South Platte Mapping and Analysis Program (SPMAP)

Implementation of a User-Centered Decision Support Tool

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Colorado Division of Water Resources

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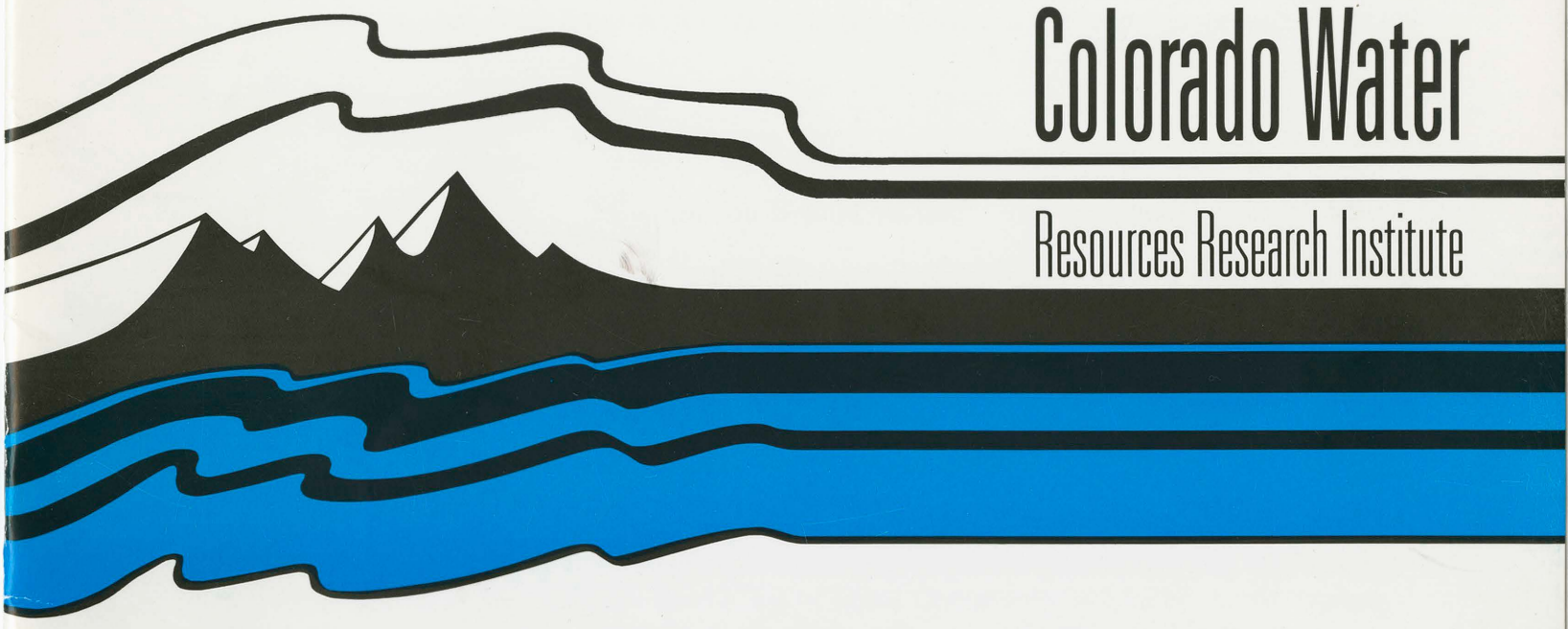

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Project Summary

The South Platte Mapping and Analysis Program (SPMAP) is a suite of tools developed by the Integrated Decision Support (IDS) Group at Colorado State University with the active participation of area water users and staff from the Division One State Engineer's Office. The primary function of the tools is to accurately determine the timing and amounts of tributary groundwater withdrawals used for irrigated agriculture and resulting river depletions in a region where ground and surface water are conjunctively used. Accurate accounting of groundwater withdrawals and depletions allows water managers to meet the challenges posed by new court decrees and legislation related to the South Platte. The tools have confirmed their worth by easing disputes during Colorado's recent unprecedented drought.

