the cooperative effort to develop and maintain these important water resource tools for the State of Colorado. If you have any questions please feel free to call.

Sincerely,

James F. Pearce, P.E.
Sr. Water Resources Specialist

JFP/ldp
cc: Leo Eisel

Bennett, Ray

From: GASP [gasp@flci.net]

Sent: Tuesday, August 28, 2001 9:01 AM

To: Ray.bennett@state.co.us

Subject: SPDSS Feasibility Study

Ray Bennett:
I have examined the current form of the South Platte Decision Support System feasibility study and have the following comments at this time. I hope that they are useful.

Regarding the need for river flow monitoring, I would like to point out that several structures currently exist that may be used to determine streamflow rather than constructing new ones. Currently, there are six inflatable diversion structures and one concrete roll-over structure spaced from Kersey to Crook. I believe that minor modifications or monitoring devices may allow each of these to become streamflow gages. Each of them require that all river flows pan over their crests.

I do not believe that they will be useful in all river stage conditions, but in those conditions where we normally operate they could work. It is my hope that the consultants look into this to either confirm or reject my thinking.

If this idea is feasible, there could be considerable cost savings that could be used to strengthen other components of the SPDSS.

would be happy to help explore this idea more fully if you think it has merit.

Jack Odor

Memorandum

Ray Bennett

Jack Byers

From: Brian J. Ahrens

Date: June 25, 2001

SPDSS Feasibility Study Draft Report

This memorandum includes the highlights of my initial thoughts after reviewing the subject report. My effort concentrated on groundwater aspects, specifically the SB-74 groundwater model and recommendations of the Technical Support Committee.

MAIN DEFICIENCIES

1 The major criticism of the SB-74 groundwater model was the manner in which the stream and alluvium was modeled. The river package was used to model the alluvium therefore the "streambed" conductance term represented the interface between the alluvium and the bedrock aquifers. This conceptualization appears to have been lost by the authors (or not fully understood) based on their discussion regarding gathering data for the streambed conductance through monitoring wells (Section 3.9.3.4) and the proposed drilling, pumping tests, and analysis of the alluvial-bedrock interface (Section 3.9.3.5, see comments below). In the proposed alternative, conductance for both of the interfaces, the stream-alluvial and the alluvial-bedrock, will be required in the groundwater model. Analysis of the alluvial-bedrock interface will require deeper and more complex (nested piezometers) wells and the cost for drilling and testing will be expensive.

2 A DMI or GUI to replace the current AUG3 program is not discussed. The AUG3 program (Dewayne Ware) is essentially a pre- and post-processor for the SB-5 Denver Basin models which allows Kevin Rein and his team (or others) to input a proposed well(s) to computed stream depletions to all stream affected by the well pumping. The post-processor then creates a map of the well and affected streams. It also creates a graph of the stream depletion (q/Q vs Time) for each stream along with a total depletion curve. The output from this program is cryptic and difficult to manage and does not always meet the needs of DWR. This program needs to be enhanced or modified and ultimately use the output from the enhanced Denver Basin groundwater model proposed in alternative #2.

DETAILED EDITS

3.7.2.2 Period of Record.

The well data available in the well permit database can in fact include time series data. The reported water levels after the well is drilled and tested can be used, with caution, to supplement or at least verify water levels at a specific points in time or changes in water levels through time.

Historic water levels are difficult to construct but are very useful in model calibration. This data should therefore not be ignored entirely.

3.8.3.3 Task 3-Collect and Analyze Existing Power Records.

Is the authority for the State Engineer to obtain power records directly from the power suppliers (associated with well pumping), limited only to the Arkansas River Basin or does his authority extend to the rest of the state? I'm not sure, but the significant effort to receive written authority from each well owner to obtain the records could be reduced. This effort is included in Alternative #3.

3.8.3.4 Task 4-Obtain Well Rating Curves.

Obtaining well rating curves would also require documenting and testing compound and complex systems because the plumbing in these systems can significantly effect the "wire-to-water" efficiency (the power conversion coefficient, PCC).

