Colorado State University

Report to the Colorado Legislature

HB12-1278 Study of the South Platte River Alluvial Aquifer

December 31, 2013

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Concerning:

HB12-1278 *Study of the South Platte River Alluvial Aquifer*

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Submitted by: Reagan M. Waskom
Colorado Water Institute
Colorado State University
Fort Collins, CO 80523-1033
http://cwi.colostate.edu

http://www.cwi.colostate.edu/southplatte

Cover photo: South Platte River. Photo by Bill Cotton, CSU

EXECUTIVE SUMMARY

In 2012 session, the Colorado Legislature passed HB12-1278, entitled *Concerning The Authorization of a Study of The South Platte River Alluvial Aquifer*, directing the Colorado Water Institute (CWI) at Colorado State University to conduct a study of the South Platte alluvial aquifer with funding provided by the Colorado Water Conservation Board (CWCB). CWI was required under the Act to present a final report to the General Assembly by December 31, 2013.

Background on the HB1278 Study

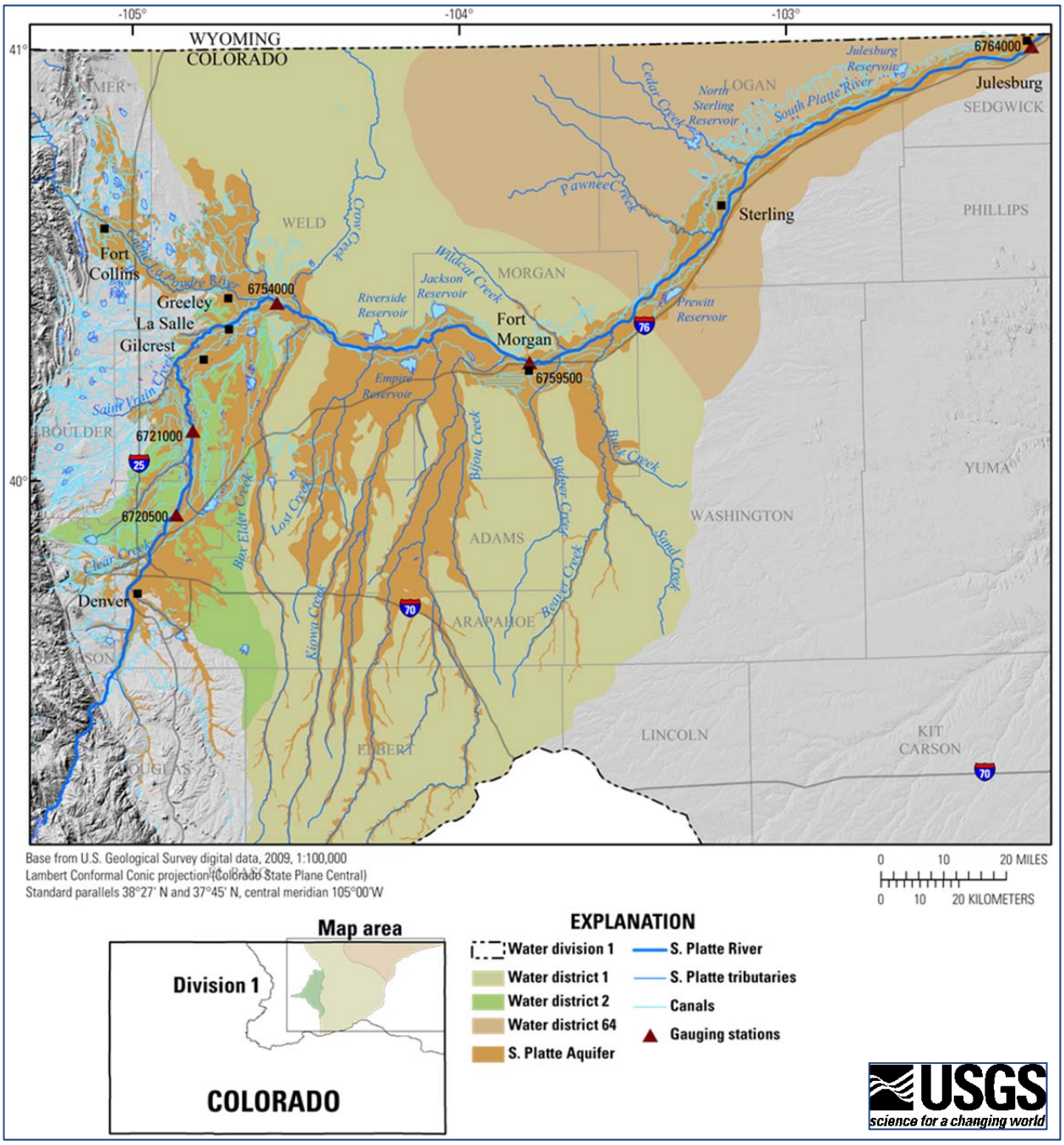
HB1278 was a result of a decade of debate that initially concerned wells that lacked court adjudicated augmentation plans to replace out-of-priority depletions. Coincident with the development of recharge structures to allow wells to operate, concerns began to arise regarding property adversely impacted by high groundwater levels. In 2008 there were homeowner reports of high groundwater levels in the Pawnee Ridge and the Country Club Hills subdivisions of Sterling. Above average precipitation in 2009, 2010, and 2011 in the lower basin increased the frequency and locations of these complaints. Homeowners reported failed septic systems and flooded basements that had not previously been a concern. Meanwhile, farmers and homeowners in the Gilcrest/LaSalle area also began relaying concerns that high groundwater levels were damaging crops and flooding basements and septic systems. Parties concerned about curtailment of wells and those concerned about high water levels appealed to the Legislature, asking if there were a way to provide mechanisms to mitigate high groundwater and create more flexibility and opportunity for agricultural water users by utilizing the aquifer more effectively. Eventually, legislators passed HB1278 to study the problem and propose solutions. The sponsors of the bill sought further information about planned utilization of the groundwater resource as a basis for improving the system of water administration in the South Platte.