In 2003 and 2004, the depletions and augmentation requirements for more than 75 percent of the wells in the South Platte River Basin were calculated using the SPMAP tools. The tools have been widely accepted throughout the South Platte and other areas of the state because they were developed with a "user-centered approach," a process in which the users play an active role in every phase of development. Using this approach, the stakeholders define their data and modeling needs, and the databases and tools required to meet the needs are developed in a way that is open and transparent to everyone.

The first phase of the SPMAP effort was initiated with funding from the Colorado Water Resources Research Institute (CWRRI) in 1995 and ended in 2000. During this initial phase, the IDS Group delivered three major pieces of software: a Geographic Information System data and analysis tool (SPGIS), a consumptive use model (SPCU), and a stream depletion model (SDF View), which calculated the elapsed time between when water is pumped or recharged and when an accretion or depletion happens in the river.

From 2001 to 2004, the SPMAP tools have been refined in response to recent court rulings, drought, and user feedback. The consumptive use model (SPCU), due to its generic or data-driven nature, had become so popular that a name change was called for to reflect that the tool is applicable beyond the South Platte region. The newly named IDSCU is an enhanced tool that is attracting users in other western states. To respond to new accounting rules required through the state and water courts, a new stream depletion model was created: the IDS Alluvial Water Accounting System (AWAS). This tool is emerging as the program of choice for most of the augmentation plans filed with the state because it is based on a model already in use by the state.

Software and documentation for the SPMAP tools are distributed through the IDS Web site:

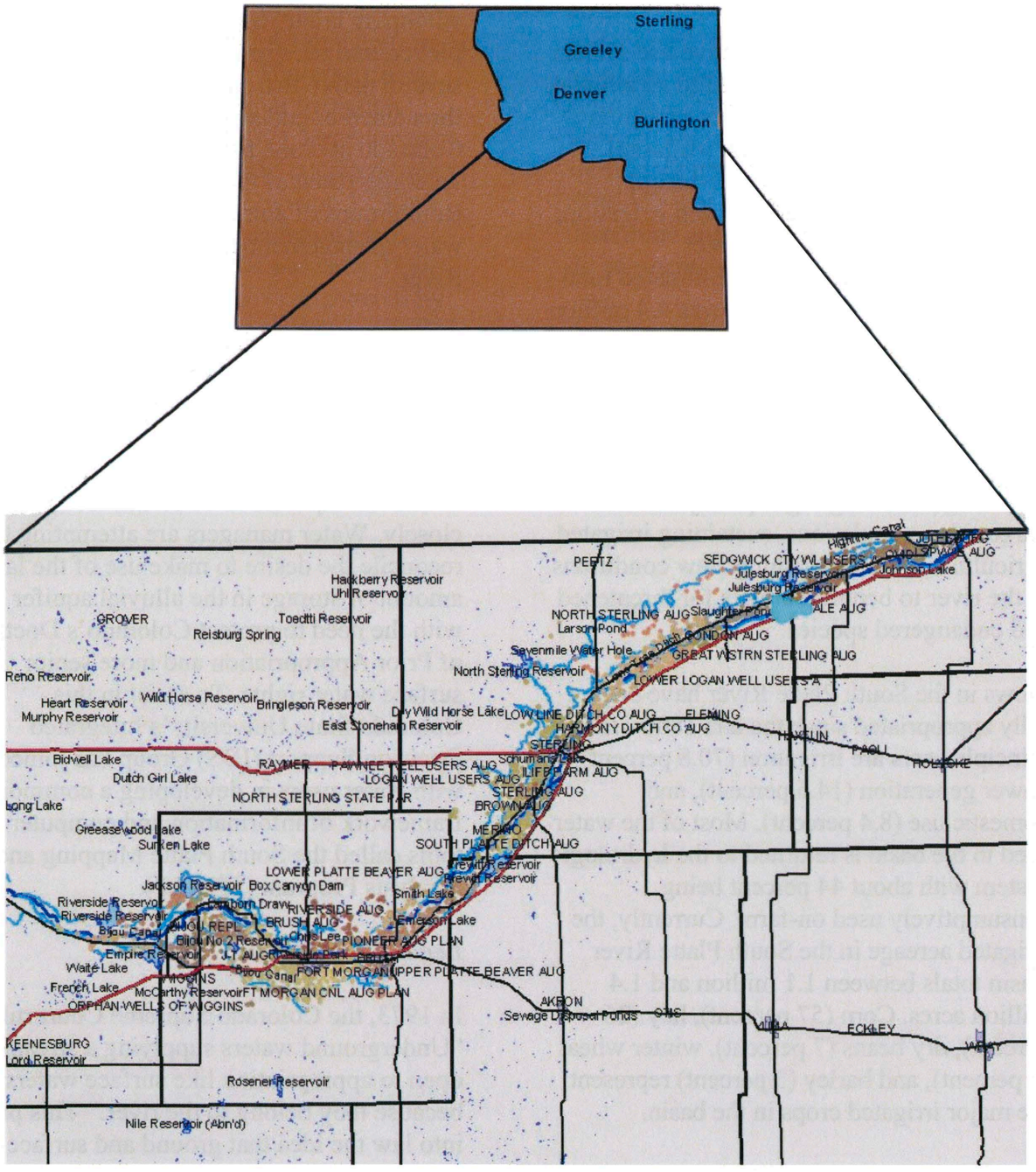
http://www.ids.colostate.edu/projects/spmap

