# HB16-1256
# SOUTH PLATTE STORAGE STUDY

## *Final Report*

***Prepared for the Colorado General Assembly, in coordination with the Colorado Water Conservation Board, the Colorado Division of Water Resources, and the South Platte Basin and Metro Roundtables***

***December 15, 2017***

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# 1. EXECUTIVE SUMMARY

## 1.1 INTRODUCTION

The South Platte Storage Study (SPSS) was initiated as a result of House Bill 16-1256 titled "South Platte Storage Study." It authorizes the Colorado Water Conservation Board, in collaboration with the State Engineer and the South Platte Basin and Metro Roundtables, to identify multi-purpose water storage options along the lower South Platte River to capture flows leaving Colorado in excess of the minimum legally required amounts. The study area for identifying storage options was the lower South Platte Basin between Greeley and the Nebraska State line. Water storage possibilities include new reservoirs, the enlargement/rehabilitation of existing reservoirs, and alternative storage mechanisms (e.g., underground storage).

The study tasks are summarized in **Figure 1-1**. Study methods and preliminary results were reviewed by and coordinated with members of the Colorado Water Conservation Board, Colorado Division of Water Resources, and South Platte Basin and Metro Roundtables through a series of three workshops and informal reviews. Members of these groups reviewed and commented on draft technical memoranda and the final project report.

The SPSS study was conducted by Stantec Consulting Services Inc., with support from Leonard Rice Engineers, Inc. Funding for the study was provided from the Colorado Water Conservation Board Water Supply Reserve Fund.

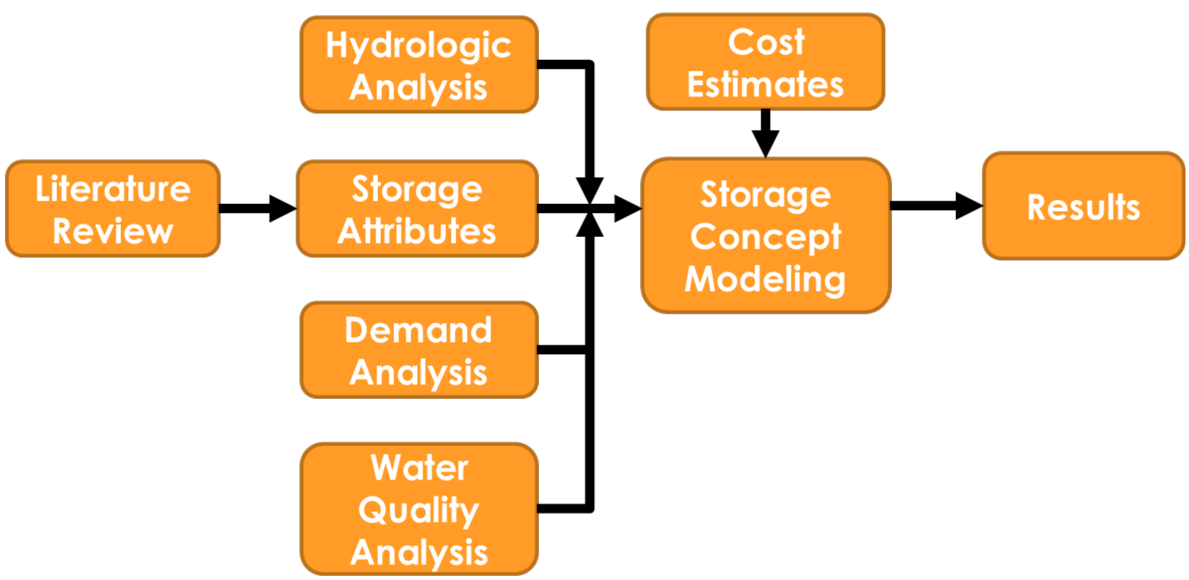



**Figure 1-1 – South Platte Storage Study Approach**

## 1.2 LITERATURE REVIEW

Past studies of storage options in the South Platte Basin were reviewed, and a database of storage options identified in these past studies was assembled. Storage options were categorized as new surface storage, existing surface storage enlargement, existing surface storage restoration, existing surface storage rehabilitation, gravel pit storage, and aquifer storage. After eliminating sites outside the SPSS study area and combining similar storage concepts, 73 surface storage options (excluding gravel pits) and 22 aquifer storage options were selected for evaluation.

## 1.3 LEGAL AND REGULATORY OVERVIEW

Federal, state and local regulations and permits that could affect the feasibility of storage options in the SPSS study area were reviewed and summarized. Key regulations and permits to consider during project development include: U.S. Army Corps of Engineers 404 permit, National Environmental Policy Act, Endangered Species Act, Platte River Recovery Implementation Program, South Platte River Compact, Colorado water rights administration, and local 1041 regulations.

## 1.4 HISTORICAL FLOW ANALYSIS

The historical flows at the Nebraska State line for the period 1996-2015 (water years) were analyzed to estimate the total amount of water leaving Colorado and the amount of water leaving Colorado in excess of the South Platte River Compact. **Table 1-1** shows statistics for total water leaving Colorado and water delivered to Nebraska in excess of the Compact for this 20-year period.

**Table 1-1. Historical Annual Flow for 1996-2015 at Nebraska State Line**

| Statistic | Physical Water Leaving Colorado (Julesburg Gage) | Water Delivered to Nebraska in Excess of the Compact (1)(2) |
|---|---|---|
| Annual Median (ac-ft/yr) | 331,000 | 293,000 |
| Annual Average (ac-ft/yr) | 436,000 | 397,000 |
| Minimum Year (ac-ft/yr) | 29,000 | 10,000 |
| Maximum Year (ac-ft/yr) | 1,957,000 | 1,904,000 |
| Total for 20-yr Period 1996-2015 (ac-ft) | 8,728,000 | 7,939,000 |

*(1) Storable flow Julesburg gage*
*(2) Future environmental flow obligations could reduce legally available water.*

## 1.5 AVAILABLE WATER FOR STORAGE

A daily point flow model was used to compute the amount of water that would be physically and legally available for storage in a new SPSS storage project. Available water was computed for two hydrologic conditions: (1) historical conditions for the 1996-2015 period of record in the point flow model; and (2) future conditions using the same basic hydrology. Future hydrology was estimated by reducing the historical point flow model results by an allowance for Identified Projects and Processes (IPPs) in Colorado's Water Plan and an allowance for existing conditional exchange water rights that have not been executed to date. Statistics defining water available for storage at five locations in the SPSS study area are given in Table 1-2. Estimated future median annual available water is 20-30 percent less than median annual available water in the 20 years between 1996 and 2015. The median is a better statistic to describe typical conditions because there are a few high flow years that skew the average in the study period.

**Table 1-2. Available Water for Selected Locations Based on Historical and Future Hydrology**

| Location | Median Annual Available Water (ac-ft) | Average Annual Available Water (ac-ft) | Available Water in Wet Year (ac-ft) | Available Water in Normal Year (ac-ft) | Available Water in Dry Year (ac-ft) |
|---|---|---|---|---|---|
| | All Years | All Years | 1999 | 2010 | 2002 |
| **Historical Hydrology (1996-2015)** | | | | | |
| South Platte River near Kersey | 165,000 | 262,000 | 707,000 | 378,000 | 14,000 |
| South Platte River near Weldona | 179,000 | 281,000 | 731,000 | 411,000 | 18,000 |
| South Platte River near Balzac | 185,000 | 297,000 | 771,000 | 440,000 | 18,000 |
| Lowline Ditch/Henderson Smith Ditch | 200,000 | 314,000 | 799,000 | 476,000 | 33,000 |
| South Platte River at Julesburg | 289,000 | 397,000 | 951,000 | 627,000 | 79,000 |
| **Future Hydrology Based on IPP and Conditional Water Right Adjustments** | | | | | |
| South Platte River near Kersey | 116,000 | 214,000 | 580,000 | 275,000 | 6,000 |
| South Platte River near Weldona | 127,000 | 231,000 | 601,000 | 303,000 | 9,000 |
| South Platte River near Balzac | 144,000 | 246,000 | 641,000 | 326,000 | 9,000 |
| Lowline Ditch/Henderson Smith Ditch | 154,000 | 261,000 | 666,000 | 357,000 | 15,000 |
| South Platte River at Julesburg | 232,000 | 332,000 | 815,000 | 494,000 | 54,000 |

## 1.6 WATER DEMAND

Maximum potential water demands in the SPSS study area were estimated for use in the subsequent analysis to determine feasible sizes for conceptual SPSS storage projects. Agricultural and municipal & industrial (M&I) demands were estimated for four water districts and counties in the SPSS study area between Denver and Julesburg based on data from the Statewide Water Supply Initiative (SWSI 2010). Maximum demands on SPSS reservoirs were assumed to be equal to the future water supply gap or shortage (difference between demand and supply) for the lower South Platte Basin as reported in SWSI 2010. For purposes of the storage analysis, demands were aggregated at the five key locations on the South Platte River at which available water was estimated. **Figure 1-2** summarizes available supply and maximum potential demand values used for the SPSS analysis. Total median available supply is less than the total shortages in the upper part of the study area; for example, at the Denver gage the median available supply is 5,000 ac-ft compared to total M&I and agricultural water shortages of 106,000 ac-ft. In the lower part of the study area the median available water is greater than the total M&I and agricultural water shortages (232,000 ac-ft median available supply compared to 18,000 ac-ft shortages at the Julesburg gage).

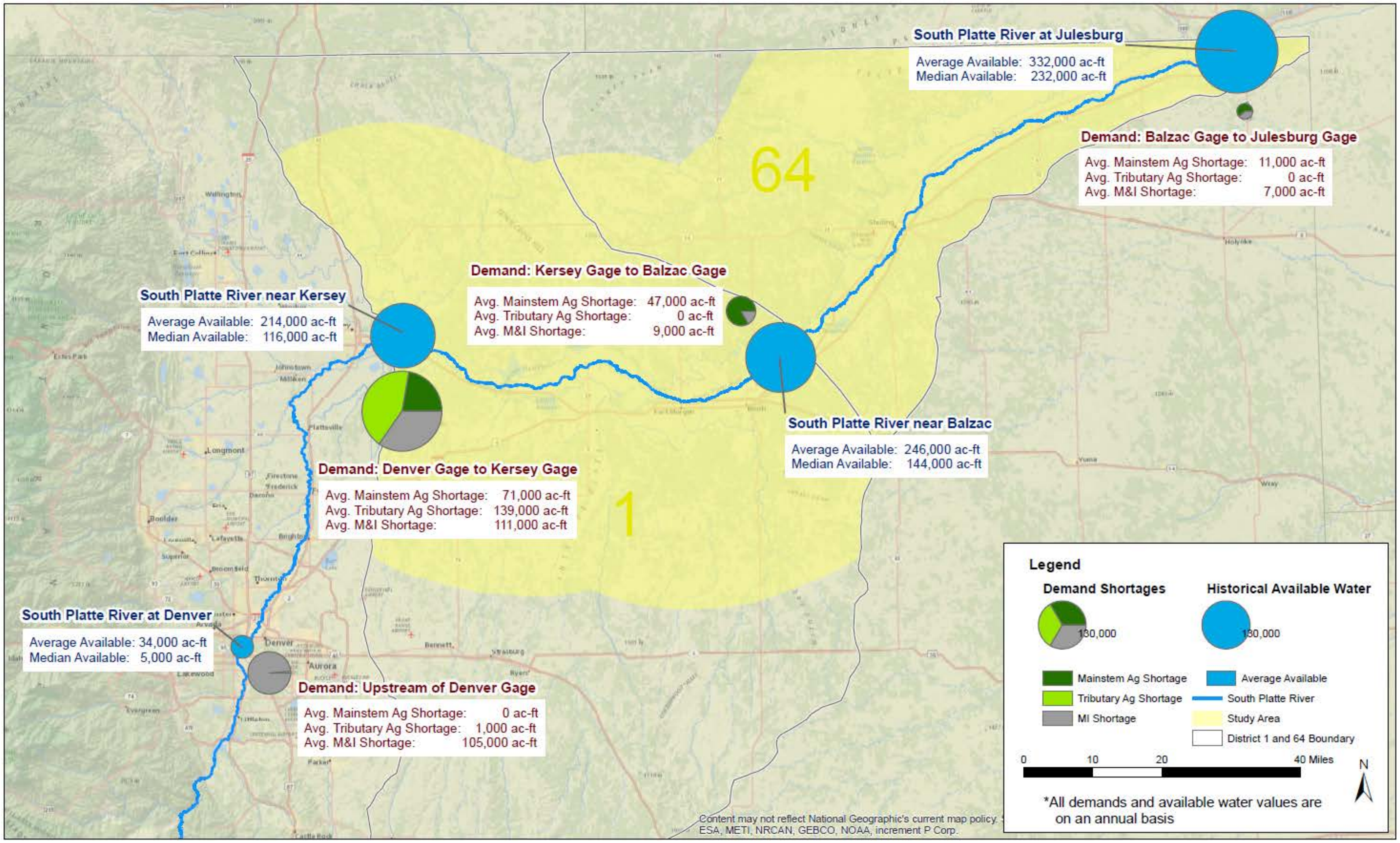



**Figure 1-2. Summary of Available Water and Maximum Potential Demands at Key Locations in SPSS Study Area**

## 1.7 WATER QUALITY

The quality of water available for a new storage project in the lower South Platte Basin could affect the feasibility of putting that water to beneficial use. Similarly, enlarging or rehabilitating existing reservoirs would only be feasible if water quality would be appropriate with treatment for the intended uses.

Existing water quality data for stream segments and reservoirs was reviewed and impaired water bodies based on the state's water quality assessment were identified. Water diverted for storage in the SPSS study area would be adequate quality for irrigation use, as these sources are currently widely used for agricultural purposes. However, if used directly as a drinking water supply, water from any new SPSS storage project would require a high level of treatment (e.g., reverse osmosis, ion exchange) to remove a number of problematic constituents including arsenic, selenium, sulfate, total dissolved solids, and uranium. In addition, water used for aquifer storage in managed groundwater basins would have to be treated prior to recharge to protect existing groundwater quality.

## 1.8 STORAGE OPTIONS

The SPSS evaluation process involved analyzing storage options (individual reservoir or aquifer storage facilities) and more comprehensive storage concepts or solutions. Storage concepts include individual storage options or combinations of storage options integrated with all other infrastructure required to have an operational storage project. Storage options were analyzed first, and the most promising options were incorporated into storage concepts. The overall storage evaluation process is summarized in **Figure 1-3**.