This report, with its associated appendices and online material, describes and evaluates the history and current status of groundwater use and water level trends, surface water use and trends, the spread of phreatophytes, and the climate of the S. Platte basin in order to better understand the potential opportunities for improved surface/alluvial groundwater conjunctive use in the basin.

The Basin

The S. Platte basin of northeast Colorado has 150 years of water management history and some 18,600 decreed points of diversion. The average annual river flow over the past four decades at Julesburg (since 1969), near the Nebraska border, is approximately 478,000 acre-feet (AF), but within this period there has been tremendous variation in average annual flow, ranging from 55,000 to 2.1 million AF/yr. Return flows from irrigation make a large contribution to stabilizing river flows. A century and a half of water supply development in the basin has resulted in an extensive network of diversion ditches, canals, and reservoirs, all of which seep large amounts of water into the alluvial aquifer, creating a gaining river downstream of Denver for almost the

entire year. By 1970 there were over 8,200 high capacity wells in the S. Platte alluvium pumping approximately 500,000 AF of water annually, resulting in declining groundwater levels. Strict administration of well augmentation requirements after the year 2000 led to curtailment and eventual abandonment of some wells coincident with the development of recharge projects to augment out-of-priority groundwater depletions for many other wells.



Area of the HB1278 Investigation in the South Platte Alluvial Aquifer in Water Districts 2, 1, and 64, Extending Approximately From Denver to Greeley to Julesburg.

HB1278 Study Approach

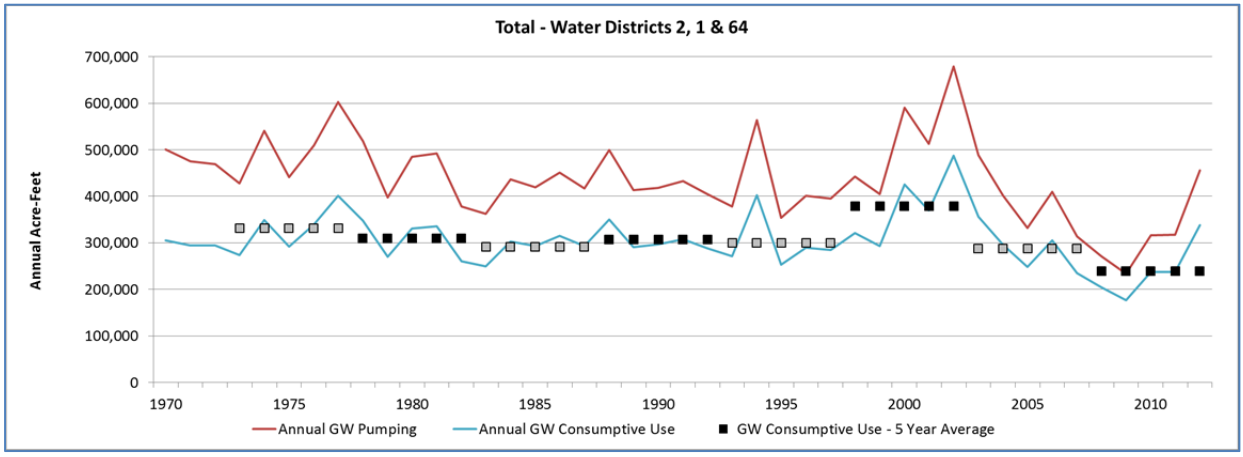
The problem of surface and groundwater interaction is difficult to accurately measure or model. HB1278 did not authorize the development of new models to study the system, but rather an evaluation of the available data to address the objectives of the Act. Our general plan of work for this study was to use the existing data tools in the South Platte Decision Support System (SPDSS) developed for the CWCB. The groundwork laid by the SPDSS was extremely valuable to the HB1278 study. However, we did not use the SPDSS groundwater model, which was released during the course of the HB1278 study and at this time is only calibrated up to 2006. We used the SPDSS to develop datasets on groundwater levels, surface and groundwater diversions, river flow, call records, stream gain and loss, augmentation, artificial recharge, phreatophytes, and other factors for analysis. Our general approach was to compare these factors on a multi-year basis to smooth out annual variation in climate and hydrologic conditions in order to detect long-term trends, looking most closely at trends since 2000, when we entered the current era of stricter administration of groundwater. Colorado State University (CSU) conducted trend analyses on observation well levels to determine if groundwater levels were changing in response to recent management. U.S. Geological Survey (USGS) simultaneously conducted an independent analysis of groundwater trends using data from 1,670 wells that included more than 150,000 observations for calendar years 1953-2012 and developed a proposed long-term monitoring well network to improve future understanding of groundwater conditions. We determined at the outset to focus on publically available data from HydroBase, the USGS National Water Information System, the National Oceanic and Atmospheric Administration, the Colorado Agricultural Meteorological Network, and LandSat data that could be accessed and replicated by any interested party.

Summary of Findings

The S. Platte basin is subject to a number of variable climate, hydrologic, geologic, and human factors interacting to create an extremely complicated set of conditions impacting the alluvial aquifer. In almost all years there is inadequate water in the river to meet all of the demands, and the excess flows that do occur occasionally are not always predictable in place and time. The data record, particularly groundwater levels, pumping volumes, and climate is irregular, and it must be understood that there remain unknowns and uncertainties in the findings. While variations in the data record introduce uncertainty in exact values of basin-wide parameters, various trends are apparent that allow us to make a number of observations, which taken together reveal certain generalizable findings. In summary:

- Combined groundwater consumptive use for irrigation in Water Districts 2, 1, and 64 has varied with snowpack and precipitation over the past three decades. Since 2008, the combined three water districts have been pumping an average of approximately 320,000 AF/yr, with local areas of well curtailment gradually being offset by new or expanded pumping as augmentation supplies are developed over time. Agricultural pumping has decreased by the highest percentage in Water District 2, from a recent high of 120,000 AF in 2002 to 40,000 AF in 2012 as augmentation sources remain difficult to acquire, limiting pumping in that district. Long-term average groundwater consumptive use in Water District 1 is relatively stable since the 1980s at 180,000 AF/yr with some relocation due to curtailment and development of new augmentation supplies. Long-term average groundwater

consumptive use in Water District 64 has increased by approximately 10,000 AF to an average of 110,000 AF/yr as development of augmentation water supplies has allowed increased pumping. Curtailment and abandonment of wells in Water Districts 2 and 1 is reflected in lower pumping amounts in Water District 2 and slightly lower pumping amounts in areas of Water District 1, potentially affecting local groundwater levels in recent years.