The SPMAP tools are continually being updated in response to user feedback.

Introduction

Water Use in the South Platte

Although not unique in Colorado, the sophistication of the Lower South Platte water delivery system is unparalleled. The average native annual surface water runoff from the South Platte River and its tributaries is about 1.4 million acre-feet,



The South Platte Watershed in Colorado with Detailed Map of Augmentation

exclusive of imports. About 70 percent of the annual streamflow of the South Platte occurs during spring runoff from the Rocky Mountains. Some 20 ditches and tunnels transport more than 400,000 acre-feet of water from the North Platte, the Colorado, and the Arkansas river basins to the South Platte River system, which gives an available average annual surface water runoff of 1.8 million acre-feet.

The South Platte is a conjunctive use system in which the river is connected to an alluvial aquifer. The lower portion of the basin in Colorado uses wells to obtain irrigation water. Currently, 800,000 acre-feet of groundwater are pumped for crop irrigation, according to the Colorado Water Conservation Board (2005). Estimated total off-stream water use in 1990 was 4.4 million acre-ft. Of this amount, 71 percent is surface water, and 29 percent is groundwater.

Water managers in the South Platte are facing competing demands for water including providing high-quality water to burgeoning populations, sustaining irrigated agriculture, and establishing flow conditions in the river to benefit habitats for threatened and endangered species.

Flows in the South Platte River have been fully appropriated since the late 1800s; the principle users are irrigation (70.8 percent), power generation (14.6 percent), and domestic use (8.4 percent). Most of the water used in the basin is returned to the hydrologic system with about 44 percent being consumptively used on-farm. Currently, the irrigated acreage in the South Platte River Basin totals between 1.1 million and 1.4 million acres. Corn (57 percent), hay (26 percent), dry beans (7 percent), winter wheat (6 percent), and barley (3 percent) represent the major irrigated crops in the basin.

The South Platte Basin is home to 2.9 million people, nearly 70 percent of Colorado's total population. Between 1990 and 2000, population in the basin grew by 31 percent (Colorado Water Conservation Board, 2005).

At least four federally listed endangered bird species may be found in the Platte River Basin at different times of the year: whooping crane, inferior least tern, piping plover, and peregrine falcon. There are also several native fish species that are listed as threatened or endangered species in Colorado and one fish, the pallid sturgeon, federally listed as threatened in Nebraska. Both groups of animals may be affected by water management on the South Platte River.

Recently, prolonged, severe drought and rapid urban growth have exacerbated conflicts between water users. These conflicts have caused the amount of groundwater depletions from well pumping in alluvial aquifers to be scrutinized more closely. Water managers are attempting to reconcile the desire to make use of the large amount of storage in the alluvial aquifer with the need to protect Colorado's Doctrine of Prior Appropriation and more senior surface water rights. To assist in this, Colorado State University's Integrated Decision Support (IDS) Group has joined with water users in developing a common framework of information and computer tools called the South Platte Mapping and Analysis Program (SPMAP).

Legal Requirements

In 1973, the Colorado Supreme Court ruled, "Underground waters supplying a stream are open to appropriation like surface waters, because they belong to the river." This put into law the idea that ground and surface

waters are intrinsically connected, and therefore there is a need to consider them jointly in water resource management decisions.