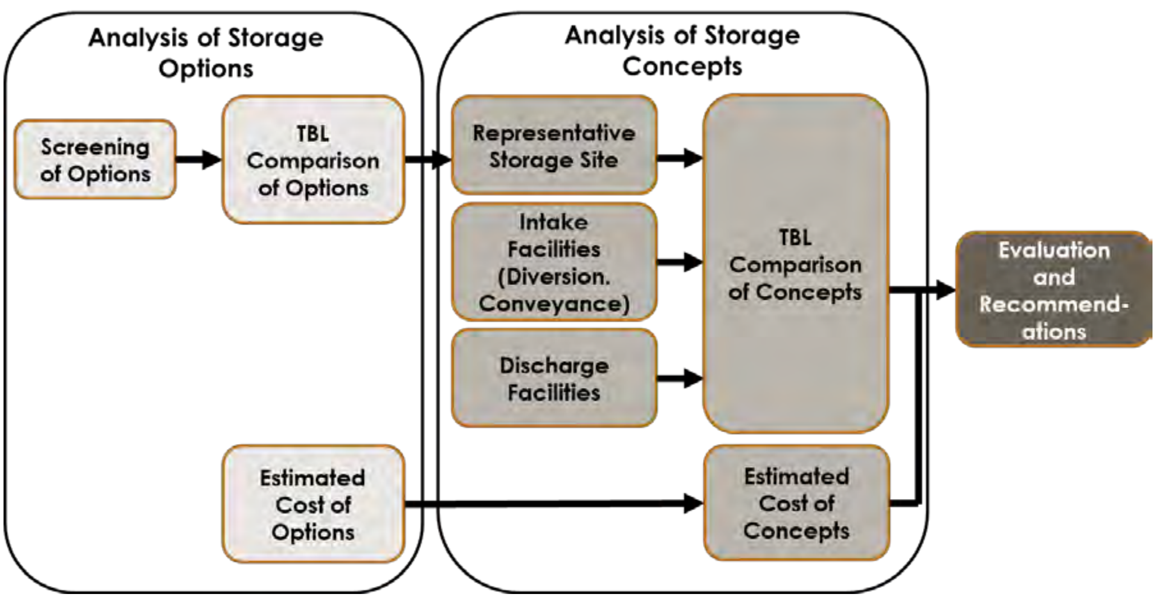



**Figure 1-3. SPSS Storage Evaluation Process Overview**

The long-list of possible storage sites in the SPSS study area was screened to identify those with the most potential for incorporating into SPSS storage concepts. Storage options not selected for use in creating storage concepts are not necessarily infeasible or inferior, depending on the particular application, and should be retained for consideration in any future studies. The storage site screening process is summarized in **Figure 1-4**. Surface and aquifer storage options remaining after the screening process are shown in **Figure 1-5**.

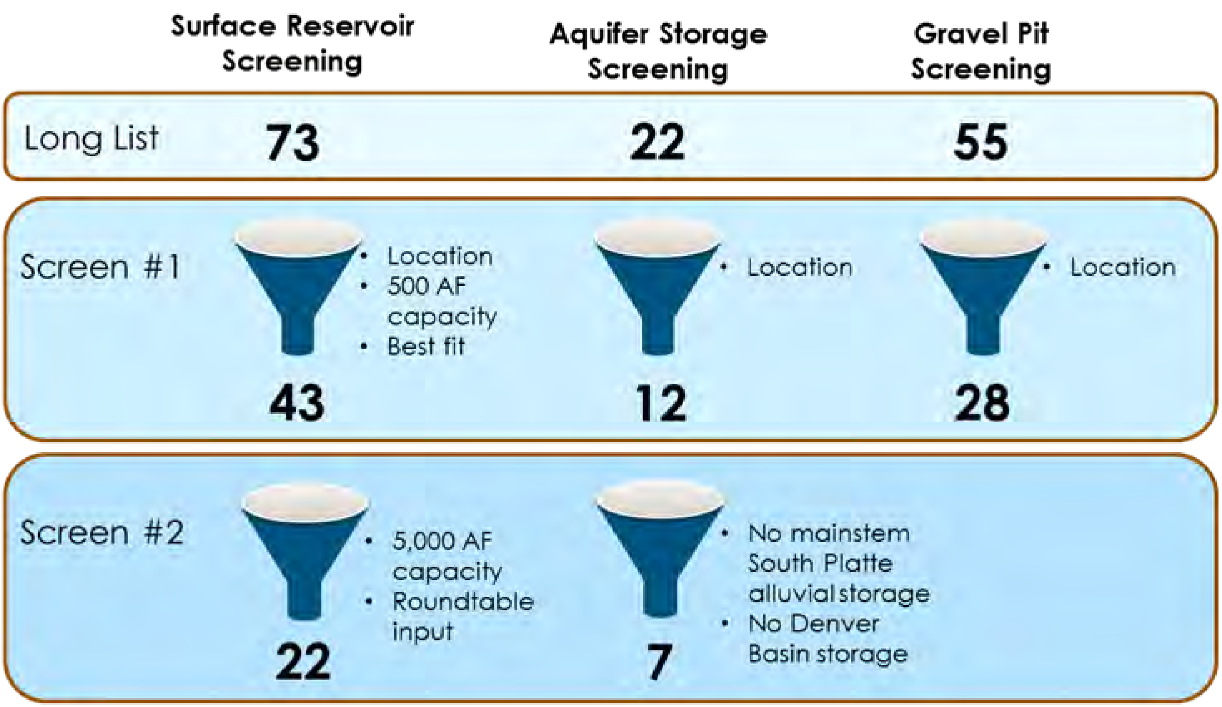



**Figure 1-4. Summary of Storage Site Screening Process**

Storage options were evaluated for 25 technical, environmental and social criteria based on available information on the sites and experience of the project team. Using this triple bottom line (TBL) type of evaluation process usually involves weighting categories of criteria in different ways to explore different value systems of stakeholder groups. For this study three criteria weighting scenarios were tested: equal weights, higher weighted technical criteria, and higher weighted environmental criteria. Most storage options ranked similarly regardless of the weighting scenario. **Table 1-3** lists the average of the scores under the three weighting scenarios. Because storage categories have different characteristics in terms of how they would be developed and operated, it is appropriate to compare sites within categories but not necessarily between categories.

Current cost estimates for surface storage options were developed based primarily on past studies supplemented by additional work by the consultant team. Costs were expressed in 2017 dollars and include permitting, design, land acquisition, and construction, with an accuracy of -50% to +100%. Results are summarized in **Table 1-3**. Costs were not estimated for certain storage options that were not included in storage concepts described later in this report.

Aquifer storage concepts were assumed to be supplemental supply projects that would either work in conjunction with a surface reservoir or be smaller stand-alone projects. To standardize the comparative analysis they were assumed to have infiltration basins with 5,000 ac-ft/month (82 cfs) capacity for recharge and extraction wellfields with 4,000 ac-ft/month (65 cfs) capacity for recovery.

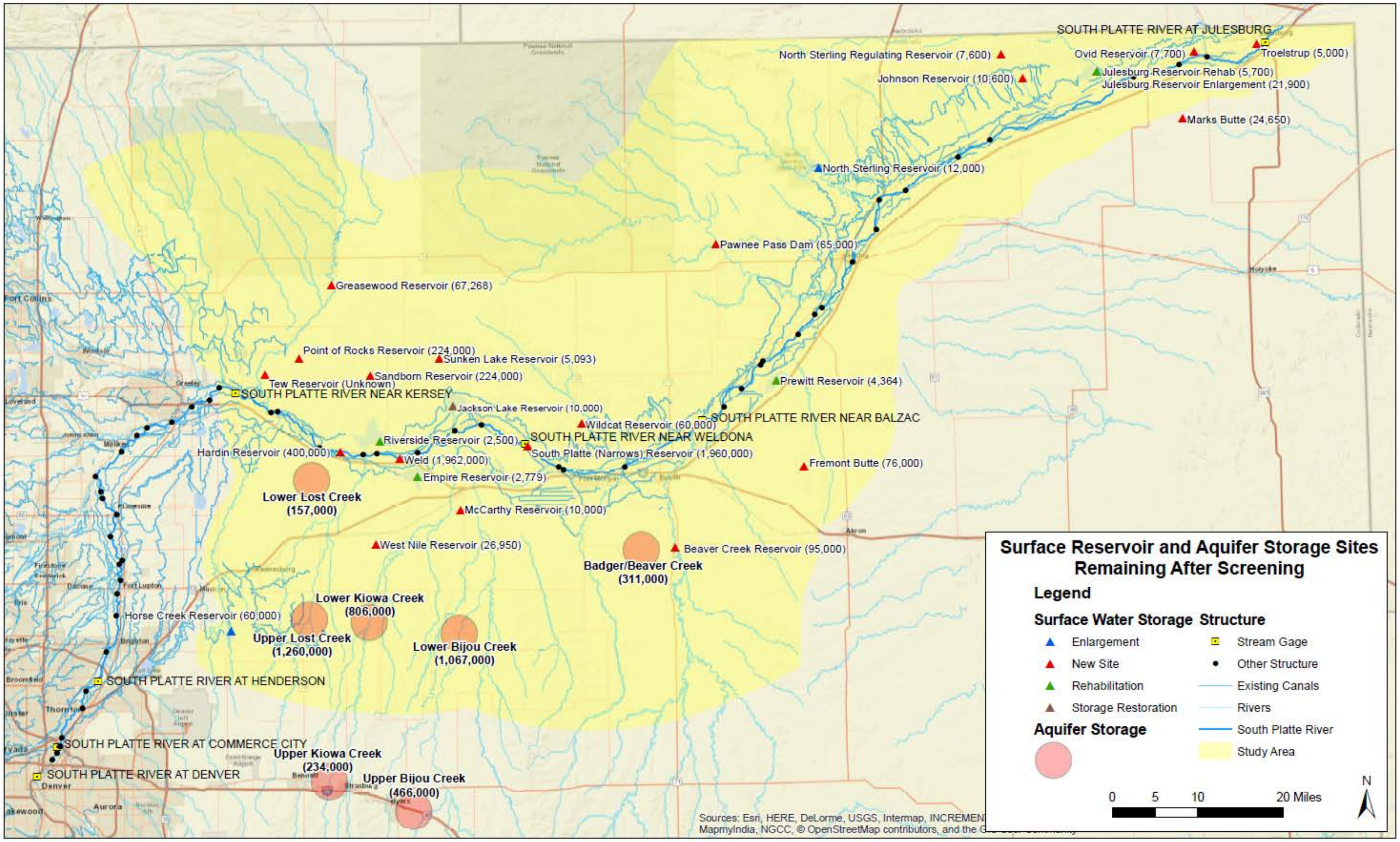



**Figure 1-5. Surface Reservoir and Aquifer Storage Sites Remaining After Screening**

## Table 1-3. Storage Option Costs and Scores

| Storage Type/Name | Storage Capacity (ac-ft) | Estimated 2017 Cost ($ million) | Unit Cost ($/ac-ft) | Average of Scores for 3 Weighting Scenarios (1) |
|---|---|---|---|---|
| **New Site - Mainstem** | | | | |
| South Platte (Narrows) Reservoir | 1,960,000 | $145 | $74 | 11.2 |
| Hardin Reservoir | 400,000 | - | - | 8.7 |
| **New Site – Off Chann** | | | | |
| Sandborn Reservoir | 224,000 | $131 | $580 | 11.0 |
| West Nile Reservoir | 26,950 | $59 | $2,100 | 8.5 |
| McCarthy Reservoir | 10,000 | $27 | $2,500 | 9.3 |
| Wildcat Reservoir | 60,000 | $79 | $1,300 | 14.3 |
| Pawnee Pass Dam | 75,000 | $254 | $3,400 | 10.7 |
| Fremont Butte Reservoir | 76,000 | $74 | $980 | 11.2 |
| North Sterling Regulating Reservoir | 7,600 | $38 | $5,000 | 11.7 |
| Johnson Reservoir | 10,600 | $24 | $2,300 | 11.7 |
| Ovid Reservoir | 7,700 | $24 | $3,100 | 10.8 |
| Troelstrup Reservoir | 5,000 | $19 | $3,700 | 10.8 |
| Beaver Creek Reservoir | 95,000 | $66 | $690 | 13.2 |
| Point of Rocks Reservoir | 224,000 | - | - | 13.5 |
| Sunken Lake Reservoir | 5,100 | - | - | 10.2 |
| Greasewood Reservoir | 67,300 | - | - | 9.8 |
| **Enlargement** | | | | |
| North Sterling Reservoir Enlargement | 12,000 | $22 | $1,800 | 11.7 |
| Julesburg Reservoir Enlargement | 21,900 | $44 | $2,000 | 13.7 |
| **Rehabilitation** | | | | |
| Empire Reservoir Rehab | 2,779 | $14 | $5,000 | 16.0 |
| Prewitt Reservoir Rehab | 4,364 | $5.5 | $1,300 | 14.3 |
| Julesburg Reservoir Rehab | 5,700 | $31 | $5,400 | 17.8 |
| Jackson Lake Reservoir Rehab | 10,000 | $37 | $3,700 | 15.2 |
| Riverside Reservoir Rehab | 2,500 | $13 | $5,200 | 16.0 |

| Storage Type/Name | Storage Capacity (ac-ft) | Estimated 2017 Cost ($ million) | Unit Cost ($/ac-ft) | Average of Scores for 3 Weighting Scenarios (1) |
|---|---|---|---|---|
| **Aquifer Storage** | | | | |
| Lower Lost Creek Basin | 157,000 | $39 | N/A(2) | 19.2 |
| Upper Lost Creek Basin | 1,260,000 | $39 | N/A(2) | 16.7 |
| Lower Bijou Creek Basin | 1,067,000 | $39 | N/A(2) | 17.5 |
| Upper Bijou Creek Basin | 466,000 | $39 | N/A(2) | 13.5 |
| Lower Kiowa Creek Basin | 806,000 | $39 | N/A(2) | 16.0 |
| Upper Kiowa Creek Basin | 234,000 | $39 | N/A(2) | 13.5 |
| Badger/Beaver Creek Basin | 311,000 | $39 | N/A(2) | 15.8 |

*(1) Range of possible scores is 0 – 34.*
*(2) Not applicable. Cost is a function of recharge and extraction hydraulic capacities, not storage capacity.*

## 1.9 STORAGE CONCEPTS

Storage concepts were organized based on the reach of the lower South Platte River in which a storage project would be located, the reach from which water would be diverted, and whether storage would be achieved in a surface reservoir or groundwater basin. Storage concepts consisted of a specific storage option, an approach to capture water from the South Platte River, and an approach to deliver water to meet demands. While hundreds of possible storage concepts could be envisioned in the lower South Platte Basin, eight representative storage concepts were selected to investigate the range of practical storage projects in the region.

Each storage concept was simulated using a MODSIM water resources model developed for this project. To simplify the analysis and focus on differences due to storage options, surface storage concepts had the following consistent features:

- A representative storage option at the maximum physical capacity.
- New dedicated 800 cfs (520 mgd) river diversion with 10,000 ac-ft gravel pit for regulating storage. Although existing irrigation canals could be used to assist in filling some storage options, a detailed analysis of this opportunity was outside the SPSS scope.
- 400 cfs (260 mgd) bi-directional conveyance from intake to storage.
- Release back to river in the bi-directional pipeline to meet downstream demands or exchange to Kersey demand location.
- 150 cfs (100 mgd) conveyance to the Brighton area to meet demands in the Denver metro area.