Estimated Total Annual Pumping and Groundwater Consumptive Use in Water Districts 2, 1, and 64.

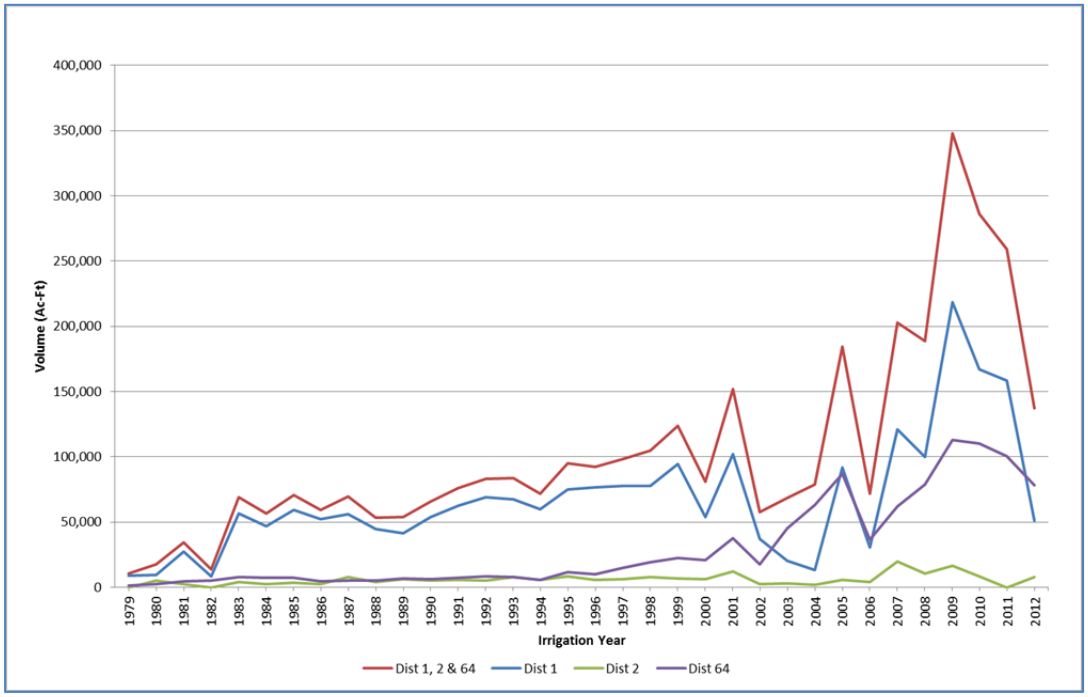
Average Annual Surface Diversions, Pumping, Consumptive Use Groundwater Pumping, and Augmentation for Water Districts 2, 1, and 64, for the Period of 2008-2012.

	WD 2	WD 1	WD 64	Total
	----------	Average (2008-2012) in AF/yr		----------
Total Surface Diversion	376,583	673,869	257,766	1,308,217
Total Pumping	31,195	177,490	110,612	319,298
CU GW Pumping	23,138	134,872	80,781	238,791
Surface Augmentation	18,487	6,067	5,493	30,047
Recharge Augmentation	11,166	131,287	91,819	234,271
Total Augmentation	29,653	137,354	97,312	264,318

- Well pumping curtailments have shifted irrigation water demands to more reliance on surface water, particularly in Water District 2, likely resulting in more canal and ditch seepage coincident with reduced groundwater pumping.
- The number of days of administrative call on the river has increased since the late 1990s from an average of 102 to 305 days annually in Water District 2, from 55 to 271 days annually in

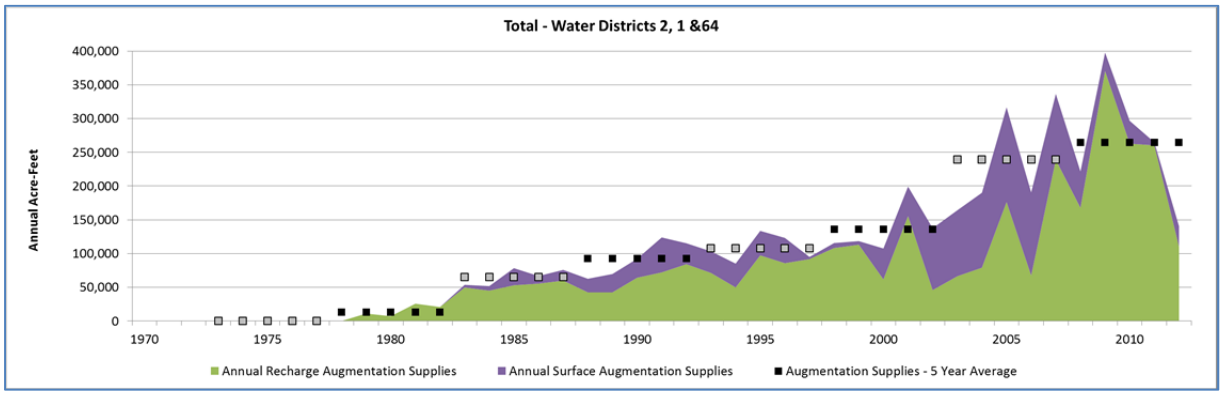
Water District 1, and from 72 to 177 days annually in Water District 64, increasing augmentation requirements and decreasing free river periods when augmentation supplies can be diverted.