For decades, well pumping in the South Platte was regulated primarily by annually renewed Substitute Water Supply Plans (SWSP). As Scott Cuthbertson (2005), an Assistant Division Engineer for Division 1, explains, "From the enactment of the 'Water Right Determination and Administration Act of 1969' until the recent Supreme Court ruling in Simpson vs. Bijou Irrigation Company, et al. (02SA377), large capacity, mainly irrigation wells had operated under three principal plans in Division 1. While there were several augmentation plans decreed in the mid-1970s and early 1980s, the majority of the wells were covered by either the decreed Poudre Plan of one of two annually renewed Substitute Water Supply Plans operated by Central Colorado Water Conservancy District or the Groundwater Appropriators of the South Platte (GASP)."

All this changed with the Simpson v. Bijou Irrigation Company ruling, which specified that the State Engineer did not have the authority to approve SWSP and that augmentation plans needed to be decreed by water court. Now, as new augmentation plans are working their way through water court, the State Engineer's office still can approve annual SWSP. However, there is a significant need for computer tools, like SPMAP, that can help these new plans determine augmentation requirements and do augmentation accounting.

The User-Centered Development Process

As water issues are becoming more contentious and more water is being removed from agricultural use, it is important for water users to work with a common set of tools and information. Colorado State University and, by extension, the IDS Group are viewed as impartial third parties in water issues; consequently, the SPMAP tools have been accepted by the water user community at large, preventing costly and lengthy legal battles. Water users also have accepted these tools because of the user-centered approach that has been used for tool development.

The "User-Centered DSS Development Approach" is an interactive and dynamic development process in which the users play an integral part. Using this approach, the stakeholders define their data and modeling needs. The defined needs then are evaluated by water users and the Integrated Decision Support Group, and the tools required to meet the needs are determined. The databases and tools are developed in a way that is open and transparent to everyone. The models are data-driven, which means that many of its functions can be configured by the user and can be applied to different regions. This also allows for the evaluation of many different alternatives and scenarios. Cooperatively, the users and developers decide on the number of alternatives and scenarios that it is reasonable for the software to accommodate. The development process is designed to allow for broad stakeholder participation in the creation and implementation of the tools.

User groups that have played an important role in the development of the SPMAP tools are:

- Northern Colorado Water Conservancy District (NCWCD)
- South Platte Lower River Group, Inc. (SPLRG)
- Central Colorado Water Conservancy District (CCWCD)
- Colorado State Engineers Office (SEO), Division 1
- Lower South Platte Water Conservancy District (LSPWCD)
- Colorado Water Resources Research Institute (CWRRI)
- Colorado Cooperative Extension Service
- Colorado Agricultural Experiment Station

All the tools and associated documentation are available on the Web at:

http://www.ids.colostate.edu/projects/spmap

The SPMAP Products

The SPMAP tools have all been developed in the Windows 95/98/NT environment and can be used in combinations or as stand-alone models.

South Platte Geographic Information System (SPGIS)

SPGIS makes quality spatial data available to water managers for the Lower South Platte River Basin. GIS themes for well locations, transmissivity contours, and stream depletion factors have been developed and combined with other useful map themes like roads, weather stations, and town locations and populations to provide a comprehensive tool for mapping and analysis.

IDS Consumptive Use Model

The IDSCU Model is a data-driven model that allows users to calculate evapotranspiration (ET), the water used by crops, using a number of different monthly and daily ET methods. The model allows the user to:

1. project ET into the future or the past, based on historical data in order to simulate different water availability scenarios;
2. access the State Engineer's database, HYDROBASE, to develop surface diversion records and weather data;
3. use Access or dbase tables to create input data sets;
4. compute a complete water budget;
5. compare consumptive use (CU) values computed with different daily and monthly ET methods, information that can be used to develop calibrated Blaney-Criddle crop coefficients;
6. compare the ET calculated by different ET methods;
7. evaluate application efficiencies of wells by comparing depletions of groundwater computed using a water budget with pumping records multiplied by a presumptive depletion factor; and
8. export the CU of groundwater to IDS AWAS.