ASR concepts were limited to a combined inflow rate of 82 cfs (54 mgd) based on the assumed recharge capacity and an outflow rate of 65 cfs (43 mgd) based on the assumed recovery wellfield capacity. All storage concepts were simulated to release water from storage to meet demands as follows.

- First, release to the South Platter River to meet downstream demands.
- Second, exchange to Kersey to meet northern Front Range demands.
- Third, pump to Brighton to meet Denver metro area demands.

No attempt was made in this study to optimize infrastructure or operational assumptions for any of the concepts. The new MODSIM model was used to estimate the firm yield for the eight selected storage concepts. Table 1-4 provides a short description of each storage concept, and the annual firm yield (yield that can be delivered every year) with and without a pipeline to Brighton. This pipeline is an expensive component of any solution so firm yield with and without this component was computed.

### Table 1-4. Storage Concept Annual Yield for Maximum Capacity of Representative Storage Sites

| Storage Concept | Representative Storage Site(s) | Diversion Reach | Limiting Capacity | Annual Firm Yield with Pipeline to Brighton (ac-ft/yr) | Annual Firm Yield without Pipeline to Brighton (ac-ft/yr) |
|---|---|---|---|---|---|
| **Surface Reservoir Concepts** | | | | | |
| Mainstem Storage | South Platte (Narrows) | Greeley-Weldona | 1,960,000 ac-ft | 62,000 | 47,000 |
| Upper Basin Storage | Sandborn | Greeley-Weldona | 224,000 ac-ft | 22,000 | 20,000 |
| Mid Basin Storage North | Wildcat | Weldona-Balzac | 60,000 ac-ft | 9,000 | 7,000 |
| Mid Basin Storage South | Beaver Creek | Weldona-Balzac | 95,000 ac-ft | 11,000 | 8,000 |
| Lower Basin Storage | Julesburg, Ovid, Troelstrup | Balzac-Julesburg | 40,300 ac-ft | 24,000 | 24,000 |
| Existing Reservoir Improvements | Riverside, Jackson, Prewitt, Julesburg, North Sterling | Greeley-Weldona Weldona-Balzac Balzac-Julesburg | 56,464 ac-ft | 17,000 | 15,000 |
| **Aquifer Storage Concepts** | | | | | |
| Groundwater Basin Storage West – Recharge Limited | Lower Lost Creek Aquifer | Greeley-Weldona | 5,000 ac-ft/month recharge | 8,400 | 8,400 |
| Groundwater Basin Storage East – Recharge Limited | Beaver/Badger Aquifer | Weldona-Balzac | 5,000 ac-ft/month recharge | 8,000 | 8,000 |

Similar to the evaluation of storage options, storage concepts were evaluated for 20 TBL criteria based largely on the criteria listed in HB16-1256, and total costs for all components included in the concepts. Table 1-5 summarizes storage concept costs and TBL scores. Cost estimates include the following assumptions:

- No water treatment costs are included for water delivered to the Brighton or Kersey demand nodes for M&I use.
- Additional infrastructure needed to convey water from Brighton or Kersey to ultimate project beneficiaries is not included.
- All concepts only make use of new diversion structures and intakes. Any potential for use of existing irrigation canals is not considered.
- All concepts include an expensive pipeline and pumping system to Brighton in order to maximize the yield and allow for an even comparison of storage options. Eliminating the pipeline reduces firm yield by 0 to 15,000 ac-ft/yr, and reduces total storage concept cost by $280M - $780M.

**Table 1-5. Summary of Storage Concept Costs for Maximum Representative Storage Sites**

| Storage Concept (Representative Sites) | Storage Capacity (ac-ft) | Storage Cost ($M) | Intake System Cost ($M) (Diversion, Gravel Pits, Pipes, Pump) | Delivery System Cost ($M) (Pipe to Brighton, Kersey Gravel Pits) | Total Storage Concept Cost ($M) | Total Unit Cost ($/AFY Firm Yield) | TBL Score (Range: 0-20) |
|---|---|---|---|---|---|---|---|
| **Surface Reservoir Concepts** | | | | | | | |
| Mainstem Dam (Narrows) | 1,960,000 | $145 | $0 | $380 | $525 | $8,500 | 11.5 |
| Upper Basin Storage (Sandborn) | 224,000 | $131 | $168 | $322 | $621 | $28,000 | 12 |
| Mid Basin Storage North (Wildcat) | 60,000 | $79 | $141 | $433 | $652 | $72,000 | 11 |
| Mid Basin Storage South (Beaver) | 95,000 | $66 | $407 | $437 | 910 | $83,000 | 11 |
| Existing Reservoirs (Riverside, Jackson, Prewitt, Julesburg, North Sterling) | 40,300 | $121 | $221 | $322 | $662 | $39,000 | 10 |
| Lower Basin Storage (Julesburg, Ovid, Troelstrup) | 56,464 | $118 | $92 | $826 | $1,037 | $43,000 | 8 |
| **Aquifer Storage Concepts** | | | | | | | |
| Groundwater Storage West (Lost Creek) – Recharge Limited | 157,000 | $39 | $238 | $158 | $435 | $52,000 | 12 |
| Groundwater Storage East (Badger/Beaver) – Recharge Limited | 311,000 | $39 | $160 | $270 | $469 | $59,000 | 10.5 |

## 1.10 CONCLUSIONS AND RECOMMENDATIONS

### 1.10.1. Conclusions

#### 1.10.1.1 Available Water, Demand and Water Quality

The following conclusions relate to available water in the SPSS study area.

1. A large supply of water is available for beneficial use in the lower South Platte Basin. Between 1996 and 2015, an annual median of approximately 293,000 ac-ft/yr of water was delivered to Nebraska in excess of the South Platte Compact. Excess available water varied between 10,000 ac-ft/yr and 1,904,000 ac-ft/yr over this period.
2. Under future conditions, average annual water available for diversion to a new storage project would vary from approximately 214,000 ac-ft/yr at Kersey to 332,000 ac-ft/yr at Julesburg. Median annual available water would vary from approximately 116,000 ac-ft/yr at Kersey to 232,000 ac-ft/yr at Julesburg, highlighting the influence of a few high runoff years on streamflow statistics in the South Platte Basin.
3. Annual streamflows in the study area are characterized by a few very high flow years. A large mainstem dam or several off-stream dams with large diversion structures would be required to capture a large portion of the available streamflow.
4. Available water at Kersey is much less than at Julesburg due to return flows in the lower basin. A large lower basin reservoir(s) would be required as part of a storage scheme to capture a large portion of available flow upstream of the state line.
5. Because the vast majority of storage options are located off the main South Platte River channel, physically available water is constrained by the diversion capacity and the capacity of conveyance facilities from the river to the storage reservoir. Large diversion and conveyance structures would be needed to capture and convey water from the river to off-channel storage. At the Balzac gage near the middle of the SPSS study area, a diversion capacity of 550 cfs would be needed to capture 85 percent of the available water.
6. Future water shortages in the lower South Platte Basin based on the water supply gap estimated in SWSI 2010 are significant, and exceed the estimated available water in the future. Annual municipal and agricultural demands that could potentially be served by water from a SPSS storage project total over 502,000 ac-ft/yr for the Denver Metro Area, the Northern Front Range Region, and the lower South Platte basin below Greeley.
7. Water quality throughout the SPSS study area is adequate for agricultural use but would require advanced water treatment for direct municipal use.

#### 1.10.1.2 Storage Options and Concepts

Conclusions related to the SPSS analysis of storage opportunities in the lower South Platte Basin are summarized as follows.

1. Many off-channel storage options are feasible and can be combined in a wide variety of water supply concepts.
2. Firm yields of 9,000 ac-ft/yr to 62,000 ac-ft/yr were estimated for the representative storage concepts analyzed for this study.
3. Capital costs for storage concepts range from $7,400 to $78,200/ac-ft/yr, exclusive of treatment costs, with a pipeline to Brighton. Without the pipeline to Brighton the concept costs range from $3,300 to $47,000/ac-ft/yr exclusive of treatment costs. The upper end of this range greatly exceeds the cost of recent water development projects in Colorado.
4. Not surprisingly, a large mainstem reservoir has the best performance in terms of putting the state's water to beneficial use. However, permitting obstacles may be insurmountable.
5. Aquifer storage projects are more limited by recharge and recovery rates rather than storage volume. Typical aquifer storage projects are designed as supplemental supply sources, not as projects to recharge large volumes of water diverted during peak spring snowmelt periods. This results in lower firm yield, and does not attempt maximize use of potential storage capacity as occurs with surface reservoirs. However, a related benefit is that aquifer storage projects are relatively low cost and can be scaled up over time (not constructed all at once). These unique characteristics make aquifer storage projects difficult to compare to surface water storage projects.
6. Storage options lower in the basin tend to be more efficient (better storage:yield ratio) because there is more water available. However they are further from the main demand centers.
7. Combinations of storage options working conjunctively can provide significantly more benefit than individual options. A combination of upper basin and lower basin storage concepts rivals the large mainstem dam option for firm yield benefits. However, there will be reduction in efficiency as the number of projects goes up, and even with multiple storage project a large amount of available water would leave Colorado.
8. No feasible storage concepts or reasonable combinations of concepts are capable of putting all the available flow in the lower South Platte River to beneficial use. This is shown in **Table 1-6**. Therefore as a general principle, more storage will always be "better" in this region in terms of maximizing available supply for basin water users.

## Table 1-6. Water Leaving the State under Future Hydrology for Simulated Storage Concepts

| Storage Concept | Median Annual Water Leaving State (ac-ft) | Percentage of Available Water Contributing to Beneficial Use (1) |
|---|---|---|
| No Storage | 249,000 | - |
| Mainstem Storage | 150,000 | 51% |
| Upper Basin Storage | 210,000 | 19% |
| Mid Basin Storage North | 196,000 | 21% |
| Mid Basin Storage South | 192,000 | 22% |
| Lower Basin Storage | 78,000 | 44% |
| Existing Reservoir Improvements | 100,000 | 50% |
| Groundwater Basin Storage West | 213,000(2) | 18% |
| Groundwater Basin Storage East | 196,000(2) | 21% |

*(1) Includes evaporation losses and other losses which would not be beneficial uses*
*(2) Assumes maximum size to capture peak spring runoff. Actual projects would be smaller and leave more water at the state line.*

9. Because nearly all concepts require off-channel storage and diversion from the South Platte River, intake capacity constraints can be important and there are benefits to having multiple off-channel storage projects to minimize the effects of these constraints.
10. Enlargements and rehabilitations of existing reservoirs tend to score higher than new reservoirs in the multi-criteria ranking process.
11. Triple bottom line scores for the storage sites analyzed in this study were fairly similar at this level of analysis without specific information on how the sites would be used in a water supply strategy; thus the triple bottom line scoring process should not be used to eliminate options at this time.
12. Any of the storage concepts could be candidates for further study in the future under the right circumstances. However, concepts with more storage higher in the basin generally offer a greater potential for benefits and could be more attractive to a broader variety of potential participants.
13. Multiple large storage projects, including one low in the basin, would be required to capture a substantial amount of the available water above the state line.
14. Even a combination of conjunctively operated storage projects would not be capable of addressing the majority of the combined overall M&I and agricultural water supply gaps in the South Platte Basin.

### 1.10.2. Recommendations

The SPSS team developed the following recommendations for future work.

1. Better estimates of future hydrology should be developed to refine the anticipated available water under future basin operations. Completion of the South Platte Decision Support System would facilitate further hydrologic and operational studies.
2. Exchanges will be important to making storage work cost effectively for many applications. A more robust method of estimating future exchange potential may be needed to refine this important aspect of the analysis.
3. Site-specific and owner-specific analyses will be needed when particular project opportunities are identified in the future. The work in the SPSS is a starting point for more specific alternative investigations, but substantial additional analysis will be required to test the feasibility of specific storage options based on points of diversion, intake systems, and methods of operating to meet demands.
4. Aquifer storage and recovery projects will require site specific aquifer characterization and pilot testing. Pilot testing and preliminary design can begin at a relatively low cost due to the scalability of ASR systems.
5. Using existing irrigation canals to fill storage sites could significantly reduce infrastructure costs for some concepts. Partnerships with irrigation companies and available canal capacities should be investigated further.
6. Cooperative storage projects with multiple users, multiple components and multiple purposes would have the best chance of success. The state, Roundtables and water users should continue to explore opportunities for cooperative multi-use storage projects in the lower South Platte Basin.
7. Gravel pit storage opportunities were not considered in detail in this study. Gravel pits have been used extensively for storage along the South Platte River upstream of Greeley. An investigation of gravel pit storage opportunities downstream of Greeley may be warranted.
8. Use of water from SPSS storage projects directly for M&I use would require advanced water treatment. Recharge into aquifer storage would also require treatment. Additional investigation is required into the feasibility of available advanced treatment processes on water quality from the study area, particularly in the further downstream reaches of the South Platte River.
9. Investigation is warranted into how storage could support future implementation of alternative transfer method (ATM) projects per recommendations in the South Platte Basin Implementation Plan. Most or even all ATM project would need storage to increase yield and project efficiency. Investigation is needed into how new storage projects could be utilized in combination with ATMs to efficiently store and deliver available water as well as water provided from ATM projects. This combination could potentially make both new storage and ATM projects more feasible and help meet the water supply gaps in the basin.
10. Future storage projects would have an impact on Colorado’s water obligation to the PRRIP. Membership in SPWAP in addition to coordination with the State of

Colorado and SPWAP would be necessary to comply with all PRRIP mitigation requirements for new South Platte water storage projects. Further investigation into SPWRAP effects of new storage projects is recommended.

11. This study did not simulate conjunctive operation of a large surface storage project with an ASR project. Benefits of conjunctive use should be investigated.
12. This study did not evaluate potential supplies or storage opportunities upstream of Kersey on the South Platte River or Poudre River. Extending the water availability study and the investigation of potential storage options upstream of Kersey on the South Platte River and Cache la Poudre River should be considered.

# 2. INTRODUCTION

The South Platte Storage Study (SPSS) was initiated as a result of House Bill 16-1256 titled "South Platte Storage Study." HB16-1256, provided in **Appendix A**, was signed into law by the Governor on June 9th, 2016. It authorizes the Colorado Water Conservation Board (CWCB), in collaboration with the State Engineer (SEO) and the South Platte Basin and Metro Roundtables, to identify multi-purpose water storage options along the lower South Platte River to capture flows leaving the state in excess of the minimum legally required amounts. The study area for identifying storage options was the lower South Platte Basin between Greeley and the state line. The study area is shown in **Figure 2-1**. Water storage possibilities include new reservoirs, the enlargement/rehabilitation of existing reservoirs, and alternative storage mechanisms (e.g., underground storage).