- Many recharge facilities have been built recently in the S. Platte basin as part of augmentation plans. Water Districts 2, 1, and 64 combined have developed over 230,000 AF of augmentation supplies based on five-year averages, reflecting the increase in recharge site construction, and some higher runoff flows available to divert for recharge. Large spatial and temporal variation in annual augmentation supplies is observed, with excess in some areas and deficiencies in other areas.

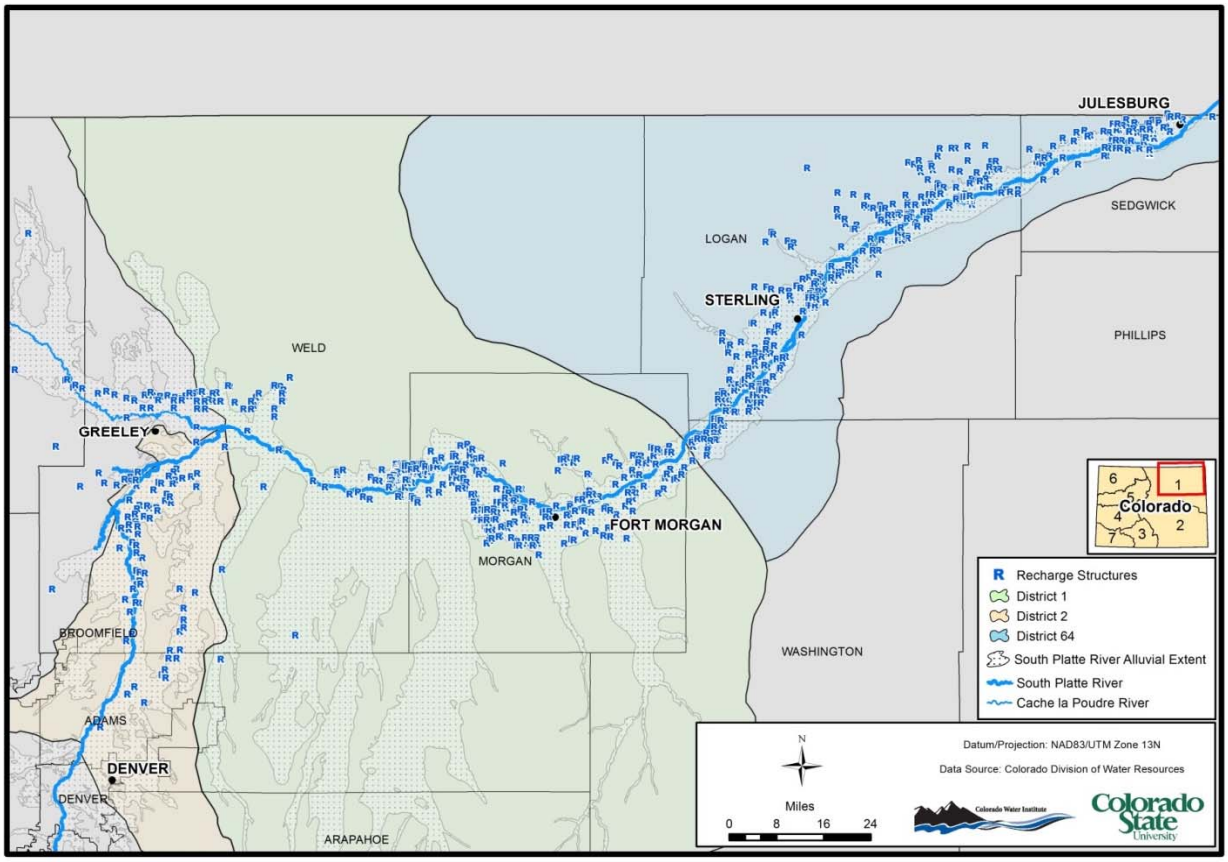


Artificial Groundwater Recharge Diversions in Water Districts 2, 1, and 64.

- Augmentation plan operators may only divert recharge water when in priority and augmentation plans may recharge more water than required for some part of the year to meet the minimum needed in other months.
- Extensive development of recharge ponds and lined gravel pit storage projects in the past decade have likely changed local groundwater gradients. While prolonged wet weather contributes to groundwater recharge, it does not explain the rising groundwater levels observed throughout the basin since 2002, or the lack of a rising trend during the wet periods of the 1980s or 1990s.