IDS Alluvial Water Accounting System (IDS AWAS)

Colorado water managers need to determine the lag time from when a well is pumped or water is recharged to a recharge site and when a depletion or accretion happens in the river. Historically, in Colorado, the Stream Depletion Factor (SDF) (Jenkins, 1968) method has been used to determine the impact of groundwater depletions on a particular stream, and the IDS Group has developed the SDF View model to calculate monthly depletions or accretions using this method. However, the SDF methodology is an analytical solution based on several boundary assumptions. Although analytical solutions are convenient and can be valuable if properly calibrated, to be useful, the assumptions of an analytical solution must closely match the conditions that are being modeled. Consequently, there was a demand from water users that the analytical model used to calculate depletions needed to include options for different boundary conditions and time steps. For example, water users with wells located close to the river needed a model that could provide them with a daily time step as their well pumping quickly impacts the river. In response to these user requests, the IDS

Alluvial Water Accounting System was created.

AWAS can calculate river depletions using the *Stream Depletion Factor* method (Jenkins, 1968) or *The Analytical Stream Depletion* method developed in 1987 by Dewayne R. Schroeder. The latter method uses analytical equations described by Glover (1977) and others. The AWAS model can calculate depletions using daily or monthly time steps. The user has the option to evaluate a number of different boundary conditions: alluvial, infinite, no flow, and effective SDF. Model input for AWAS either can be in the form of pumping records for each well consisting of a pumping rate and duration or net consumptive use or recharge in a daily or a monthly time step. Year type can be set to calendar, irrigation, or USGS. Data can be projected into the future or past based on historical records, and the effect of turning off the well by specifying an end date beyond the period of record can be simulated.

Development Timeline

- **1995-96:** Project efforts focused on spatial data collection and evaluation. A GIS tool was developed as an extension to ArcView 3.0+ to provide users with the capability to view and use spatial data, such as themes for irrigated lands, well locations, stream depletion factors, hydrography, weather stations, county boundaries, roads, and cities.
- **1997-98:** A Consumptive Use model called the South Platte Consumptive Use (SPCU) Model and an interface for a Stream Depletion Factor (SDF) Model were developed. Satellite images were purchased to determine irrigated land area, field delineation, and crop type classifications. A Graphical User Interface (GUI) for the CU model was begun.
- **1998-99:** The Stream Depletion Factor (SDF) interface called SDF View was released with documentation. SDF View allows the user to estimate the lag time between when irrigation well water is pumped from, or water is recharged to, an alluvial unconfined river aquifer and when a depletion or accretion happens in the river. SDF View was used in developing managed groundwater recharge as a water supply for a future Platte Basin Endangered Species Recovery Program in Colorado, Nebraska, and Wyoming.
- **1999-2000:** A major task completed in 2000 was the development of the SPCU Model as a stand-alone interface. Additional methods and options were added to the model. For example, the SPCU Model now could retrieve data from the statewide database being developed by the State Engineer's office called HYDROBASE. SPGIS, SDF View, and SPCU Model interfaces were updated, and documentation was provided. This concluded the initial SPMAP project and provided a well-defined set of deliverables.
- **2000-2001:** This was the first year devoted to enhancing the initial SPMAP tools. Additional layers were added to SPGIS. Also, the ArcView interface was improved by developing the capabilities to locate wells using footing calls, to generate well locations using GPS data, and to determine the SDF value of a well by interpolating from the SDF coverage. The CU component of the model also was enhanced by allowing users to generate input and output displays for all year types (calendar, irrigation, and water) and to generate weather scenarios. A daily SDF module was prototyped. This daily version was considered particularly important to farms with wells close to a river.
- **2001-2002:** The capabilities of the SPCU Model were expanded to allow users to compute daily CU using the Kimberly-Penman method. Water budgets also could be calculated using daily methods. The daily SDF module was tested and improved.
- **2002-2003:** This was a period of severe drought, which reinforced the value of the SPMAP tools and called for some changes in the SPCU and SDF View tools. As more and more user groups around the state began using the SPCU Model, the decision was made to change the tool's name to the IDSCU Model to show that the tool is applicable throughout Colorado, not only to the

South Platte region. The IDSCU Model was expanded to include options for computing monthly CU by using the Pochop and Hargreaves methods. Daily options were expanded to include the Kimberly-Penman and ASCE methods. Options were added to the IDSCU Model to allow users to calculate monthly well pumping from annual records. Tools for reading generic input data from Access or dBase files were developed to accommodate the needs of user groups. A new tool also was created to calculate river depletions: the IDS Alluvial Water Accounting System (AWAS). IDS AWAS gives users the option of calculating river depletions using *The Analytical Stream Depletion* method developed in 1987 by Dewayne R. Schroeder, a method that uses analytical equations described by Glover (1977) and others. IDS AWAS represents a substantial improvement in calculating daily SDF..