3.9.3.5 Task 5-Conduct Aquifer Pumping Tests.

The pumping tests proposed would be inadequate to analyze the alluvial-bedrock interface based on the length (7 days) and location of the tests. The tests should be conducted in areas of low activity in order to isolate and measure the impact of the test pumping. Ideally, the test site would have similar aquifer characteristics as the areas of highest pumping. If the tests are conducted in areas of highest pumping, there will be too much "noise" in the measurements and the test pumping will be difficult or impossible to isolate. Also, if the tests are not of sufficient length (i.e., extended to 30 days or more) the impact of the test pumping may not ever be observed. These considerations will greatly affect the costs associated with this task.

CCWCD

central colorado water
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3209 West 28th Street
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August 30, 2001

Mr. Ray Bennett
Division of Water Resources
1313 Sherman Street, Room 818
Denver, CO 80203

Re: Review and Comment on Draft SPDSS Feasibility Study

Dear Ray:

Thank your for the opportunity to review and comment on the above referenced document. I noticed that specific studies in Box Elder and Beebe Seep are not included in any of the three alternatives. In Central's 2001 Substitute Supply Plan approval letter Mr. Simpson has mandated that Central continue documenting depletions in the Box Elder and Beebe Seep tributaries and the impact these tributary depletions have on the South Platte River. Central indicated to several SPDSS consultants that this effort should be a major component in the SPDSS effort. Wells in the Box Elder and Beebe Seep have an estimated in-basin depletion of 80,000 to 100,000 acre-feet. These wells provide sole source and supplemental irrigation water to over 100,000 acres in both basins. Central provides augmentation coverage for approximately 1/3 of the 4000 irrigation wells from Denver to Julesburg. The amount of water and the issues involving the depletions from these tributaries is monumental in terms of dollars and water supply for Central.

I will review the draft document and alternatives with the Board of Directors at the September Board meeting. If the Board has any additional concerns, I will provide them to you at that time.

Sincerely,

Forrest Leaf, P.E.
District Engineer

D:\SPDSS\Bennett Comment Letter.wpd

MEMORANDUM

January 25, 2001 (modified July 5, 2001)

TO: Ray Bennett

FROM: Jim Hall

SUBJECT: Well Location Program

As a follow up to our conversation, Dick and I have discussed accelerating the well location program to identify the location of all non-exempt alluvial ground water wells within the South Platte basin and its tributaries excluding designated basins. This work involves doing background research of decrees, well permits and augmentation; GPS'ing and tagging wells; entering GPS and other data into a data base; and finally notifying and following up with well owners who have problems associated with their wells (location discrepancies, no augmentation etc...). We do not presently determine what lands each well irrigates in our effort. From our experience, we know that task would more than double the workload. These estimates also do not include any purchases of satellite imagery that assist us in locating possible active wells as we assume we will be able to use imagery obtained for the DSS project.

We believe we have to investigate 13,000 well locations (though some may no longer be in existence) in the South Platte alluvium. . We have located approximately 3000 wells to date. Thus, we have approximately 10,000 wells to investigate. We presently are able to locate approximately 800-1000 wells per year with available staffing. We are funded for six person months from the ground water management fund and pull together resources from other places for an additional 4-5 person months. At this rate, we estimate we are still over 10 years from finishing our well location program.

With the resources presently dedicated and the following additional resources described, we believe we could investigate all wells by June 30, 2004. Two of the additional FTE's could be at the Assistant level costing approximately $2300 per month including benefits. We would suggest the third FTE be at the Tech II or III level which would cost approximately $5143 including benefits. The Tech II or III is needed to lead the project. This person must have excellent people skills, be very organized and have extensive knowledge regarding the South Platte Rules and Regulations, well permit applications, plugging and abandoning wells, enforcement actions and Division 1 computer applications and data. This person would be responsible for pursuing illegal wells, writing the letters that are needed and meeting with users if necessary. In addition the individual would coordinate, train and quality check all fieldwork.