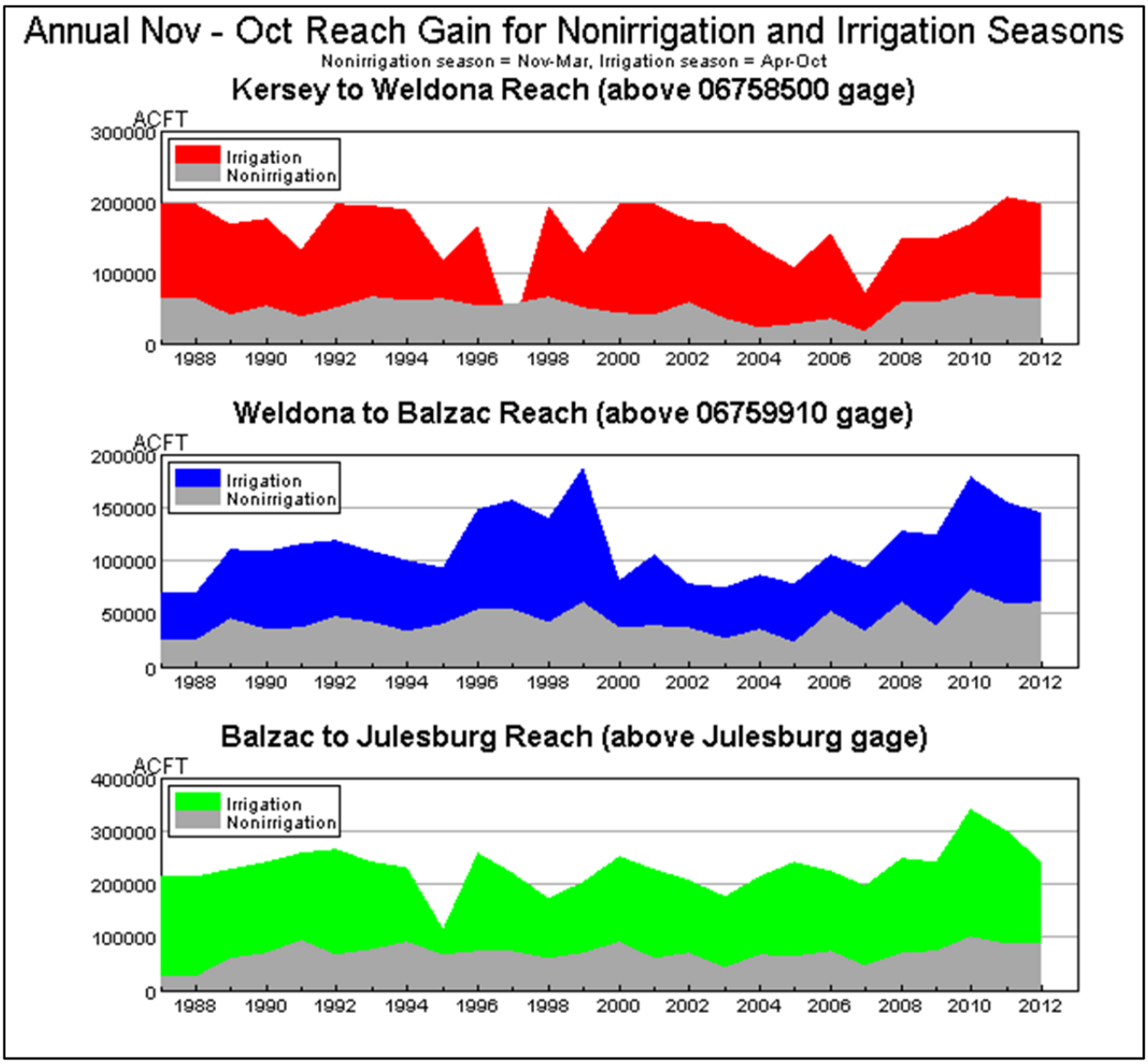


Total Annual Surface and Groundwater Supplies Developed to Meet Augmentation Plan Requirements in Water Districts 2, 1, and 64.

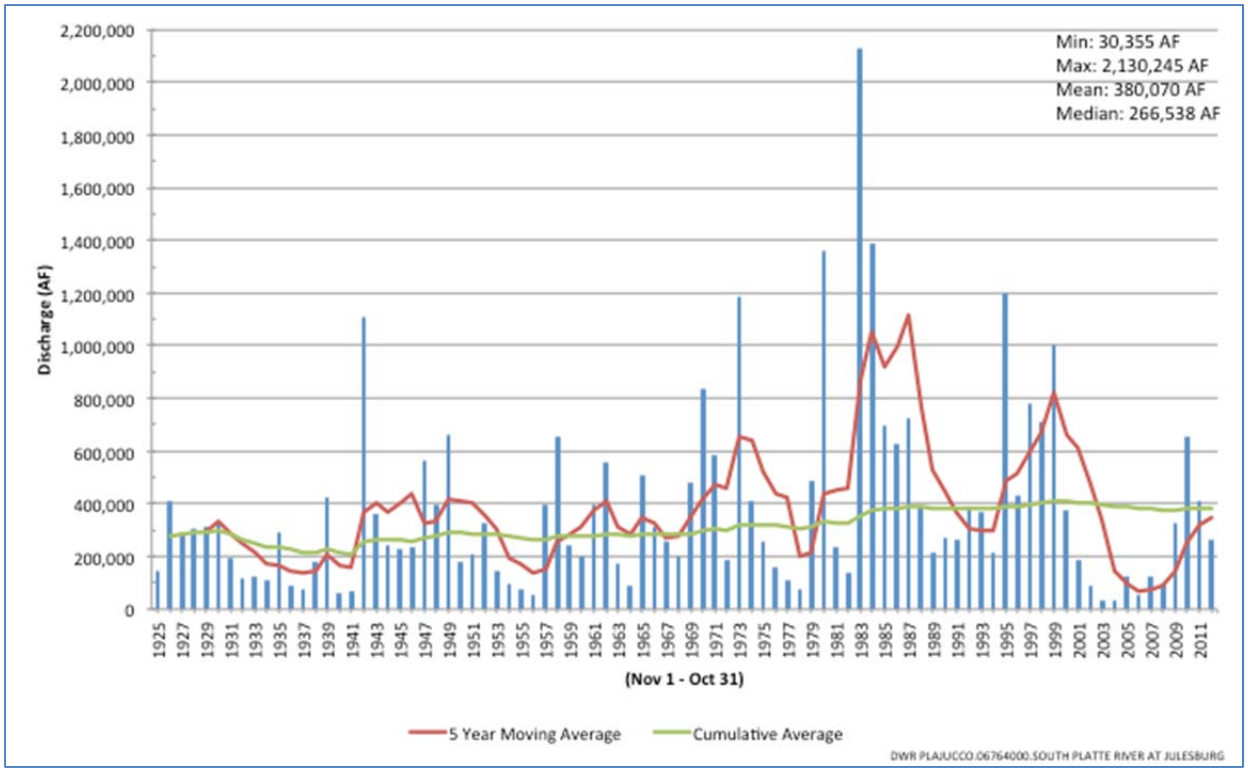


Location of Existing Recharge Structures in the S. Platte Basin.

- A point flow analysis tool was developed for the HB1278 study to quantify the historical monthly, seasonal, annual, and decadal stream reach gains and losses between mainstem streamflow gages located in Water District 1 and 64. Stream gains are highest in the S. Platte during the irrigation season and the lowest in November and December, ranging from approximately 3-9 cfs/mi, consistent with previous studies. Reuse of return flows and accretions increases downstream, with the surface diversions in the lower reach being nearly equal to available stream gains. A rising trend in stream gain can be observed in recent years.