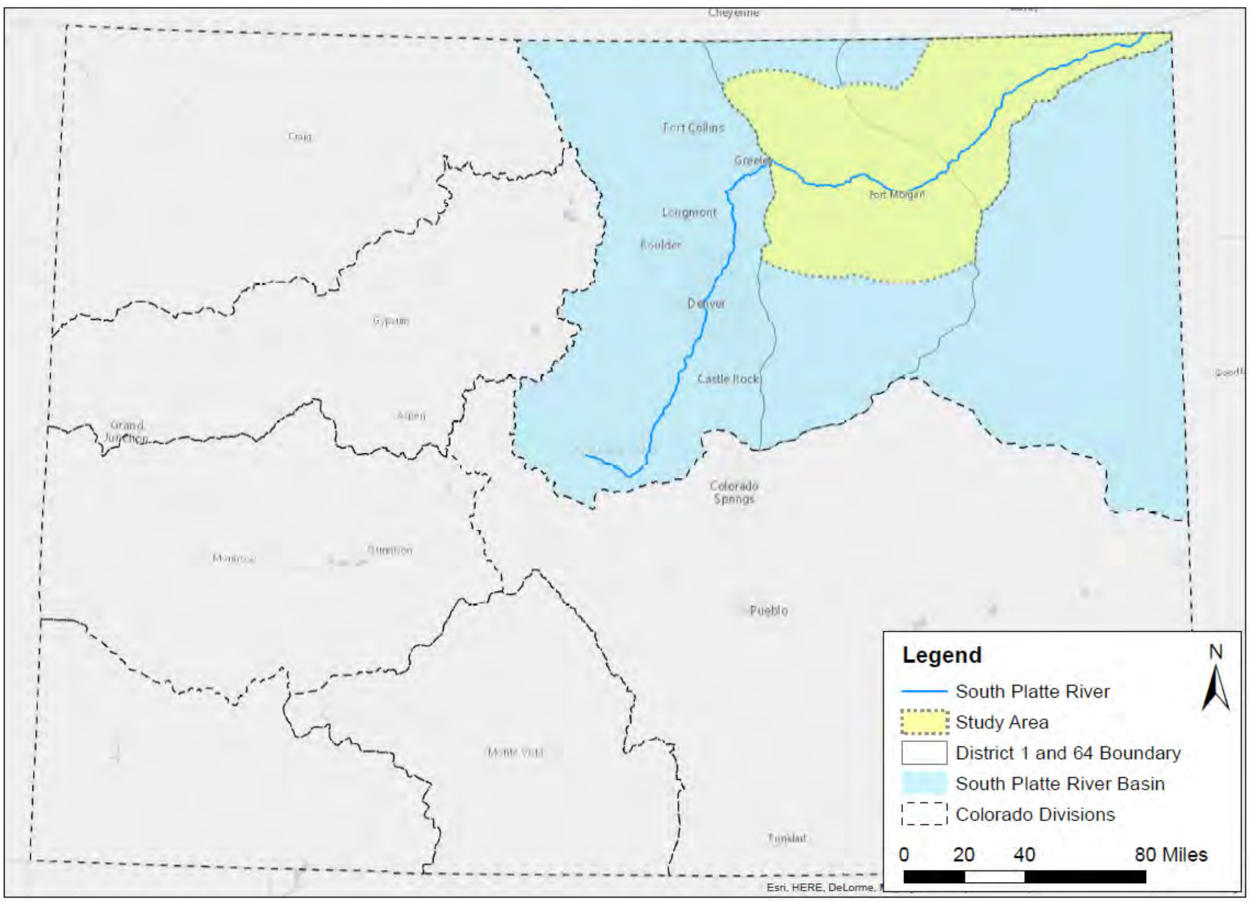



**Figure 2-1. Study Area for South Platte Storage Study**

This report presents a summary of the analysis and results of the SPSS. Detailed descriptions of technical approaches and preliminary results for specific topics were provided in technical memoranda (TM) during the course of the project. These TMs are included as appendices to this report. The study approach is summarized in **Figure 2-2**.

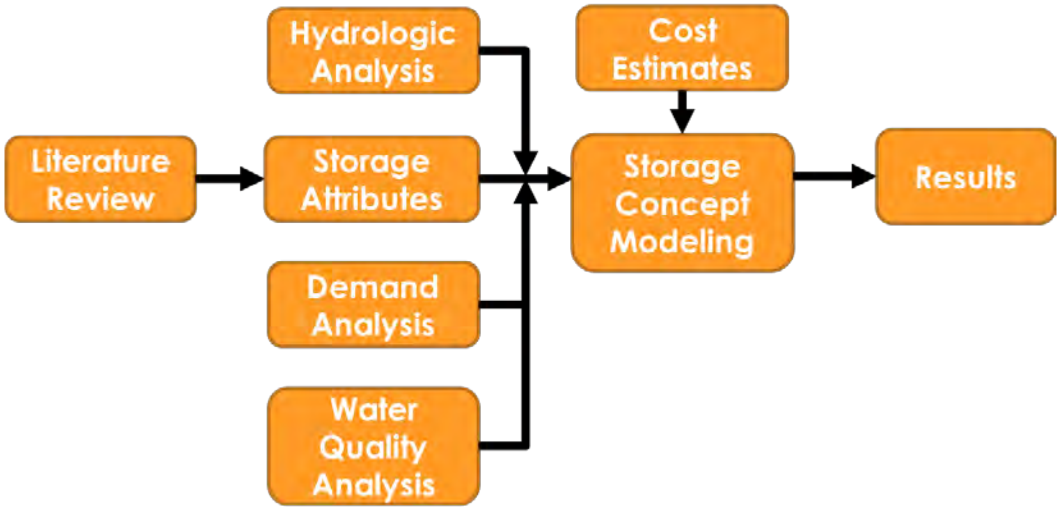



**Figure 2-2. South Platte Storage Study Approach**

Study methods and preliminary results were reviewed by and coordinated with representatives of the Colorado Water Conservation Board (CWCB), Colorado Division of Water Resources (CDWR), and the South Platte Basin and Metro Roundtables. Three workshops were held with representatives of these groups to present preliminary findings and receive direction on future tasks. They also provided reviews of draft technical memoranda and the final project report.

The SPSS study was conducted by Stantec Consulting Services Inc., with support from Leonard Rice Engineers, Inc. Funding for the study was provided from the Colorado Water Conservation Board Water Supply Reserve Fund.

# 3. PREVIOUS STUDIES

## 3.1 INTRODUCTION

Storage opportunities in the South Platte Basin have been studied by a variety of different agencies, including the state and individual water users. Some of these past studies sought to address broad regional water needs (e.g., the South Platte Basin Implementation Plan (HDR/West Sage, 2015)), while others were conducted by individual water users to meet their own storage needs. In some cases, those storage opportunities were part of water users' long term plans and are included in Colorado's Water Plan (CWCB, 2015) as Identified Projects and Processes (IPPs). In other cases, storage opportunities were ruled out by the water user that studied them because they did not meet the needs of the water user. These storage opportunities previously ruled out have been included herein because they could be an opportunity for others.

## 3.2 SOURCES OF INFORMATION

The sources of information reviewed for this study are listed in **Appendix B**. Pertinent information for storage sites was extracted from a variety of reports and databases. Reports covering areas throughout the basin were reviewed, but the emphasis was on storage options in the designated SPSS study area between Greeley and the state line.

## 3.3 STORAGE SITE CLASSIFICATION

Storage sites found in the literature review were separated into three main categories: surface storage sites, aquifer storage sites, and gravel pit sites. Gravel pit storage was separated from the surface storage category because it was treated differently in this study, as described below. For the purpose of this study, gravel pit storage was evaluated based on general geographic location, not as individual sites.

### 3.3.1. Surface Storage Sites

Surface storage sites were classified into four sub-categories to help identify opportunities for this project. Sub-categories for surface storage opportunities were enlargements of existing reservoirs, identified new reservoir sites, existing reservoirs with rehabilitation potential, and existing reservoirs with storage restoration potential. These categories are defined in **Table 2-3**.

Storage sites identified as IPPs in Colorado's Water Plan are included in the inventory. Although the water users promoting these IPPs may be planning to use all the potential storage capacity, there may be opportunities for further enlargements of these reservoirs to incorporate the needs of additional partners. Additional analysis will need to be performed to determine if IPP sites can potentially be enlarged for use by others.

Storage projects identified in other studies that were screened out for that project purpose could still be feasible for this study and were included in the inventory.

### Table 2-3. Surface Storage Category Definitions

| Category | Description |
|---|---|
| **Enlargement** | This group includes existing reservoirs that have been previously studied to determine feasibility of an enlargement. If available, information such as enlarged capacity and enlargement feasibility from previous enlargement studies was captured for use in this investigation. |
| **New Site** | These are sites where a new surface storage facility could be feasible. Information such as potential reservoir capacity and feasibility from previous studies is usually available. |
| **Rehabilitation** | These sites are existing reservoirs that have a storage restriction imposed by the State of Colorado Dam Safety Branch. By rehabilitating the dams at these locations, the storage restrictions could be removed and additional storage would then become available. |
| **Storage Restoration** | Sites in this category include existing reservoirs that have reduced storage capacity due to sedimentation. Storage capacity at these sites could be recovered by dredging the sediment and disposing it. |

### 3.3.2. Aquifer Storage Sites

This group of storage sites includes options that use deep confined or shallow unconfined aquifers to store water. For this summary these sites are represented by a single point on a map, but in reality aquifer storage could occur over a broad area in the aquifer porous space underground. These options require points of recharge and extraction that were analyzed when formulating the storage concepts.

### 3.3.3. Gravel Pit Storage

Gravel pit storage sites were separated from the surface water storage category because they were treated differently than the larger surface reservoir options in this study. The individual gravel pit storage options are small and were not considered for long term storage on their own; however, groups of individual gravel pits in the same general area could be combined into a larger storage complex that could provide sufficient capacity to meet the needs of this study. In addition, these sites may be used to support other storage solutions, for example by providing temporary storage to hold exchange water until it can be exchanged further upstream. For purposes of this storage site inventory, gravel pit locations were mapped separately from other surface reservoir options so locations of possible gravel pit complexes could be considered later in the project.

## 3.4 SUMMARY OF REVIEWED STORAGE SITES

The potential surface storage sites in the South Platte River Basin cataloged in this literature review are listed in **Appendix B**.

**Figure 3-1** shows potential new, enlarged, rehabilitated and restored surface storage sites in the SPSS study area. **Figure 3-2** shows cataloged aquifer storage options for the SPSS study area. Locations indicated on the map are representative of the general aquifer locations; aquifer spatial boundaries are not depicted. **Figure 3-3** shows active permitted sand, gravel, sand and gravel, or construction borrow material mines in the SPSS study area that could be developed as gravel pit storage.

A total of 73 surface storage options (excluding gravel pits) and 22 aquifer storage options were found in the SPSS study area through the Literature Review. Individual surface storage options in the study area vary from 3 ac-ft to 1,962,000 ac-ft of additional storage capacity, and include sites on the South Platte mainstem, on primary tributaries, and in tributary drainage areas. The inventory includes:

- 62 new reservoir sites
- 6 existing reservoir enlargements
- 4 existing reservoir rehabilitations
- 1 existing reservoir restoration
- 22 aquifer storage options
- 55 permitted gravel mining sites

Some of these options are similar (e.g., different nearby reservoir sites on the same tributary) and were filtered into a single option during the storage site evaluation.