We ~~believe~~ we could finish the well testing program by June, 2004 and we estimate the total DSS cost to be $374,000 and total cost to be $503,000 as delineated in the attached table. We estimate first year costs ~~to be $48~~,000 ($28,000 salaries and $20,000 gas etc...) The DSS cost does not include enforcement efforts and is dependent upon continuing to receive some monies from the Ground Water Management Fund. I would mention that we will probably seek to obtain additional funding from the GWMF for enforcement activities.

Please feel free if you have comments or questions concerning the information in this memorandum

Cc: Dick Stenzel

Well Location Program Costs
January 25, 2001 (Modified July 5, 2001)

Item	Cost Detail	Total Cost	DSS Cost	Total Cost
1 New Eng. Asst. (7-2001 to 6-2002)	12 mo. x 1 people x $2300/mo.	$28,000	$28,000	
Existing Eng. Asst. (7-2001 to 6-2002)	10 mo. x $2300/mo	$23,000		GWMF Cost
2 New Eng. Asst. (7-2002 to 6-2003)	12 mo. x 2 people x $2461/mo. (7% incr)	$59,000	$59,000	
Existing Eng. Asst. (7-2002 to 6-2003)	10 mo. x $2461 (7% increase)	$25,000		GWMF Cost
New Eng. Tech (7-2002 to 6-2003)	12 mo. x $5503/mo. (7% increase)	$66,000	$44,000	2/3 management DSS cost, 1/3 enforcement
2 New Eng. Asst. (7-2003 to 6-2004)	12 mo. x 2 people x $2633/mo. (7% incr)	$63,000	$63,000	
Existing Eng. Asst. (7-2003 to 6-2004)	10 mo. x $2633/mo (7% increase)	$26,000		GWMF Cost
New Eng. Tech (7-2003 to 6-2004)	12 mo. x $5888/mo. (7% increase)	$71,000	$48,000	2/3 management DSS cost, 1/3 enforcement
Office Space		$12,000	$12,000	
Gas		$74,000	$74,000	
Food and Lodging	when measuring wells in Dist. 64	$36,000	$36,000	
Supplies (including mailings)		$20,000	$10,000	$10,000 Enforcement
Legal Services	Unknown, funds out of what we pay AG annually			
Total		**$503,000**	**$374,000**	

STATE OF COLORADO

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Division of Water Resources
Department of Natural Resources

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Bill Owens
Governor

Greg E. Walcher
Executive Director

Hal D. Simpson, P.E.
State Engineer

June 20, 2001

MEMORANDUM

Jack Byers and Ray Bennett

FROM: George D. VanSlyke, Chief, Geotechnical Services

SUBJECT: Review of Draft Report, South Platte Decision Support System, Feasibility Study.

I have reviewed the draft report for the areas concerning ground water. In general the report is fairly poor. There are inaccurate statements and it is evident that the consultants did not fully review the information that was supplied to them. My comments are listed but page and section.

Section	***Comments or Corrections***
3.7	The last sentence should be changed to read: "There are well completion and ***drillers*** well logs available for ***most*** well permit records."
3.7.1	A paragraph should be added explaining that the SEO, Geotechnical Services Branch maintains a database of Geophysical well log data for the ***entire*** state. These data include information on the aquifer boundaries; sand thickness, location, and owner, permit number, depth, water level, and types of logs available. In particular, a database of over 4000 logs is maintained for the Denver Basin aquifers.
3.9.1	The third paragraph incorrectly states that the geophysical log database is derived from oil and gas logs only. In reality, the database contains information from a variety of source but primarily from water wells. Something should be added that new data on the shallow aquifers has been published by the USGS as part of the Front Range Infrastructure Initiative. This is a valuable study and resource that is not referenced.
3.9.2.1	Some of the reports listed, such as the 1981 maps and reports have been superceded by newer information. In general the 1981 reports are outdated and contain many inaccuracies. The consultant did not reference the 1986 Denver Basin Rules or

the Denver Basin Atlas Series (DBA-1 through –4). These were provided and contain the most accurate data on the structure of the Denver Basin. Also, additional mapping of the Western margin and the Boulder-Weld Coal Field area (this report, HA-742, is referenced) has resulted in refinement of the structure and input data for the SB 96-74 model. None of this is considered.