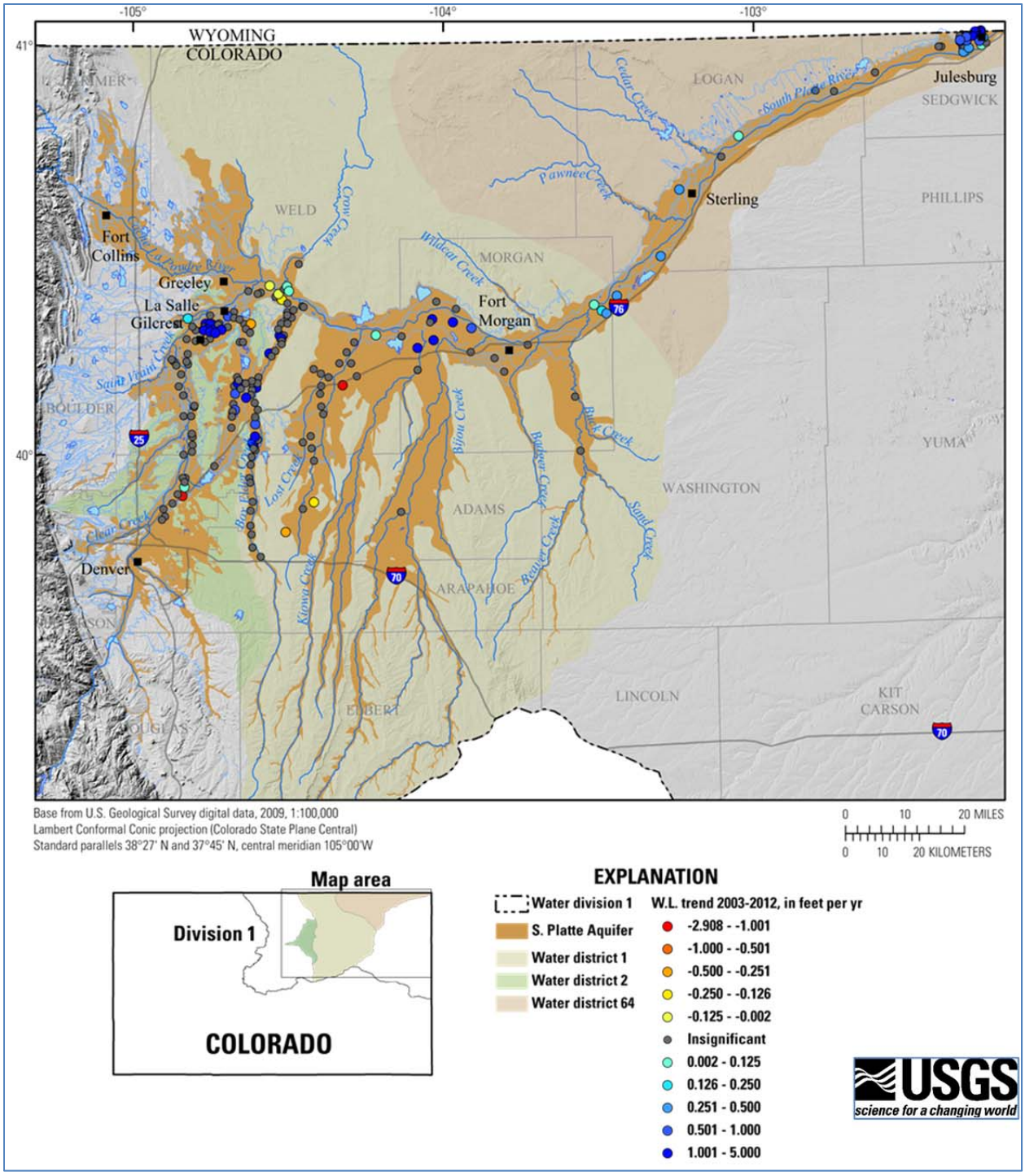


Calculated Annual River Gain Summary in AF for the Period of 1987-2012 Showing Irrigation and Off-Season Gain by Reach.

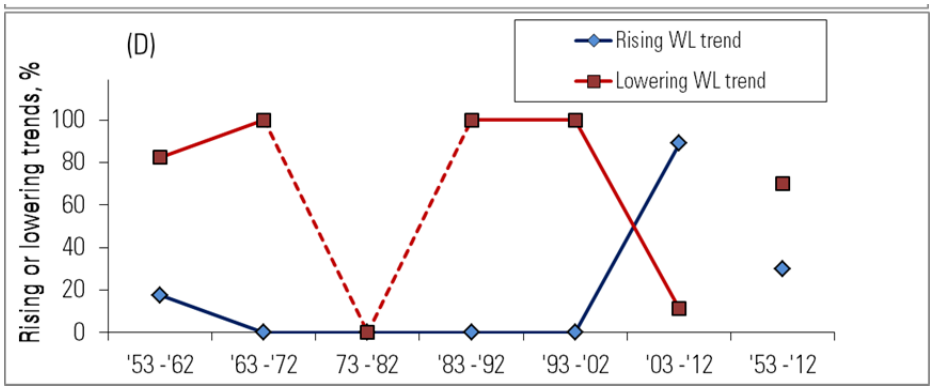


Annual Flow at the Julesburg Gage, 1925-2012.

- The long-term annual flow at the Julesburg gage near the state line averages 478,261 AF for the period of 1969-2012. The average annual flow for the period of 2000-2012 was 213,446 AF, due mainly to drought conditions in 2001-2008, and 2012.
- While there is still water available to be developed on the S. Platte in Colorado, the location and timing of that available water is highly variable. No statistically significant annual flow trends were detected at the Kersey or Julesburg gages over the past decade.
- Phreatophytes continue to increase in the basin, resulting in large quantities of non-beneficial consumptive use, perhaps as much as 250,000AF/yr.
- Localized areas of high groundwater have occurred in regions of the aquifer over the period of record and in some cases, high groundwater is commonplace. Groundwater levels have increased over the last decade (2003-2012), during which time a large number of observation wells indicate trends of rising water. The CSU and USGS analyses independently corroborated this trend of rising water levels in the recent decade. While the data do not allow direct attribution of cause, the weight of the current evidence indicates that rising groundwater is a response to curtailment of pumping after 2002 and increased recharge in the recent decade. The main areas of groundwater rise occur near Gilcrest, Fort Morgan, Sterling, and Julesburg.