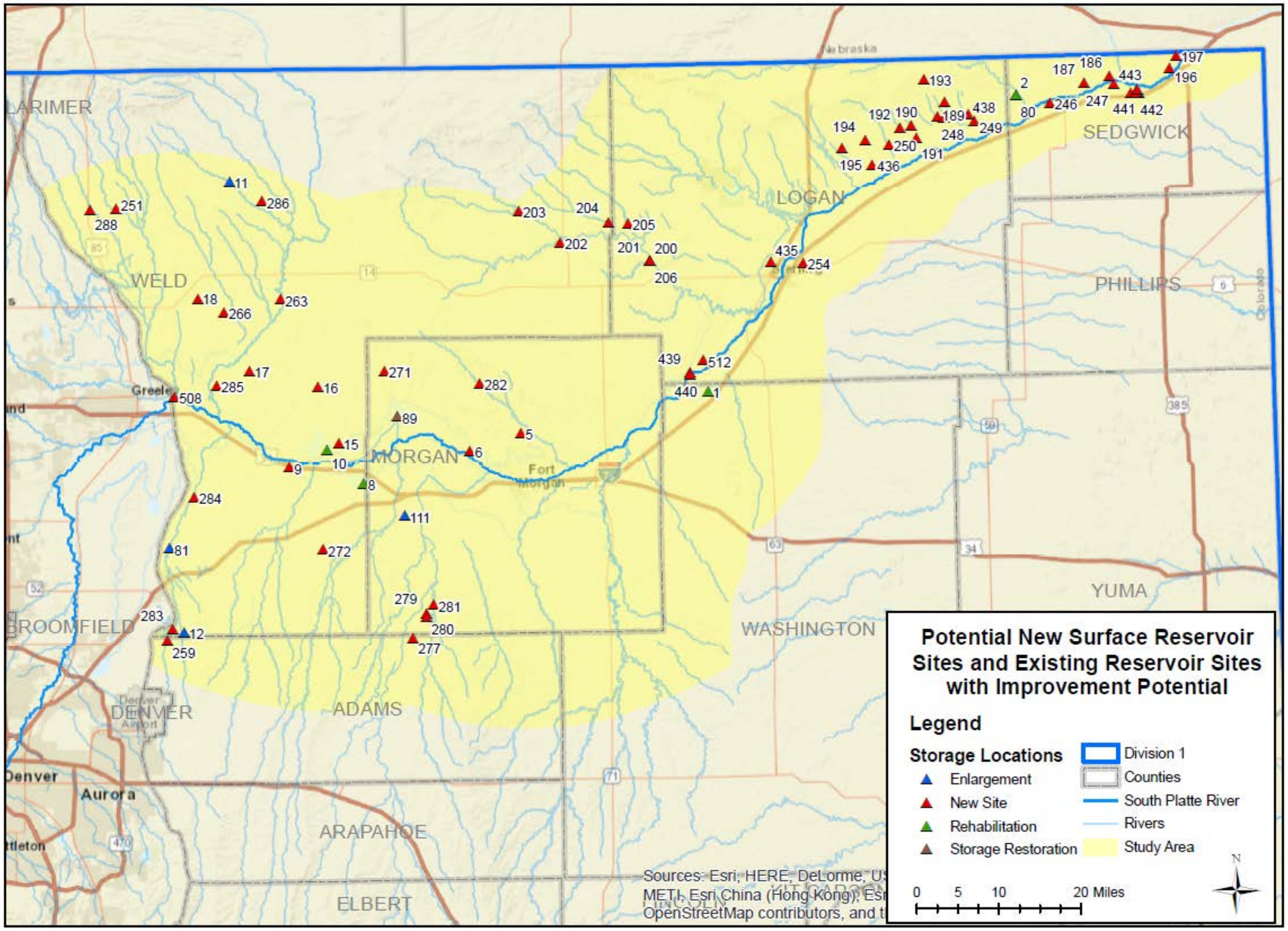



**Figure 3-1. Cataloged Sites Where New Surface Storage Could be Developed in the Study Area**

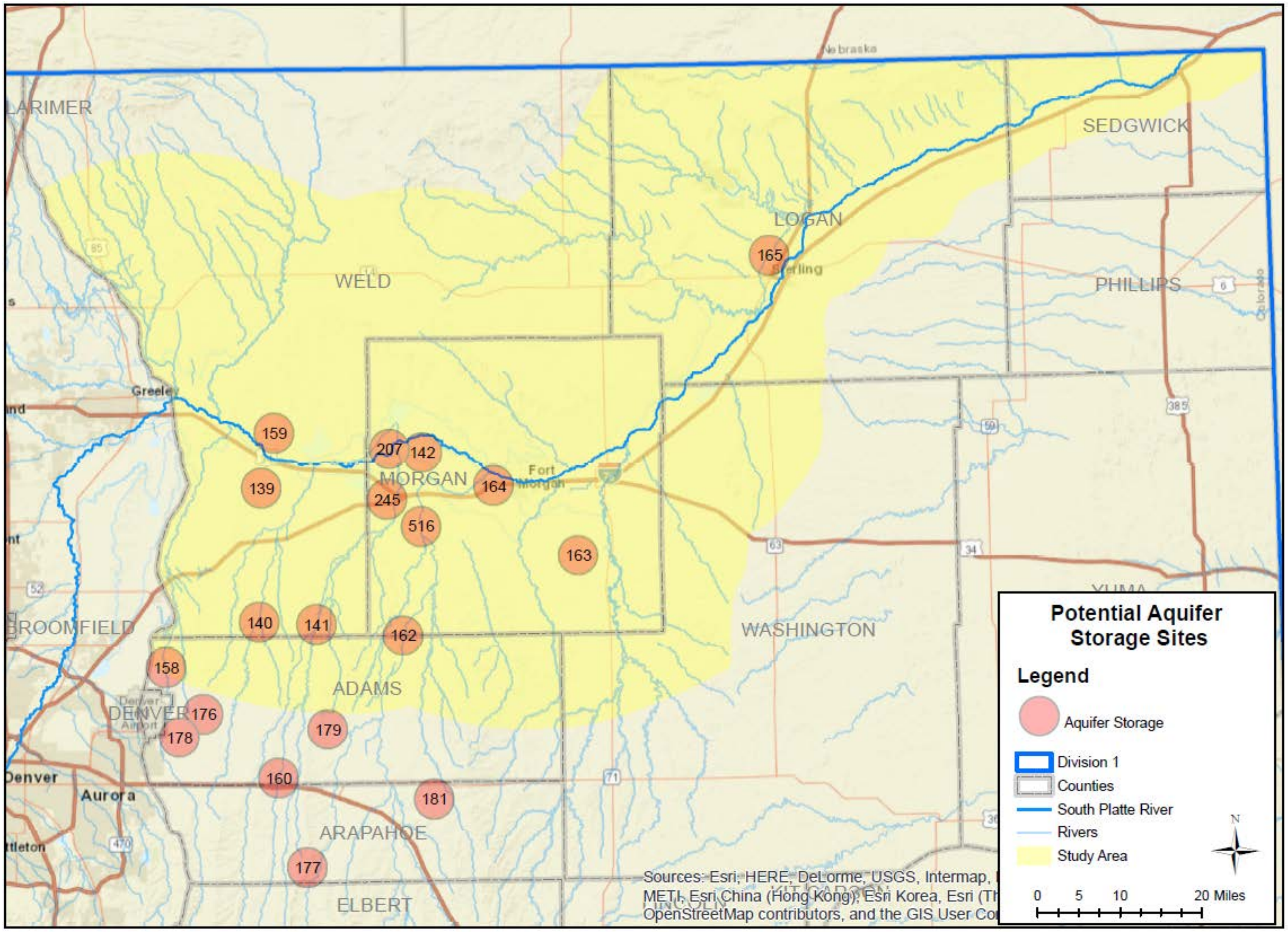



**Figure 3-2. Cataloged Aquifer Storage Sites in or Near the Study Area**

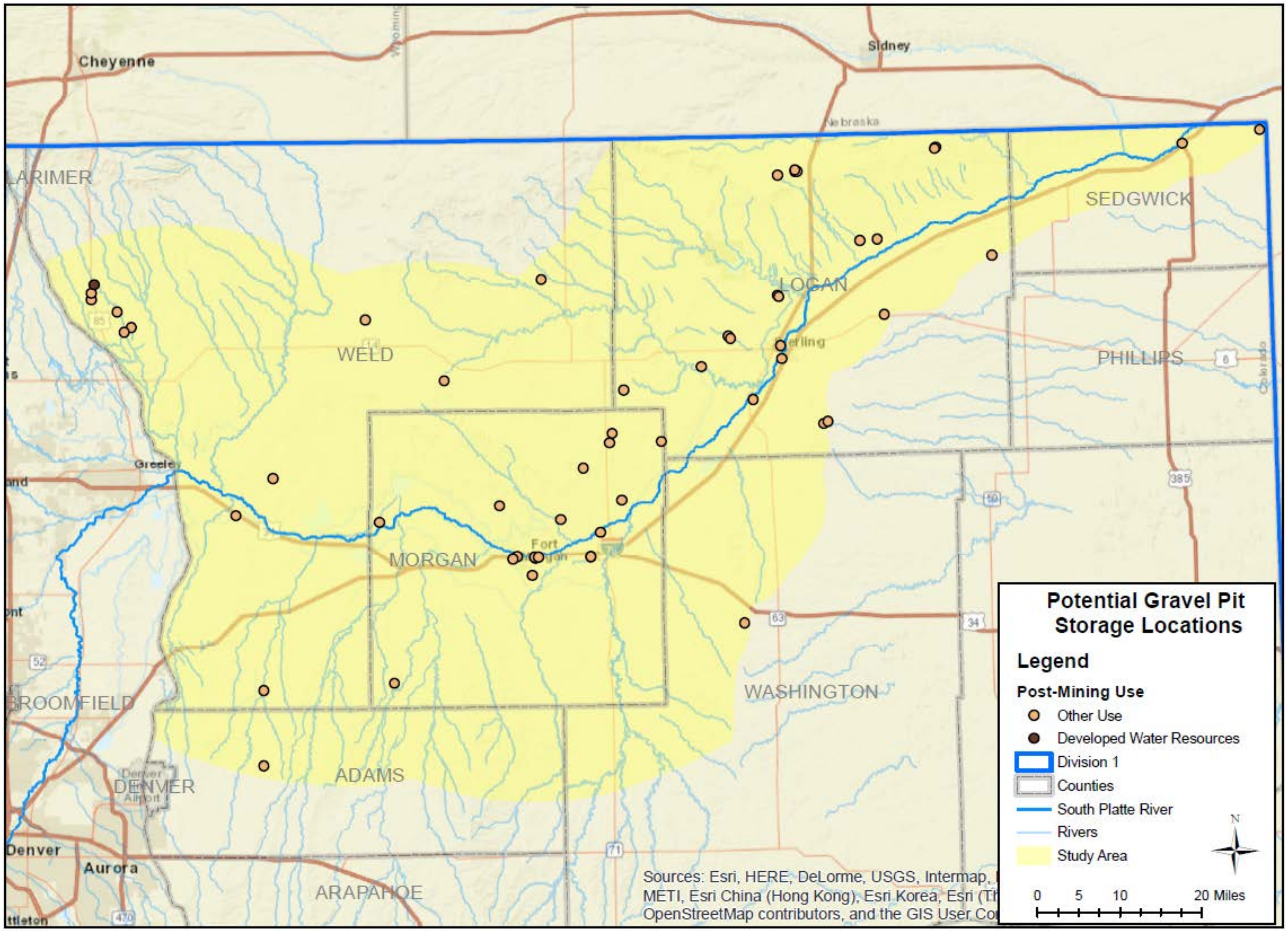



**Figure 3-3. Potential Gravel Pit Storage Sites in the Study Area**

# 4. LEGAL AND REGULATORY OVERVIEW

A review was performed of legal and regulatory factors affecting planning and implementation of potential water storage projects in the South Platte Basin. The review focused on how federal, state and local laws and regulations influence SPSS planning. Results are presented in detail in **Appendix C** and summarized below.

## 4.1 FEDERAL LAWS AND REGULATIONS

**National Environmental Policy Act (NEPA)** – NEPA requires environmental impact review and mitigation for projects involving a federal action. Several types of activities associated with development of storage projects can require federal actions triggering review under NEPA. These include the U.S. Army Corps of Engineers (USACE) issuing a 404 permit (see below); impacts to federally-listed threatened or endangered species requiring action by the U.S. Fish and Wildlife Service (USFWS); constructing projects on federal lands such as those managed by Bureau of Land Management (BLM) or the U.S. Forest Service (USFS); and connecting to federally owned facilities. An EIS can have significant impacts on project implementation schedule and budget, and in some extreme cases can render a project infeasible due to the inability to receive required federal permits.

**Endangered Species Act (ESA) and Section 7 Consultation** – Projects with a federal nexus require review for compliance with the ESA. Federal actions resulting in depletions to flows in the Platte River system are likely to jeopardize the continued existence of one or more federally-listed threatened or endangered species and adversely modify critical habitat. Analysis and mitigation of impacts would be required.

**Platte River Recovery Implementation Program (PRRIP)** – The PRRIP is a cooperative program between Colorado, Wyoming, Nebraska and the U.S. Department of Interior to provide streamlined ESA compliance for impacts of depletions in the Platte River Basin. In Colorado the South Platte Water Related Activities Program, Inc. (SPWRAP) is responsible for the operational costs of projects providing supplemental streamflows at the state line. SPWRAP would not cover a mainstem reservoir over 2,000 ac-ft, significantly complicating environmental permitting of a mainstem dam alternative.

**Clean Water Act/Section 404** – Section 404 of the Clean Water Act regulates placement of dredge and fill material in waters of the US. The South Platte River and its tributaries are waters of the US, and construction of new dams or diversion structures on these water bodies would require 404 permits. The 404 review process triggers NEPA and ESA compliance as well as requiring its own permit review and mitigation.

**National Historic Preservation Act** – Archaeological and cultural surveys and management plans would be required for storage locations and other infrastructure.

**South Platte River Compact** – The Compact sets a minimum flow target at the Interstate Station (Julesburg gage) of 120 cfs between April 1 and October 15. This effectively limits new diversions in Water District 64 in this period such that a minimum of 120 cfs is left in the river.

## 4.2 STATE LAWS AND REGULATIONS

**Water Right Determination and Administration Act** – Water storage and diversion rights for a new SPSS project would have to be adjudicated per Colorado's water rights system.

**Colorado Department of Public Health and Environment (CDPHE)** – The CDPHE Water Quality Control Division would require compliance with Section 401 of the Clean Water Act prohibiting degradation of the state's water quality. This would involve an anti-degradation review and 401 certification from CDPHE.

**Colorado Groundwater Management Act** – This act regulates management of groundwater basins that could be used for groundwater storage in the South Platte Basin. Specific regulations apply to the designated basins considered for aquifer storage and recovery in the SPSS. Groundwater management policies require that aquifer storage projects not recharge or inject water that would degrade the water quality of the aquifer.

## 4.3 LOCAL

**1041 Regulations -** 1041 regulations allow local governments to describe and designate areas and activities which may be of state interest and encourages local governments to establish criteria for the administration of these areas and activities. 1041 regulations allow local governments to put permit conditions on water projects including reservoirs and pipelines. Local governments located within the SPSS study area known to have 1041 regulations in place include Adams County, Larimer County, Morgan County, and Weld County. A state or local government may choose to adopt 1041 regulations and guidelines for administration of matters of state interest at any time.

A host of other local regulations related to construction and floodplain administration would apply to water infrastructure projects such as those considered for the SPSS.

## 4.4 SUMMARY OF KEY LEGAL AND REGULATORY EFFECTS

Legal and regulatory issues could affect the feasibility of storage options in the SPSS study area in the following key ways.

- Environmental permitting for on-channel reservoirs would be extremely difficult, particularly for reservoirs on the mainstem of the South Platte River. Past permitting efforts for a mainstem dam at the Narrows site were unsuccessful, and

environmental regulations and policies are more challenging now than they were then. Permitting obstacles may be a fatal flow for mainstem storage options.
- Compatibility with the PRRIP and SPWRAP would greatly simplify regulatory compliance for any new storage project. Off-channel dams could be covered under these programs but not mainstem dams.
- Federal and state environmental compliance would be a significant cost and schedule driver for any new storage project.
- Cooperative, multi-purpose projects that have support of and create partnerships between local, state and federal agencies would be more likely to receive the necessary regulatory approvals.

# 5. HISTORICAL FLOW ANALYSIS

## 5.1 INTRODUCTION

HB 16-1256 included a requirement to determine historical flow that could have been captured and stored in the South Platte River at the state line. Specifically, the Bill states:

"The Board, in collaboration with the State Engineer, shall conduct or commission a hydrology study of the South Platte River Basin to estimate, for each of the previous twenty years, the volume of water that:

i. Has been delivered to Nebraska in excess of the amount required to be delivered by the South Platte River Compact, Article 65 of this title; and

ii. Could have otherwise been stored in the Lower South Platte River Basin."

The South Platte Point Flow Model (PFM) was used to complete those two tasks. The PFM evaluates the historical daily flow passing structures on the mainstem of the South Platte River between the Burlington Ditch diversion (Henderson area) and the Nebraska State line based on hydrologic data, diversion records and reconstructed call records using a detailed point flow modeling approach. The point flow analysis calculates ungaged gains and losses between measured points by simple mass balance and estimates physical flow at 62 points along the river by redistributing the gains and losses according to their spatial distribution. The model does not account for existing conditional water rights that could be used more fully in the future as they are perfected nor does it consider unused reusable return flows that might be utilized in the future. The version of the PFM used in the South Platte Basin Implementation Plan was updated for this study to include a 20-year period of daily flow records from 1996 to 2015 (water years). Details of the PFM update process are provided in the "South Platte River Hydrologic Analysis TM" in **Appendix E**. Results of the historical flow analysis were presented previously in "Summary of South Platte River Historical Flow Leaving the State and Storable Water," which is provided in **Appendix D**.