NONE — Some thing needs to be added about the ongoing studies to determine aquifer properties such as specific yield. Major studies in the Castle Pines area by Robson in 1993 and in the Kiowa Core Hole by Lapey in 2000 have significant bearing on the quantity of water stored in the aquifers.

3.9.2.1.1 — The consultant has completely ignored the existence of the SB-5 data.

3.9.2.1.2 — Period of record is very important when considering how the definition of the aquifer system has evolved over time. Specifically the bedrock aquifers as defined in 1981 (the reference that the consultant likes to site), were extensively revised in the 1985 SB-5 study and have been further refined in the 1998 study. Boundaries, thickness and aquifer properties are an evolving thing and this should be noted.

3.9.2.1.3 — I believe that the completeness of record would be greatly enhanced if the consultant had at least looked at the data available.

3.9.2.1.4 — The consultant was given a copy of CWCB Colorado Ground Water Circular 11, Pump Tests in Colorado, 1965. This reference Is not listed and it is inferred that no actual field derived data on aquifer properties exist. In reality, this is the primary source of aquifer pump test data.

3.9.2.2 — Major references such as Smith and Scheider 1964, Ground Water Resources of the South Platte River Basin, USGS Water Supply Report 1658 have not been included. There are a series of Water Supply Reports covering the Basin that were apparently not looked at. I would suggest that the consultant return to the library before making statements concerning lack of data and the reliability of data looked at.

3.9.2.4 — The USGS report referenced is by Robson and Graham not Robson and Glenn.

3.9.3.1 — Almost all historical data is present in our library, therefore, it is neither **difficult** nor **cumbersome** to obtain.

3.9.3.4 — It would be necessary to drill bedrock monitoring holes to depths exceeding 1200 feet in order to obtain the information they suggest. I would estimate that there would have to be two 2500

foot deep wells The response of the deeper aquifers when confined by many hundreds of feet of overlying sediments is very important when trying to determine actual aquifer characteristics. Looking at the aquifers close to the outcrop leads to false characterization.
As an example of this, one only needs to examine the specific yield data obtained from deep core holes as opposed to those obtained at the outcrop.

3-29 3.9.3.4 What is the value of installing continuous recorders?

3.9.3.5 What are the implications of conducting pump tests in areas where the aquifer may change from confined to unconfined over the period of the test or may change within several years? Will pumping tests be the best way to obtain interconnection data? We have been working with someone who believes that down-hole temperature data may be more reliable as an indicator. It would appear that the consultant has not considered newer methods for obtaining data. The same could be said for the proposal for determining alluvial-bedrock interface data.

3.10.1 Table B-8, Appendix B is referenced as a source of existing data. However, the table does not summarize what is available or the period of record. I suggest that the Table B-8 be revised to actually list references and the period covered. As presented, no one could figure out what is available.

3.10.2.1.1 The nested wells described are production wells and are not instrumented to determine the flow between aquifers. This would take very sophisticated instrumentation before this could be done. In addition, these wells are parts of municipal systems and It is doubtful that they could be used for this purpose.

3.10.2.1.1 Water level data is available for 30 wells in the Upper Big Sandy basin. The report says that no data are available. Copies of the water level report for the basin was supplied to the consultant.

3.10.2.1.2 Water level data from the 1930's and 1940's are available in the Lost Creek and Kiowa-Bijou basins. South Platte data back to the 1950's are also available and have been identified to the consultant.

3.10.2.3.1 This is wrong. We monitor wells in Camp Creek and do not in Crow Creek.

3.10.2.3.2 Again basins are reversed.

3.10.2.3.3 Again basins are reversed.

3.10.2.3.4 Again basins are reversed.

3-34	3.10.2.4	Reference is Robson and Graham not Glenn
	3.10.3	No mention is made of the necessity for accurate field mapping of the extent of both alluvial and bedrock aquifers. There is no money budgeted for this task. I believe that a geologist should have been included in the planning of the report.
	3.10.3.4	Again, mapping is an integral part of this task that has been omitted.
	3.10.3.5	I assume that bore hole ***geophysical logging*** is necessary but not included. This could be a considerable cost for deep bedrock wells.
	3.18	The list of references is grossly incomplete.
	Table 3-1	Needs revision based on above
	Figure 3.1	Map omits water level points in North Park.
5-5	5.3.1.2.2	Item 1 and 2 are done and we have it.
	5.3.1.2.3	Item 1 is complete.