Water Level Trends at Wells with Acceptable Records from 2003 to 2012. Positive Values Indicate Increasing Water Levels and Negative Values Indicate Decreasing Water Levels.



Percentage of Wells by Decade Having Rising or Lowering Water Level Trends. (insufficient data for the decade of '73-'82)

Conclusions

These findings lead us to the conclusion that changes in water administration in the past decade, specifically curtailment of wells and increased augmentation, have served to further protect senior surface water rights from injury. Changed water administration practices have also led to increasing groundwater levels in the basin, and in some cases, these rising levels are impacting homes and property. Presently, high groundwater conditions impacting landowners appear to be localized and thus, local solutions are recommended. In contemplating any of the recommendations offered herein, it should be acknowledged that senior water rights must be protected in any adjustments to the system and that wells cannot be relieved from the obligation to replace out-of-priority depletions that cause material injury to senior surface water rights.

Water users in the basin have expended significant effort and resources in recent years to comply with the law of the river, leading to the observation that current administration of groundwater in the basin works for most water users. However, some groundwater users in Water District 2 and parts of District 1 have been adversely impacted by the shortage of affordable augmentation supplies to offset pumped depletions, limiting their ability to use the aquifer.

There are over 500 recharge projects now in place in the S. Platte basin. According to Division 1 staff, as many as 800 total recharge structures are planned in existing augmentation plans, so there are potentially many more facilities yet to be constructed. Future groundwater recharge projects should be designed, located, constructed, and managed so as to avoid creating groundwater mounds that cause harm to third parties. When the court currently evaluates a recharge project, it is primarily determining whether it will offset out-of-priority depletions, with no explicit determination if recharge might cause property damage to others in the flow path of recharged groundwater. Given the urban and suburban development occurring in the basin, the construction and operation of new recharge structures should be given further scrutiny.

HB1278 required an evaluation of whether the use of water in the basin could be improved by affording the State Engineer additional flexibility in the administration of water rights. The

Colorado Division of Water Resources (DWR) has instrumented two areas in the S. Platte basin with known high groundwater levels (Sterling and Gilcrest/LaSalle). With two years of data collected (2012-2013) to characterize water level behavior, these areas are primed for implementing pilot tests to evaluate alternative strategies for groundwater management. Pilot approaches may include permitted pumping or decreased recharge as determined to be locally appropriate to test alternative management strategies. Groundwater levels and surface diversions in the pilot areas must be accurately monitored in real time to determine impacts from the pilot management approach, and a plan to offset any injurious depletions must be established. Calibrated numerical groundwater models should be developed and tested along with analytical models in the pilot project areas. The S. Platte Decision Support System should also be employed to help evaluate the impact of management scenarios.

Developments in water court and administrative practice have diminished the Division Engineer's ability to play a management role in the distribution of water supplies. As we have already adjudicated most of the augmentation plans for high capacity irrigation wells likely to be developed within Water Districts 2, 1 and 64, the mass movement of irrigation wells into augmentation plans is widely considered to be nearly completed. The decrees are considered final and to the extent there is room for adjustment in augmentation requirements, it has to do with the administrative call. Augmentation plans respond to the administrative call, and it is the one moving part that is not fixed in the decrees. Reducing the number of days of administrative call on the river system will allow more days of free river whereby well users can acquire recharge supplies. In the past, water users worked with the Division Engineer to reduce the call period. Reestablishing this flexibility could benefit water users in the basin.

In an age when water is becoming increasingly scarce and supplies uncertain, robust data networks and decision support tools are critically needed for day-to-day operations and to build a long-term data archive to serve the needs of the people of the State of Colorado. The HB1278 study has revealed that the existing groundwater monitoring data collection network is irregular and incomplete but could rather easily be substantially upgraded. Better management decisions require higher quality and more easily accessible data. We need to install, instrument, and maintain a groundwater level monitoring network that can be used for real time management decisions. Additionally, water management organizations in the basin should be strongly encouraged to share data and collaborate on data collection.

The Division 1 Engineer has incurred significant additional duties and responsibilities as a result of the many adjudicated augmentation plans now in operation and new rules for well metering. Reported data must be taken in, checked, loaded, analyzed and provided to the public in short order if management is to be implemented based upon better information. Concurrently, we need to upgrade the data collection technology in the basin through more robust information systems, monitoring, and telemetry. Water Division 1 has 6.5 FTEs (full-time equivalents) in the Hydrographic Unit, and it has been estimated that they need 10 to 12 FTEs to do the job currently assigned to them. There is a demonstrated need for two additional fulltime FTEs in Division 1 to focus on the technical aspects of surface and groundwater tabulation and administration and one new senior staff position in DWR to provide leadership for services

focused on water rights tabulation, diversion records, structure location, and electronic workflow processes.

Given that all active tributary irrigation wells in the S. Platte alluvial aquifer are now in court approved augmentation plans, the challenge before us is to determine if there are further mechanisms and innovations to improve groundwater utilization within the context of current law. Replaced pumping depletions that result in waterlogging of agricultural fields or residential neighborhoods do not replace depletions at the river, nor do they meet the true intent of augmentation plans. Continuing to foster rising groundwater levels will inevitably salinize valuable agricultural lands and increase non-beneficial evapotranspiration (ET) by phreatophytes and evaporative upflux, wasting precious water. To the extent possible, groundwater levels should be managed to avoid waterlogging and salinization of fields.