## 5.2 FINDINGS

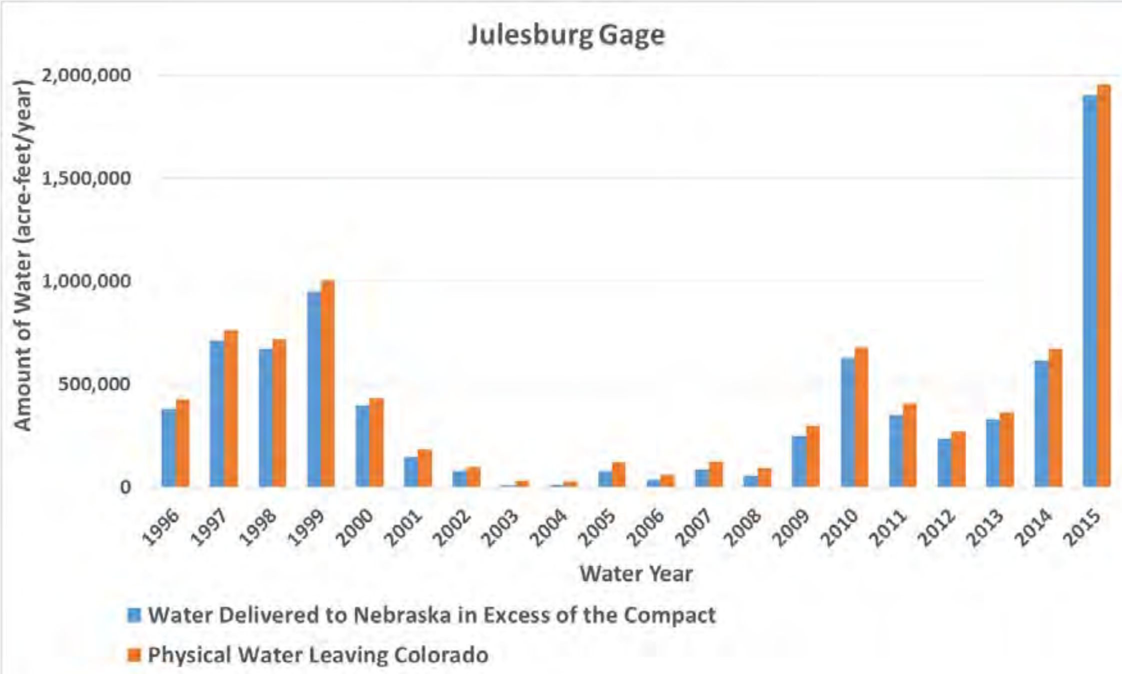
Flow records and Point Flow Model results were analyzed at the South Platte River at Julesburg stream gage near the Nebraska State line to estimate: (1) physical flow in the river; and (2) water that could have been legally stored subject to South Platte River Compact requirements (referred to herein as "storable flow" or "available water"). Storable flow is the maximum potential water that could have been stored by a reservoir on the mainstem of the South Platte River. Storable flow in an off-channel reservoir that would depend on diversions and conveyance facilities similar to the current lower basin reservoirs and irrigation canals would be significantly less.

Figure 5-1 displays annual historical flow for the 20 years from 1996 to 2015 that was delivered to Nebraska. It shows the physical flow in the river ("Water Leaving Colorado"), and the water leaving the state that could have been physically and legally stored or put to beneficial use in Colorado ("Water Delivered to Nebraska in Excess of the Compact"). It is noted that legally available flow does not account for possible environmental flow obligations for mitigation of future Colorado water development projects, so actual available flow may be less than described in this section. Figure 5-1 shows that physical and storable flow vary significantly from year to year. Table 5-1 gives selected statistics for physical flow leaving the state and storable flow at the Julesburg gage for the 20-year period from 1996 to 2015. The large difference between the median and average statistics shows the effect of a few high flow years in the study period.

## Table 5-1. Historical Annual Flow for 1996-2015 at Nebraska State Line

| Statistic | Physical Water Leaving Colorado (Julesburg Gage) | Water Delivered to Nebraska in Excess of the Compact (1)(2) |
|---|---|---|
| Annual Median (ac-ft/yr) | 331,000 | 293,000 |
| Annual Average (ac-ft/yr) | 436,000 | 397,000 |
| Minimum Year (ac-ft/yr) | 29,000 | 10,000 |
| Maximum Year (ac-ft/yr) | 1,957,000 | 1,904,000 |
| Total for 20-yr Period 1996-2015 (ac-ft) | 8,728,000 | 7,939,000 |

*(1) Storable flow Julesburg gage*
*(2) Future environmental flow obligations could reduce legally available water.*



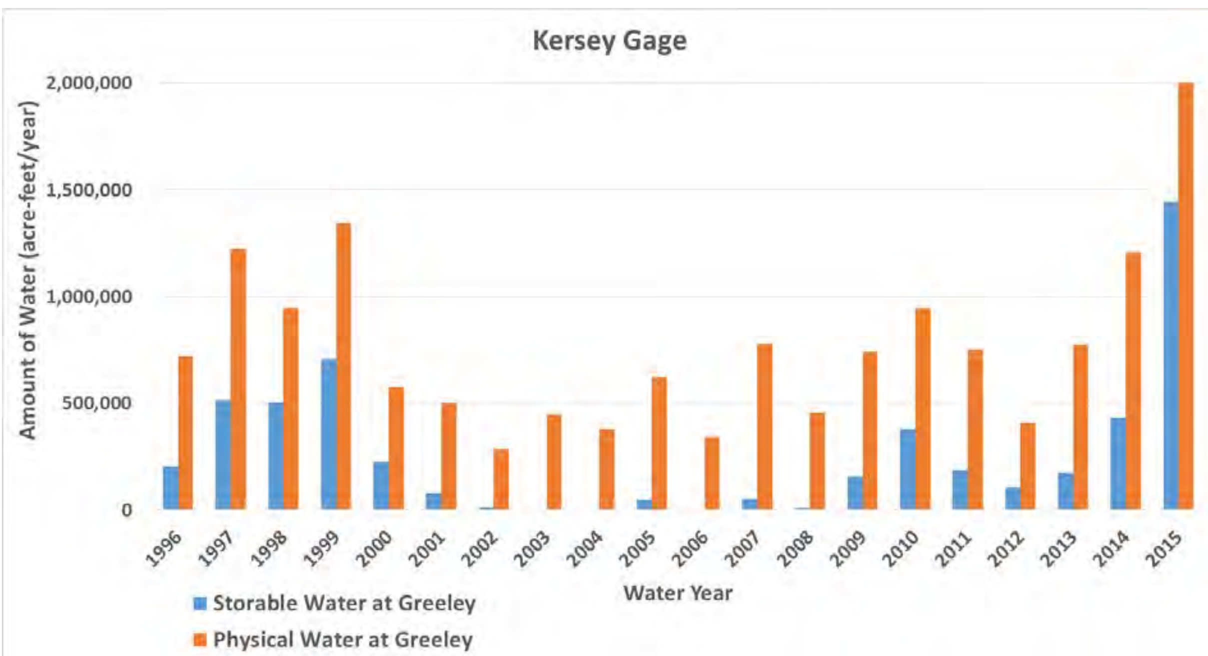

*Note: Future environmental flow obligations could reduce legally available water.*

**Figure 5-1. South Platte River Water Delivered to Nebraska (Julesburg Gage), 1996-2015**

Figure 5-2 displays the annual physical flow and storable flow at the South Platte River at Kersey stream gage from 1996 to 2015. **Table 5-2** summarizes statistics for this data. This location is below the confluence of the South Platte River and the Cache la Poudre River in Greeley, and is the upstream end of the Lower South Platte River Basin as defined in the South Platte Storage Study. As with the analysis at the Julesburg gage, storable flow is the maximum potential storable flow assuming a mainstem reservoir that could capture all available water. Although physical flow in the river at Kersey is larger than at the state line due to the lack of major downstream tributaries and the significant diversions for lower South Platte Basin water users, storable flow is a smaller percentage of total flow at the Kersey gage compared to storable flow at the Julesburg gage because of the need to satisfy downstream water rights within Colorado. As with the analysis at the Julesburg gage, potential future environmental flow obligations are not accounted for in the estimate of storable water at Greeley.

## Table 5-2. Historical Annual Flow for 1996-2015 at Greeley

| Statistic | Physical Water at Greeley (Kersey Gage) (ac-ft/yr) | Storable Water at Greeley (Kersey Gage) (ac-ft/yr) |
|---|---|---|
| Annual Median | 732,000 | 165,000 |
| Annual Average | 773,000 | 262,000 |
| Minimum Year | 285,000 | 0 |
| Maximum Year | 2,001,000 | 1,447,000 |




*Note: Future environmental flow obligations could reduce legally available water.*

## Figure 5-2. Physical and Storable Flow at Greeley (Kersey Gage), 1996-2015

# 6. AVAILABLE WATER FOR STORAGE

## 6.1 INTRODUCTION

This section describes the analysis of water legally and physically available for storage in the lower South Platte River basin under future conditions. It represents water that could be stored in a mainstem dam or diverted from the mainstem for off-channel storage. The analysis was based on adjustments to the historical PFM described previously. Adjustments were made to estimate approximate storable flows under possible future hydrologic conditions based on discounting factors such as conditional water rights and the implementation of IPPs identified in Colorado's Water Plan.

Methods and results of the available water analysis are presented in detail in the "South Platte River Hydrologic Analysis TM" in **Appendix E**.

## 6.2 HISTORICAL HYDROLOGIC ANALYSIS AND RESULTS

Available water for the historical period 1996 to 2015 was calculated for all locations in the PFM by the following steps.

1. Daily historical flow that did not have a calling water right (available flow greater than 0), was reduced by the bypass flow required to satisfy downstream uses. With input from Division 1 staff, bypass flows in **Table 6-1** were adopted as reasonable estimates of the requirements.

**Table 6-1. Bypass Flows Applied to Available Water Analysis**

| Month | Burlington to Upstream of St. Vrain Creek (cfs) | Downstream of St. Vrain Creek to Riverside Canal (cfs) | Bijou Canal to State Line (cfs) |
|---|---|---|---|
| April - October | 15 | 20 | 10 |
| November - March | 15 | 10 | 5 |

2. The South Platte River Compact requires flow at the state line to be 120 cubic feet per second (cfs) (238 ac-ft/day) or greater between April 1 and October 15. The available flow at the state line and at points throughout District 64 was reduced by 120 cfs during these dates. The Compact affects available flows in District 64 only.

3. Available water calculations were reduced by historically unused reusable return flows. These values were obtained from Aurora Water and Denver Water. It was assumed that both entities would reclaim all their reusable water supplies in the future and thus this water would not be available for downstream storage.

4. Available flow at any point along the South Platte River is affected by downstream water rights that must be satisfied. Sufficient water must be left in the river at any point to meet all downstream water rights and delivery obligations, including the South Platte River Compact.

Available water was compared between wet years, normal years, and dry years. Water year 1999 was chosen as a representative wet year, water year 2002 was chosen as a representative dry year, and water year 2010 was chosen as a representative normal year. For seasonal evaluations, February was chosen to be representative of the winter season, June was chosen to be representative of the runoff season, and August was chosen to be representative of the irrigation season.

Additionally, five locations along the South Platte River were chosen for further analysis. Four locations - South Platte River at Kersey, South Platte River at Weldona, South Platte River near Balzac, and South Platte River near Julesburg – are stream gage locations. The fifth location is the Lowline Ditch/Henderson Smith Ditch diversion, which is representative of flow in the river at Sterling. **Figure 6-1** shows these five points and their locations within the SPSS study area.

**Figure 6-2** shows historical average daily available water at all points in the Point Flow Model based on hydrologic year type. Available water increases in the downstream direction for all year types.

**Table 6-2** shows the average and median annual available water for the 1996-2015 historical period for the selected locations. The average annual available water is given as an average of all years and for a representative wet, normal, and dry year, and the median annual available water is given for all years. The significant differences between available water in wet and dry years and the significant differences between average and median statistics indicate the great variability in available water from year to year based on hydrologic conditions. These differences point to the value of storage in meeting regional demands from South Platte River flows, but also suggest that large storage capacities would be needed to generate substantial sustained yield from storage.

**Figure 6-3** and **Figure 6-4** are exceedance plots that show the percentage of time a given magnitude of available flow is equaled or exceeded in the Point Flow Model period of record for historical conditions. A daily flow exceedance plot for the Julesburg gage is shown in **Figure 6-3** , and an annual flow exceedance plot is shown in **Figure 6-4**. **Figure 6-3** shows the extreme variability in available water across the PFM period of record. On roughly half the days there is no available water at Julesburg. **Figure 6-4** shows that annual available water varies widely during the PFM period, with some years producing almost no available water. The average monthly physical flow is shown in **Figure 6-5**, which demonstrates the strong seasonality of South Platte flows.

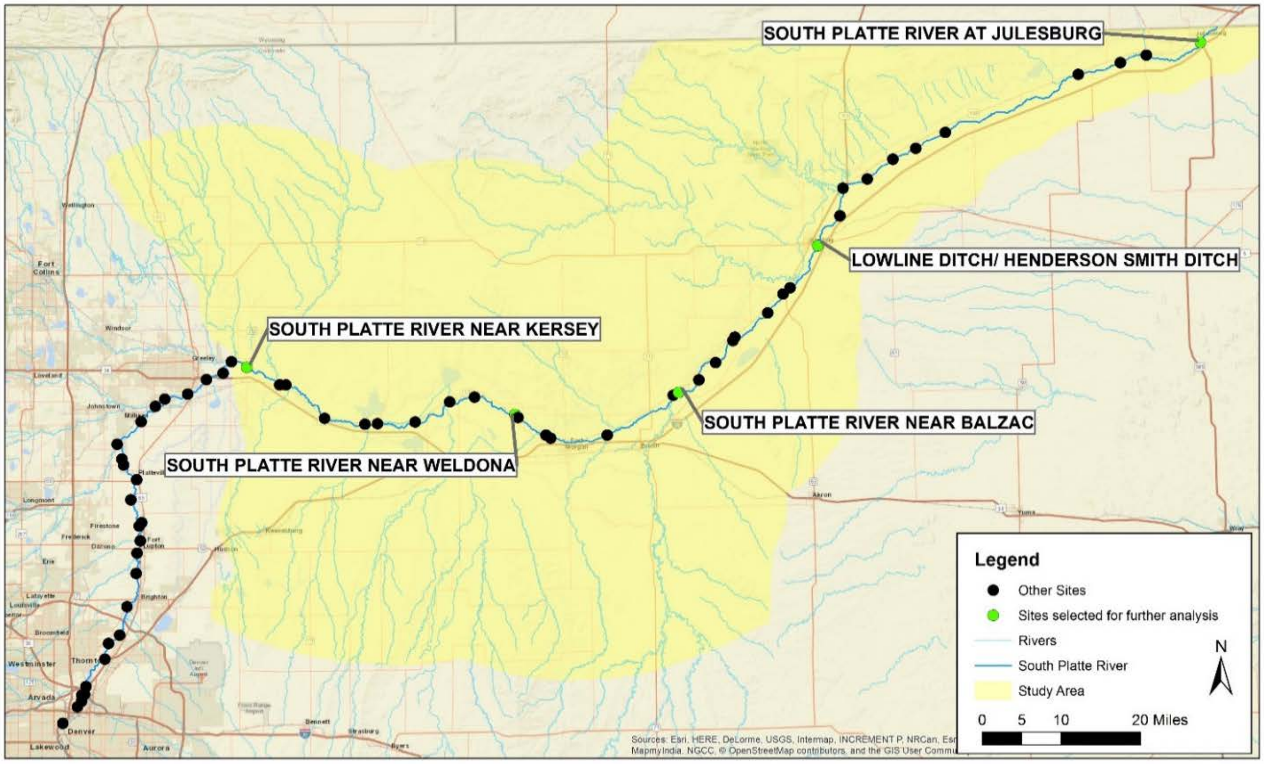



**Figure 6-1. Selected Locations for Additional Analysis**

**Table 6-2. Annual Available Water for Selected Locations Based on Historical Hydrology**

| Location | Median Annual Available Water (ac-ft) | Average Annual Available Water (ac-ft) | Available Water in Wet Year (ac-ft) | Available Water in Normal Year (ac-ft) | Available Water in Dry Year (ac-ft) |
|---|---|---|---|---|---|
| | All Years | All Years | 1999 | 2010 | 2002 |
| South Platte River near Kersey | 165,000 | 262,000 | 707,000 | 378,000 | 14,000 |
| South Platte River near Weldona | 179,000 | 281,000 | 731,000 | 411,000 | 18,000 |
| South Platte River near Balzac | 185,000 | 297,000 | 771,000 | 440,000 | 18,000 |
| Lowline Ditch/ Henderson Smith Ditch | 200,000 | 314,000 | 799,000 | 476,000 | 33,000 |
| South Platte River at Julesburg | 289,000 | 397,000 | 951,000 | 627,000 | 79,000 |