The same Section 5 comments hold for each alternative

B-23	Table B-7	Table is incomplete and needs revision. I would say that at least three times as many references are available in our library alone.
APPENDIX C		You cannot read Table C-1
	Table C-3	No fieldwork component is included.

August 30, 2001 letter from James Pearce, Senior Water Resources Specialist with the Colorado River Water Conservation District (CRWCD) providing comments on the Draft SPDSS Feasibility Study

2nd paragraph – Response

The State concurs with the CRWCD that an accurate definition of historic flows and uses are fundamental and critical to the value of the surface water planning and administration components of the SPDSS. More than 1 million dollars is expected to be expended during SPDSS development of the surface water planning model to accurately define the historic flow and use environment (includes data collection, preparation of model input data, generation of baseflows and calibration). Considerable resources are to be devoted to understanding not only the historic setting of in-basin uses but also transmountain imports and uses. Historical and current water use scenarios are envisioned that will allow a user to better understand the interrelationships between the water supplies and demands, including the effect of transmountain diversions on streamflows and water use in the basin. The SPDSS planned ability of a user to change the amount of importation or use of transmountain diversions is critical to understanding water resources of the South Platte River Basin.

3rd paragraph – Response

Present capabilities in the surface water planning and administration tools allow a modeler to track transmountain water from the source to the beneficial uses. Other capabilities allow for tracking exchanges of water as transmountain water is reused. We believe sufficient resources will be allocated to the development of the SPDSS surface water model to allow consideration of the primary aspects of delivery and use of the transmountain water. We agree that there will be many administrative and contractual details that cannot be effectively considered in a basin-wide model, but that the basic hydrologic and administrative data are important to consider. Consideration of transmountain diversions and use, including tracking the use of transmountain diversions, is believed critical to developing tools that reasonably reflect the water supplies and demands of the South Platte River Basin.

4th paragraph – Response

The recommended Alternative 2 includes a User Involvement component, including meetings and support to users of the SPDSS, as described in Sections 5.3.2.8 and 5.4.2.8. The State will maintain communications with all interested users, and opportunities to build on the South Metro Water Supply Study, as well as other relevant work being concurrently conducted within the basin, will definitely be taken advantage of.

August 28, 2001 letter from Jack Odor of the Groundwater Appropriators of the South Platte (GASP) providing comments on the Draft SPDSS Feasibility Study

Response

The suggestion to consider the use of existing diversion structures on the South Platte River to measure streamflows has been incorporated into the Feasibility Study. Due to overall cost limitations for the SPDSS, rated control structure gages are no longer included in the recommended Alternative 2. However, under Alternative 3, the utilization of existing structures will be investigated as part of the Conceptual Design Investigation, as described in Section 3.2.3.3. The State is aware of structures such as the Obermeyer gate weir at the Harmony Ditch that operates with a bladder to adjust the height of the weir crest. This type of system might have some promise for a controlled gaging section. These could be set to automatically adjust based on the flow in the river and should be ratable. According the manufacturer, the gates are rated and accurately measure flow, including under high tailwater conditions.

Response to Comments on June 11, 2001 draft SPDSS Feasibility Study from Brian Ahrens, SEO, dated June 25, 2001.

Response to General Comments:

1. The authors understand the conceptualization of the streambed conductance term as included in the existing SB 96-74 groundwater model. The proposed field program represented an effort to obtain information in a cost-effective manner to assess interactions between both the surface and alluvial aquifer systems and between the alluvial and shallow bedrock aquifers. Due to anticipated reductions in funding available for the SPDSS the groundwater-related field data collection program has been significantly revised (Sections 3.9.3 and 3.10.3). In addition the field activities related to streambed conductance are now presented as a separate task.