New water storage, both above and below ground, is needed to maximize the potential of the S. Platte system and allow more alluvial groundwater utilization. Municipal and industrial demands in the basin are projected to increase by 340,000 to 510,000 AF/yr by 2050. Given the certainty that water demands will outstrip supplies in the near future, new management tools are needed to allow more effective use of the alluvial aquifer for the benefit of Colorado. Better monitoring, data management, models, and common technical platforms are needed if water management in the S. Platte is to benefit from better science. The South Platte Decision Support System is positioned to facilitate the integration of science in planning and decision-making, but the basin must also be organized to utilize the science. The HB1278 study leads us to the conclusion that the best institutional mechanism for attaining sustainable conjunctive use of surface and groundwater in the S. Platte basin is the formation of a basin-wide authority with the ability to work with all water management organizations, using comprehensive data and the best available science for the good of the entire basin. The recent flood damage in the S. Platte and the recovery challenges water users face in 2014 points to the need for more comprehensive water management that can enable basin-wide cooperative solutions.

HB1278 asked whether management of the system could be improved while respecting senior water rights. In addition to developing information on surface and groundwater use and water levels, HB1278 directed CWI to:

- Provide information to use as a base for implementation of measures to mitigate adverse impacts in areas experiencing high groundwater levels.
- Provide information to the General Assembly, CWCB, and the State Engineer to facilitate the long-term sustainable use of South Platte water supplies.
- Determine whether additional usage of the alluvial aquifer could be permitted in a manner consistent with protecting senior surface water rights.
- Determine whether, and to what extent, the use of water in the basin could be improved or maximized by affording the State Engineer additional authority to administer water rights while ensuring protection of senior surface water rights.

In that context, our recommendations fall into four broad categories: 1. Mitigation of localized high water table conditions; 2. Increasing augmentation plan efficiency; 3. Implementation of basin-wide management; and 4. Recommendations for the State of Colorado, DWR, and CWCB. We recommend that any changes in groundwater management in Division 1 should occur through an inclusive and open process. Further explanation of the recommendations is found beginning on page 177 of the report.

<u>Recommendations</u>

1. Mitigation of localized high water table conditions

   A. *The State Engineer or the Colorado Geological Survey should be delegated responsibility by the General Assembly to provide a consultation to the water court regarding new recharge structures before construction and recommend changes in design or operation when a recharge plan is deemed likely to cause or is causing harm.*

   B. *Two pilot projects should be authorized and funded by the General Assembly to allow the State Engineer to track and administer high groundwater zones for a specified period of time to lower the water table at Sterling and Gilcrest/LaSalle while testing alternative management approaches.*

2. Increasing augmentation plan efficiency

   A. *The State Engineer should be directed by the General Assembly to promulgate new rules for the S. Platte to:*

      1) *Establish a framework for the voluntary movement of excess water supplies between augmentation plans, facilitated by the office of the Division Engineer, including a water bank or pool available for use by augmentation plan users.*

      2) *Establish basin specific guidelines for the implementation of administrative curtailment orders pursuant to 37-92-502(2)(a), C.R.S. that reduce waste and facilitate efficient management and distribution of available water supplies to storage and recharge water rights in the time and place of their need, in accordance with priority and historic practice. The guidelines should:*

         a. *Allow the Division Engineer to use the administrative call as a management tool to increase system efficiency, decrease waste and maximize diversions for beneficial use;*

         b. *Provide for storing water out-of-priority at higher elevation, and managing deliveries to downstream reservoirs as necessary;*

         c. *Minimize seniority, frequency and duration of administrative calls to the full extent consistent with the fulfillment of decreed water rights;*

         d. *Make use of all available data regarding water supply, including ground water levels, to determine the necessary administrative call date for each reach or sub-reach of the river and the alluvial aquifer system.*

3) Develop uniform and transparent reporting standards for augmentation plan accounting designed to integrate with basin data collection, modeling and management.

B. Funding should be authorized to provide the Division 1 Engineer with two additional FTEs and greater annual investment in technology upgrades. Additionally, Colorado DWR needs one additional FTE to focus on data and information services.

3. Implementation of basin-wide management

A. The General Assembly should authorize the establishment of a pilot basin-wide management entity with a defined sunset date.

B. The CWCB, CDA and DWR should work with USGS to implement the basin-wide groundwater monitoring network outlined in this report.

C. The State should cooperate with the S. Platte Basin Roundtable and water organizations in the basin to fund and conduct a helicopter electromagnetic and magnetic survey to produce detailed hydrogeological maps of the S. Platte alluvial aquifer.

D. The State should continue strong support for the development and implementation of the SPDSS and strive to improve accessibility, scope, and robust stakeholder processes.

E. The State should aggressively begin working with water users and other stakeholders in the S. Platte basin to develop multiple-benefit water storage options.

4. Recommendations to the Colorado DWR and the CWCB for improved data collection, data management, and data access

A number of specific recommendations for improving data capture, management, and display are offered to the State based upon our experience on the HB1278 study beginning on page 185 of the report.

The recommendations offered in this report carry fiscal impacts that should be weighed in consideration of their implementation. However, the S. Platte basin faces significant water shortages that will potentially impact Colorado's economic, agricultural and environmental future. The planned conjunctive use of surface and groundwater has the potential to offer benefits in terms of economic, environmental, and social outcomes through increased drought protection, water use efficiency, and the control of shallow groundwater levels and consequent soil salinity. Retrofitting conjunctive use into a prior appropriation system that favors surface water use is made difficult by the many layers of management and local interests that have evolved over time. It is important to acknowledge that most of our water management system is working well. The challenge lies in whether we can move to an even higher level of sustainable utilization. Well users must replace injurious out-of-priority depletions – that is not a matter of

question. The question is whether we are protecting senior rights while utilizing groundwater in a way that optimizes the entire system.

The S. Platte alluvial aquifer provides a storage vessel that far surpasses anything that could feasibly be built in the modern era. However, to avoid over-appropriation of the groundwater resource, the sustainable use of the S. Platte alluvial aquifer requires us to find the right balance between long-term recharge and diversion by pumping. The economic and population growth expected in the S. Platte basin over the next several decades and the anticipated water shortages should compel us to get better organized to capture and store excess flows, reduce waste from nonbeneficial consumptive use, and put the alluvial aquifer to optimum sustainable use.

The data, full report and all appendices for the HB1278 study can be found online at: http://www.cwi.colostate.edu/southplatte.