*Notes: Based on 1996-2015 historical streamflows and river operations, adjusted to remove Denver Water and Aurora Water reusable return flows and account for all existing water rights and South Platte River Compact obligations. Available water" is water physically and legally available to be diverted to a new water supply project like SPSS.*

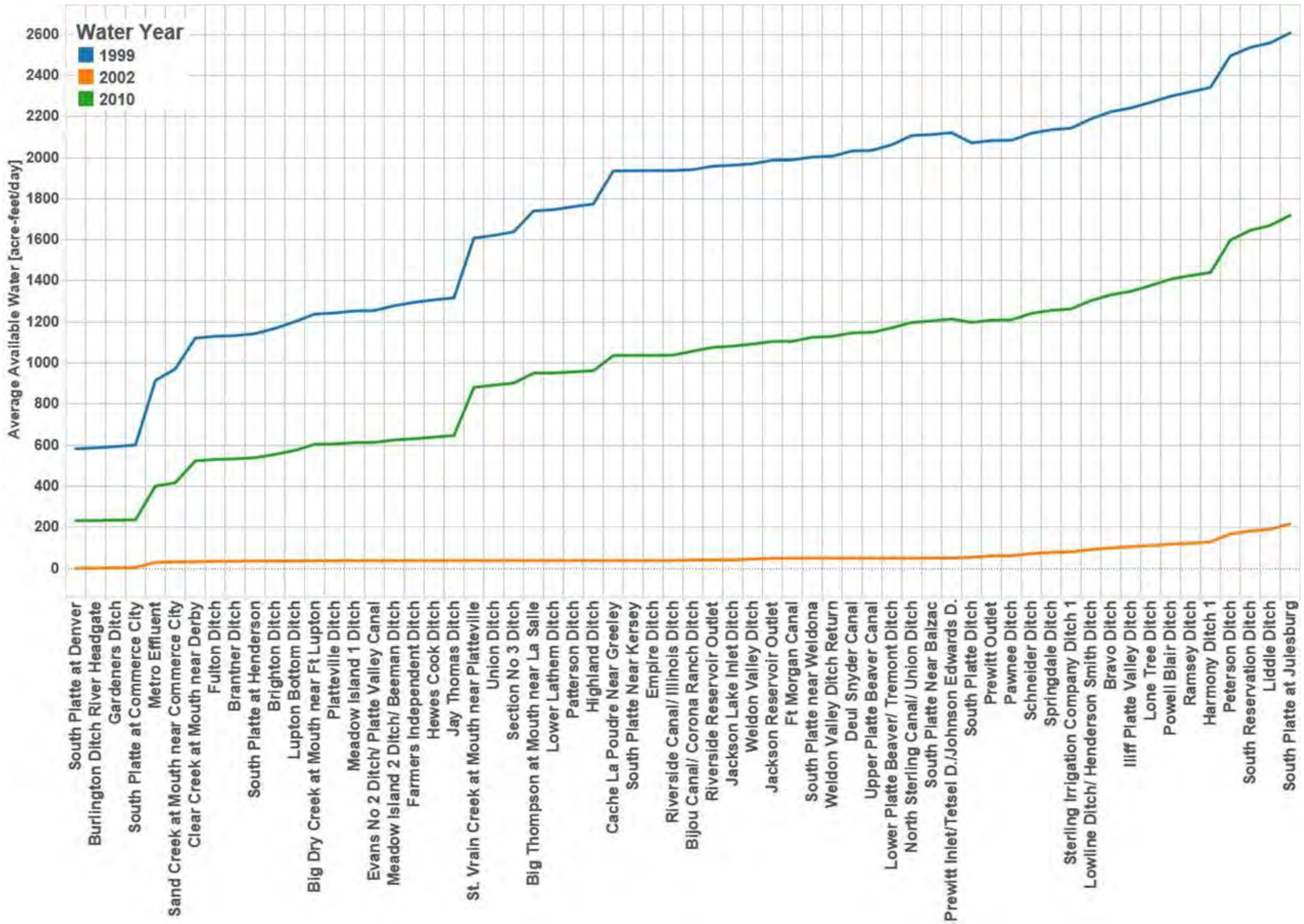



**Figure 6-2. Historical Daily Average Available Water for Representative Wet, Normal, and Dry Years**

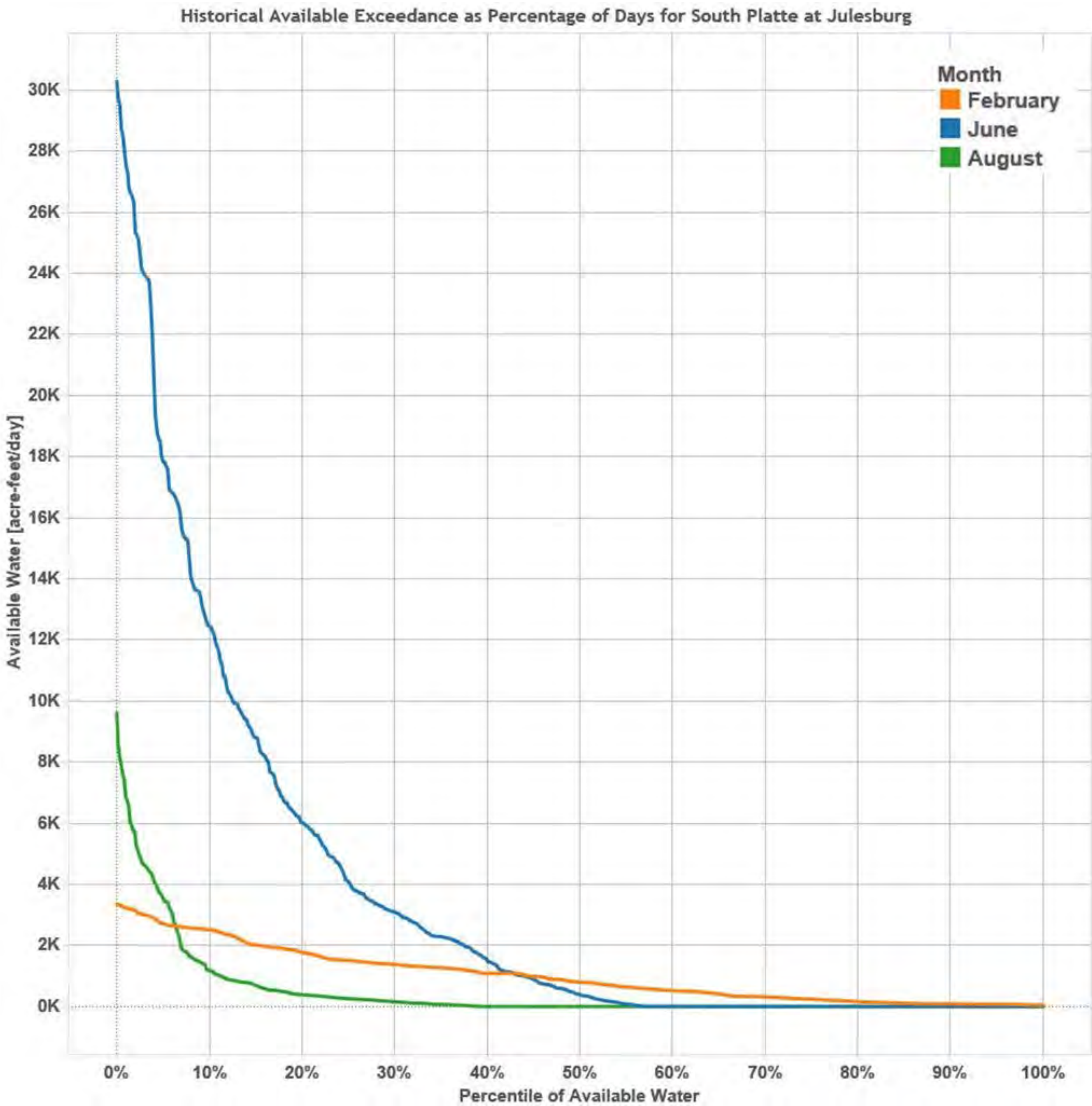



**Figure 6-3. Historical Daily Available Water Exceedance for Representative Months, South Platte at Julesburg**

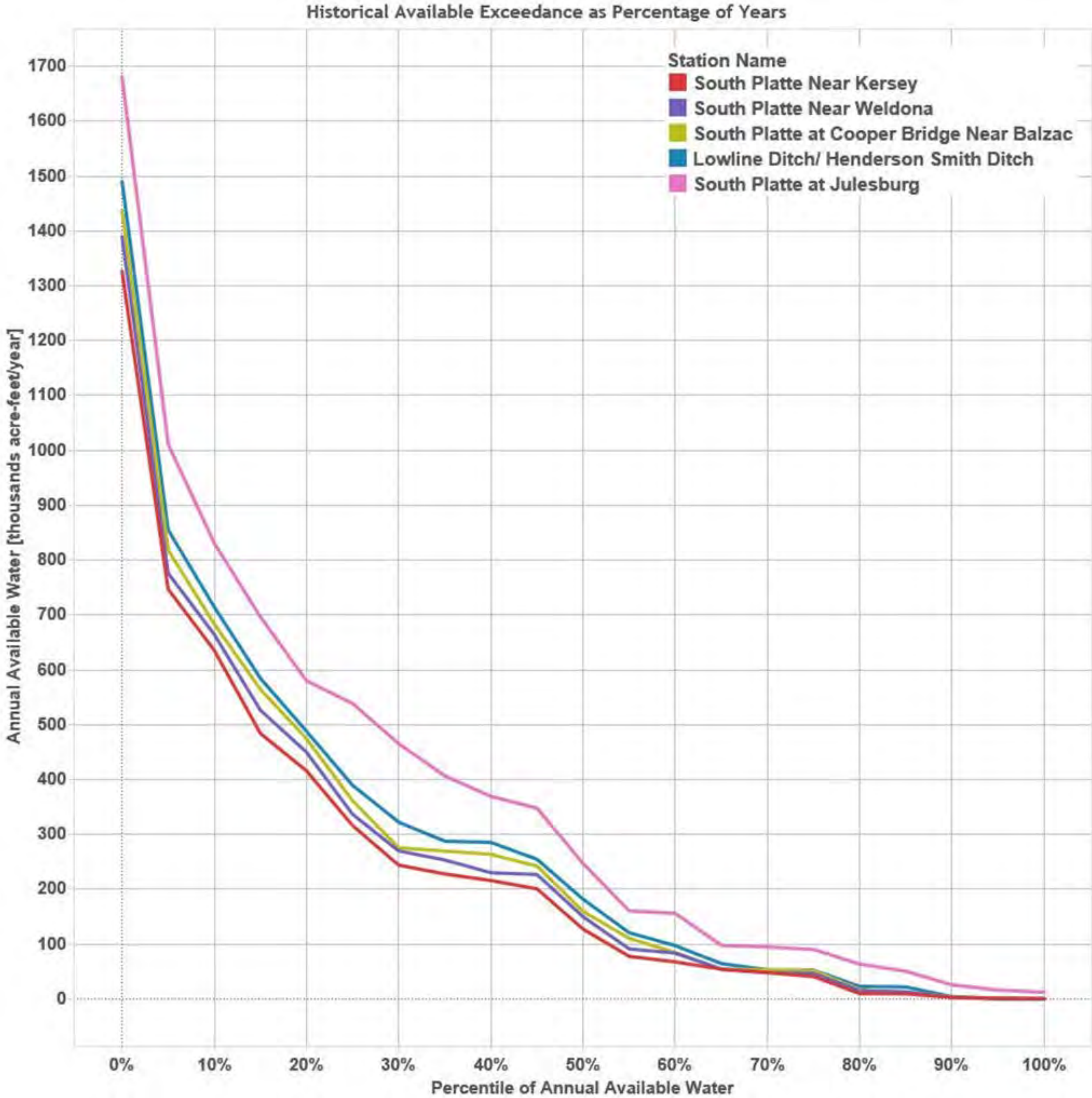



**Figure 6-4. Historical Annual Available Water Exceedance at Five Key Locations**

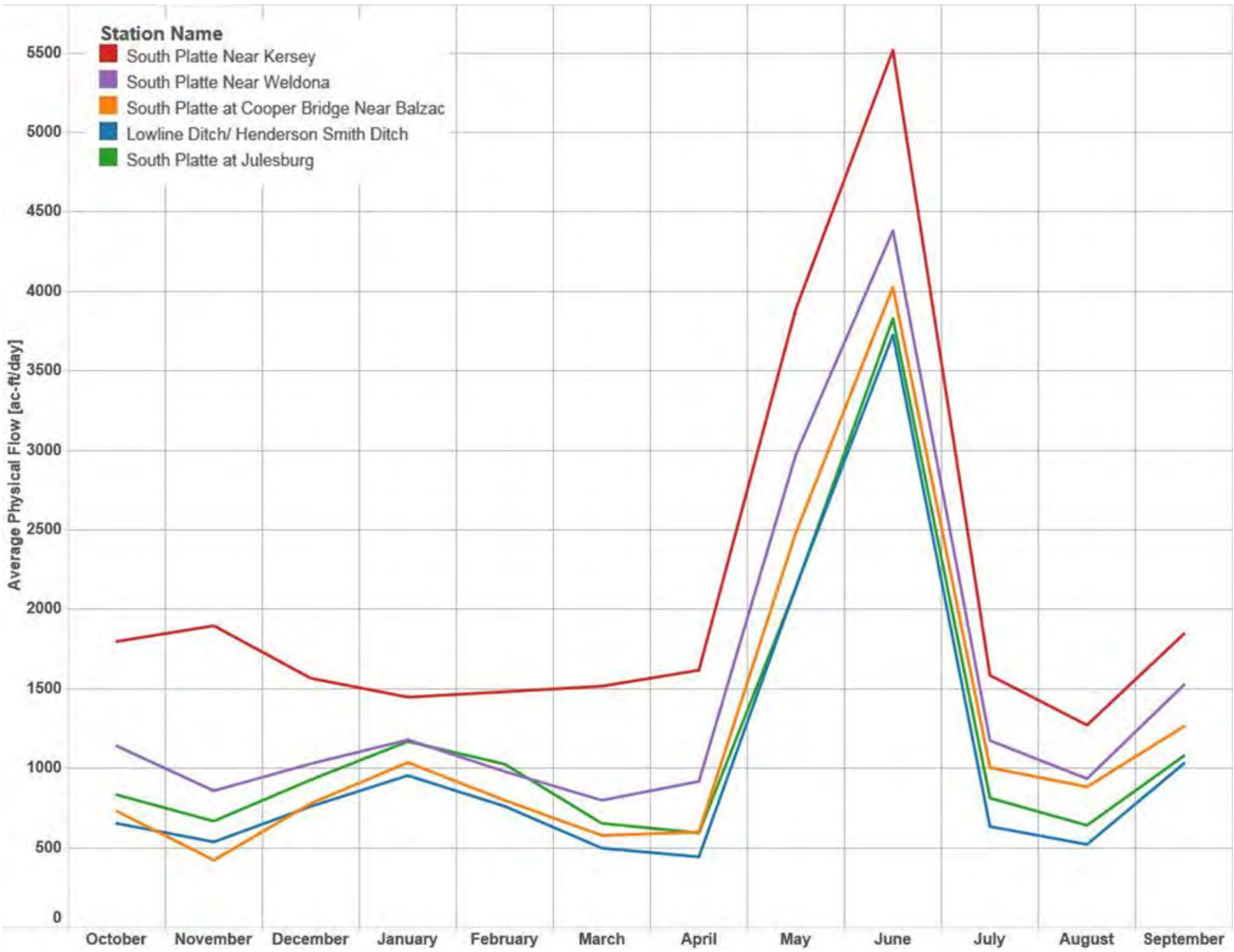



**Figure 6-5. Average Monthly Physical Flows**

## 6.3 FUTURE HYDROLOGIC ANALYSIS AND RESULTS

HB 16-1256 specified that this storage study should be based on historical hydrology to answer the question, “How much water could we have stored in recent years if storage had been in place?” However, it is recognized that future hydrologic conditions will not be the same as historical conditions due to development of conditional water rights, implementation of proposed IPPs from Colorado’s Water Plan, changed operations by water users, and a host of other factors. Based on direction from the CWCB, CDWR and Roundtables, SPSS planning was performed using future hydrology.