2. A discussion of the AUG3 pre- and post-processor for the existing SB 96-74 groundwater flow model has been added to Section 4.4.2.2. The need for enhanced tools to evaluate stream depletions and accretions was described in Section 2.5.1. Enhancing the AUG3 program or developing a similar one based on the SPDSS has been added to the list of potential enhancements in Section 4.4.3.1.

Response to Specific Comments:

Section 3.7.2.2. This comment applies more to the water level measurement section (3.10.2.2) and is noted.

Section 3.8.3.3. The text has been revised to remove the owner permission discussion.

Section 3.8.3.4. The text has been revised to discuss the site-specific issues associated with individual piping systems.

Section 3.9.3.5. This section has been revised significantly, however, it is still assumed for budgeting purposes that, on average, pumping durations of 7 days should be sufficient to collect adequate data needed to characterize aquifer properties.

Response to Comments on June 11, 2001 draft SPDSS Feasibility Study from Forrest Leaf, CCWCD, dated August 30, 2001.

A discussion of Central's groundwater monitoring program in the Box Elder and Beebe Seep areas has been added to Section 3.10.2.1.1. We understand the significance of groundwater-based irrigation in this region and look forward to Central's cooperation in sharing information pertinent to the SPDSS.

Response to Comments on June 11, 2001 draft SPDSS Feasibility Study from Jim Hall, SEO Division 1, dated July 5, 2001.

We agree with the recommended well location program and included this recommendation in Section 3.7.3 of the June 11 draft. Costs have been allocated for this program as part of the current SPDSS implementation budget.

Response to Comments on June 11, 2001 draft SPDSS Feasibility Study from George Van Slyke, SEO, dated June 20, 2001.

Section 3.7. The text has been revised as suggested.

Section 3.7.1. The text has been revised to incorporate the comment.

Section 3.9.1. The text has been revised and suggested citations have been added to address the comment.

Section 3.9.2.1. The text has been revised and suggested citations have been added to address the comment.

Section 3.9.2.1.1. The text has been revised to address the comment.

Section 3.9.3.1.2. Comment noted.

Section 3.9.2.1.3. Comment noted.

Section 3.9.2.1.4. The subject reference was cited several times previously in the Section, but the text was revised to address the comment.

Section 3.9.2.2. The text has been revised and suggested citations have been added to address the comment.

Section 3.9.2.4. The text has been revised to address the comment.

Section 3.9.3.1. The text has been revised to address the comment.

Section 3.9.3.4. We agree with the comment regarding the need for even deeper bedrock monitoring wells than have been proposed. However, due to cost considerations, deep wells cannot be justified at this time. Per the second comment, continuous water level recording devices are recommended to collect data shorter-term aquifer stresses associated with pumping that may not be detected by the current annual sampling program.

Section 3.9.3.5. Aquifer pumping tests will provide information on the properties of the tested aquifer as of the time of the test. Changes in the aquifer from confined to unconfined and interactions between aquifers will be assessed using other methods, including numerical groundwater flow modeling.

Section 3.10.1. The text has been revised to clarify what is included in Table B-8.

Section 3.10.2.1.1. The text has been revised to address the comments.

Section 3.10.2.1.2. Comment noted.

Section 3.10.2.3. The text has been revised to address the comments in each of the subsections.

Section 3.10.2.4. The text has been revised to address the comment.

Section 3.10.3. The text has been revised to address the comment.

Section 3.10.3.4. The text has been revised to address the comment.

Section 3.10.3.5. This task has been eliminated in the current text.

Section 3.18. The references have been expanded, per the comment.

Table 3-1. The table will be revised as appropriate.

Section 5.3.1.2.2. The text has been revised to address the comment.

Section 5.3.1.2.3. The text has been revised to address the comment.

Table B-7. The table will be revised as appropriate.

Table C-1. The table will be revised as appropriate.

Table C-3. Field work is an integral component of many of the Data Collection activities