- **2003-2004:** The capabilities of the IDSCU model were enhanced to calculate a water budget using daily data. Users transitioned from SDFView to AWAS, and consequently additional capabilities were added to AWAS to provide it with options and a graphical user interface similar toSDFView. In addition, documentation was developed for AWAS, and a major effort was launched to train users in the SPMAP programs, particularly IDSCU and AWAS. Daylong training workshops were held on the Colorado State University campus to packed audiences.

User Reactions

"The magnitude and timing of depletions impacting the river as a result of well diversions are determined by modeling. Several models have been approved by the Division Engineer for the South Platte system. Colorado State University's AWAS program using Glover-based alluvial aquifer transport equations appears to be the emerging model and interface of choice by most plans."

—Scott Cuthbertson, Assistant Division Engineer, Division I

"With the increasing pressures to maintain and secure augmentation supplies, the computer software of SPMAP has become indispensable. It is being used by the major augmentation suppliers for accounting purposes."

—Jon Altenhofen, NCWCD Supervisory Water Resource Engineer

"The SPMAP system is vital to Lower's (Lower South Platte Water Conservancy District) future missions and goals....results from the SPMAP will be used in water rights court proceedings...."

—John Eckhardt, Former General Manager LSPWCD

"Central utilized SPMAP this past year in development of our 2003 Substitute Water Supply Plan, and it was a critical component of our work. Past efforts have been invaluable as we prepare to augment over 1,500 wells in 2004."

—Tom Cech, CCWCD Executive Director

"These tools are starting to be used extensively for augmentation accounting for well user groups needing to replace out-of-priority well depletions."

—James R. Hall, Division Engineer, Water Division One, Office of the State Engineer

"The feedback loop of water users applying the modules in decision support with the CSU-IDS Group making modifications as needed on a quick turnaround has been tremendous...."

—Jon Altenhofen, NCWCD Supervisory Water Resource Engineer

"...this effort has been more productive and has provided far more benefits to water users than any previous CSU effort that Central has been involved in."

—Forrest Leaf, Consultant Former CCWCD District Engineer

Future Work

More than 75 percent of agricultural wells (more than 5,000) in the South Platte are administered using the tools developed as part of the SPMAP project. The current tools compute well depletions and recharge accretions at the river. However, there is a need for an additional tool that can do the augmentation accounting that will allow users to balance their demands (depletions) with their supplies. An augmentation methodology and associated computer tool is being developed that will use inputs from other SPMAP programs.

The new tool is being created in close cooperation with water users and the State Engineer's Office. The tool, which is effectively a new SPMAP module, will use groundwater withdrawals calculated with IDSCU or imported from another database in spreadsheet format to compute the depletions on the river using a groundwater model. The user may choose to calculate the depletions on the river using a model based on the Stream Depletion Factor, Glover equations for alluvial aquifers implemented in AWAS, or a spreadsheet-type format. The groundwater depletions will be linked to water supply information from reservoir releases, recharge pond accretions, and augmentation wells. The result of these calculations is the net effect on the river for individual augmentation plans. However, the implementation of this methodology is complicated by the fact that the water supplies might contain river-routing lag times that need to be taken into account and by the need to allow for by-pass flows or exchanges at river head gates. The new tool also will be able to merge multiple augmentation accounting files so that the state or water users with large numbers of wells and replacement supplies can develop a single file containing all their depletions and supplies.

As with the other SPMAP modules, the tool will be distributed via the World Wide Web. An additional Web component will be developed where the state will post the accounting for each augmentation plan. The Web site will be setup in such a way that users will be able to choose to quickly view the summary information for the accounting or to obtain more detailed information on the specific data and models used to generate the information.

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