The SPSS used similar methods for adjusting historical hydrology to represent future conditions as were applied in the South Platte Basin Implementation Plan (BIP). In the BIP a routine was developed to reduce historical flows by diversions anticipated from

IPPs in Colorado's Water Plan. This routine used estimates of IPP annual yields obtained from the IPP proponents, and reduced available water equally in all months. The routine allowed the user to select individual IPPs or all IPPs for inclusion in the analysis, since the BIP acknowledges that not all IPPs are likely to be ultimately implemented.

For the SPSS the method of reducing available flows to account for implementation of IPPs from the BIP was modified by assuming a distribution of diversions between peak runoff months and the rest of the year for those proposed projects that would increase future diversions. It is recognized that many factors can affect the magnitude and timing of diversions for future projects, and detailed analyses of specific IPPs was not contemplated for this project. Estimates in this study were only developed to provide a rough order of magnitude of the effect of IPPs on water available for a new South Platte storage project. IPPs which are expected to reduce future demands were not considered in the adjustment of available flows. The IPPs, their estimated yield from the BIP, and the assumed distribution of their diversions between the peak runoff months of May/June and the rest of the year are listed in **Table 6-3**.

**Table 6-3. Assumed Seasonal Distribution of Future Diversions for IPPs**

| IPP Project | Provider | Annual Yield (ac-ft/yr) | May-June Diversions | July-April Diversions |
|---|---|---|---|---|
| ACWWA Reuse Flow Project | ACWWA, SMWSA | 3,520 | N/A | N/A |
| Alternative Northern Water Supply Project | Town of Castle Rock | 2,500 | 80% | 20% |
| ASR Future Storage | Town of Castle Rock | N/A | - | - |
| ASR Pilot Phase Storage | Town of Castle Rock | N/A | - | - |
| Chatfield Pump Station | Denver Water | 3,000 | 50% | 50% |
| Chatfield Reservoir Storage Reallocation Project | Colorado Water Conservation Board, Centennial Water and Sanitation District, Central Colorado Water Conservancy District, Castle Pines North Metro District, Colorado Parks and Wildlife, Castle Rock, Center of Colorado Water Conservancy District, Castle Pines Metro District | 8,500 | 80% | 20% |
| Conservation | Centennial Water and Sanitation District | 1,764 | N/A | N/A |

| IPP Project | Provider | Yield (ac-ft/yr) | May-June Diversions | July-April Diversions |
|---|---|---|---|---|
| Conservation | City of Greeley | 3,000 | N/A | N/A |
| Conservation | City of Northglenn | 600 | N/A | N/A |
| Conservation | City of Thornton | 3,500 | N/A | N/A |
| Conservation | Longmont | 3,500 | N/A | N/A |
| Conservation | Town of Castle Rock | 3,350 | N/A | N/A |
| Consolidated Mutual Water District Reservoir Construction | Consolidated Mutual Water Company | N/A | - | - |
| Denver Water Reuse | Denver Water | 1,750 | N/A | N/A |
| Downstream Reservoir Exchanges | Denver Water | 12,000 | 70% | 30% |
| Halligan Reservoir Enlargement | City of Fort Collins | 7,000 | 80% | 20% |
| Highway 93 Lakes | Arvada | 500 | 80% | 20% |
| Milton Seaman Reservoir Enlargement | City of Greeley | 6,600 | 80% | 20% |
| New Storage Projects | City of Northglenn | 1,500 | 70% | 30% |
| Northern Integrated Supply Project | Town of Erie, City of Lafayette, Left Hand Water District, City of Fort Morgan, City of Dacono, Town of Eaton, Town of Windsor, City of Fort Lupton, Fort Collins - Loveland Water District, Central Weld County Water District, Town of Evans, Morgan County Water Quality District, Town of Severance, Town of Frederick, Town of Firestone | 40,000 | 70% | 30% |
| Plum Creek Diversion & WPF Upgrades | Town of Castle Rock | 4,100 | 80% | 20% |
| Prairie Waters Project | Aurora | 15,700 | 50% | 50% |
| Reclaimed Water | Erie | 5,390 | N/A | N/A |
| Reuse | City of Thornton | 2,000 | N/A | N/A |
| Reuse Plan | City of Northglenn | 700 | N/A | N/A |
| Rueter Hess Reservoir Enlargement | Parker Water and Sanitation District, Castle Rock, Castle Pines North, Stonegate | 14,810 | 80% | 20% |

| IPP Project | Provider | Yield (ac-ft/yr) | May-June Diversions | July-April Diversions |
|---|---|---|---|---|
| South Platte and Beebe Draw Well Project - Reuse | City of Brighton | 3,200 | N/A | N/A |
| South Platte Protection Plan | Denver Water | N/A | - | - |
| Thornton Northern Project | City of Thornton | 13,500 | 50% | 50% |
| Union Pumpback Pipeline | Longmont | 4,950 | 50% | 50% |
| Union Reservoir Enlargement | Longmont | 1,770 | 80% | 20% |
| Westminster Agreement | City of Brighton | 2,000 | 50% | 50% |
| Westminster Gravel Storage | Westminster | N/A | - | - |

*Notes: Projects with N/A in the Diversions fields reduce future demand rather than increasing future diversions. Projects with N/A in Yield field did not have yield estimates available from the BIP. Projects with blanks in the Diversions fields did not have adequate yield information. Any potential influences of these IPPs on future storable flow was not accounted for in the SPSS analysis.*

Future flows were also adjusted to account for conditional exchange rights that were not utilized in the historical period in the PFM but could be utilized in the future. Conditional water rights were tabulated and allocated to the major reaches in the SPSS study area. Based on input from the Division Engineer it was assumed 33 percent of conditional exchanges were not duplicative and would likely be perfected upstream of Kersey, and 25 percent of conditional exchanges were not duplicative and would likely be perfected downstream of Kersey. These are rough approximations but were considered adequate for this analysis. Daily flow reductions to reflect conditional exchange rights being perfected and exercised in the future are summarized in **Table 6-4**.

### Table 6-4. Reduction in Historical Daily Flows to Account for Conditional Exchange Rights

| Reach | Total Conditional Exchanges (cfs) | Reductions to Daily Historical Flows | |
|---|---|---|---|
| | | Conditional Exchanges Assuming 25% are Made Absolute and Operated Concurrently (cfs) | Conditional Exchanges Assuming 33% are Made Absolute and Operated Concurrently (cfs) |
| Above Denver | 1,900 | - | 630 |
| Denver to Kersey | 7,600 | - | 2,500 |
| Kersey to Balzac | 1,100 | 280 | - |
| Balzac to Julesburg | 1,200 | 300 | - |

Table 6-5 shows historical average annual and median annual available water adjusted for IPP diversion estimates. These results assume all IPPs for which yield information was available in the BIP are implemented, while all IPPs without yield information in the BIP are not implemented. This is conceptually consistent with the scenario in Colorado's Water Plan that assumes 60 percent of all IPPs will ultimately be implemented. Table 6-5 also shows the reduction in available water compared to the results of the historical hydrology analysis. Future average annual available water is 16-18 percent less than average annual available water in the 20 years between 1996 and 2015.

Figure 6-6 gives a comparison of the daily available water exceedance between the historical hydrology and the future hydrology adjusted for IPPs and conditional exchanges. Figure 6-7 shows the future average and median physical flow and available flow throughout the SPSS study area; these PFM results were used in the analysis of SPSS alternatives.

## Table 6-5. Future Available Water for Selected Locations Based on Historical Hydrology and Adjustments

| Location | | Median Annual Available Water (ac-ft) | Average Annual Available Water (ac-ft) | Available Water in Wet Year (ac-ft) | Available Water in Normal Year (ac-ft) | Available Water in Dry Year (ac-ft) |
|---|---|---|---|---|---|---|
| | | All Years | All Years | 1999 | 2010 | 2002 |
| South Platte River near Kersey | With IPP Adjustment | 116,000 | 214,000 | 580,000 | 275,000 | 6,000 |
| | Difference from Historical | -49,000 | -48,000 | -127,000 | -103,000 | -8,000 |
| South Platte River near Weldona | With IPP Adjustment | 127,000 | 231,000 | 601,000 | 303,000 | 9,000 |
| | Difference from Historical | -52,000 | -50,000 | -130,000 | -108,000 | -9,000 |
| South Platte River near Balzac | With IPP Adjustment | 144,000 | 246,000 | 641,000 | 326,000 | 9,000 |
| | Difference from Historical | -41,000 | -51,000 | -130,000 | -114,000 | -9,000 |
| Lowline Ditch/Henderson Smith Ditch | With IPP Adjustment | 154,000 | 261,000 | 666,000 | 357,000 | 15,000 |
| | Difference from Historical | -46,000 | -53,000 | -133,000 | -119,000 | -18,000 |
| South Platte River at Julesburg | With IPP Adjustment | 232,000 | 332,000 | 815,000 | 494,000 | 54,000 |
| | Difference from Historical | -57,000 | -65,000 | -136,000 | -133,000 | -25,000 |

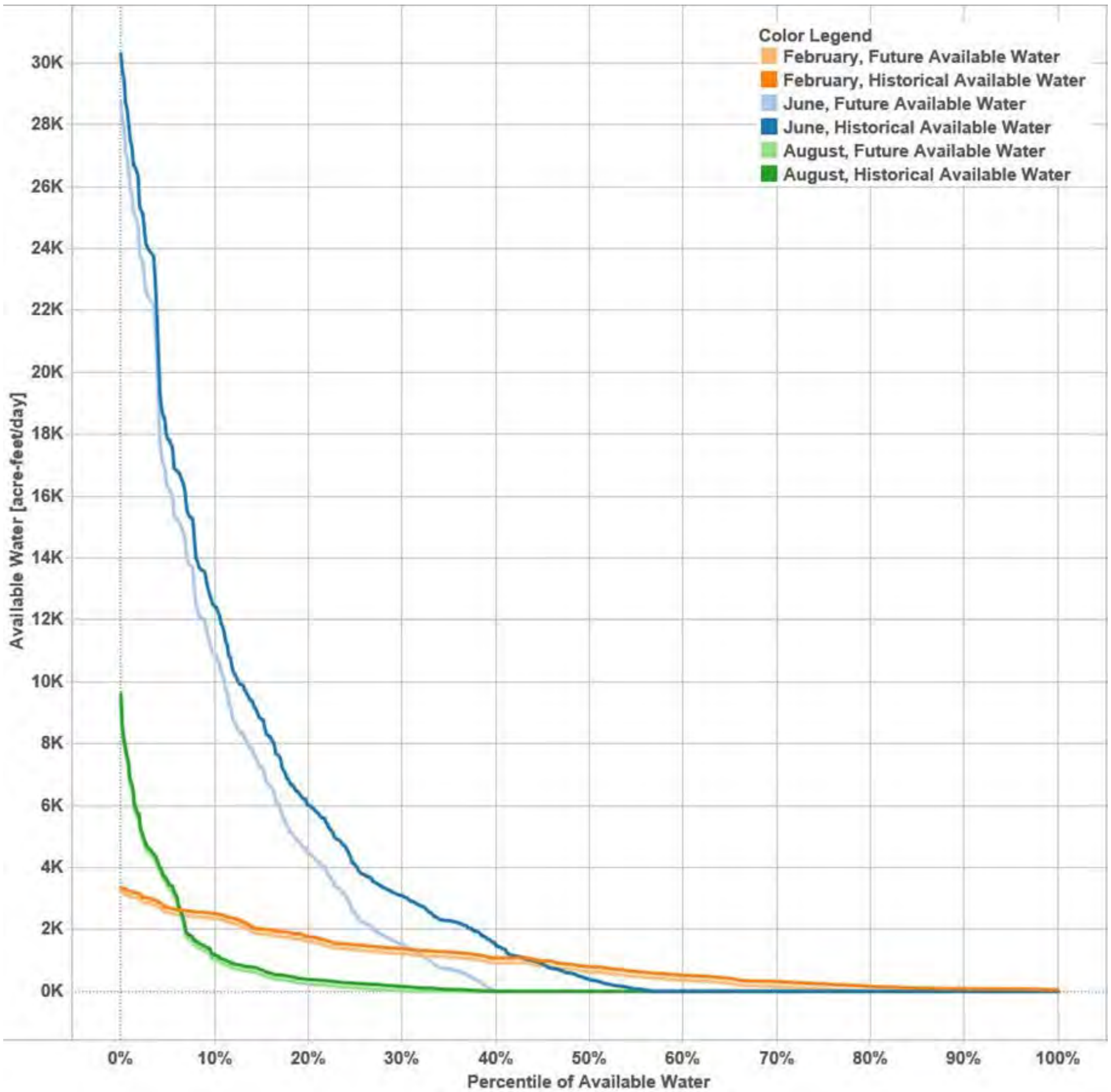



**Figure 6-6. Historical and Future Available Water by Month for South Platte at Julesburg Gage**

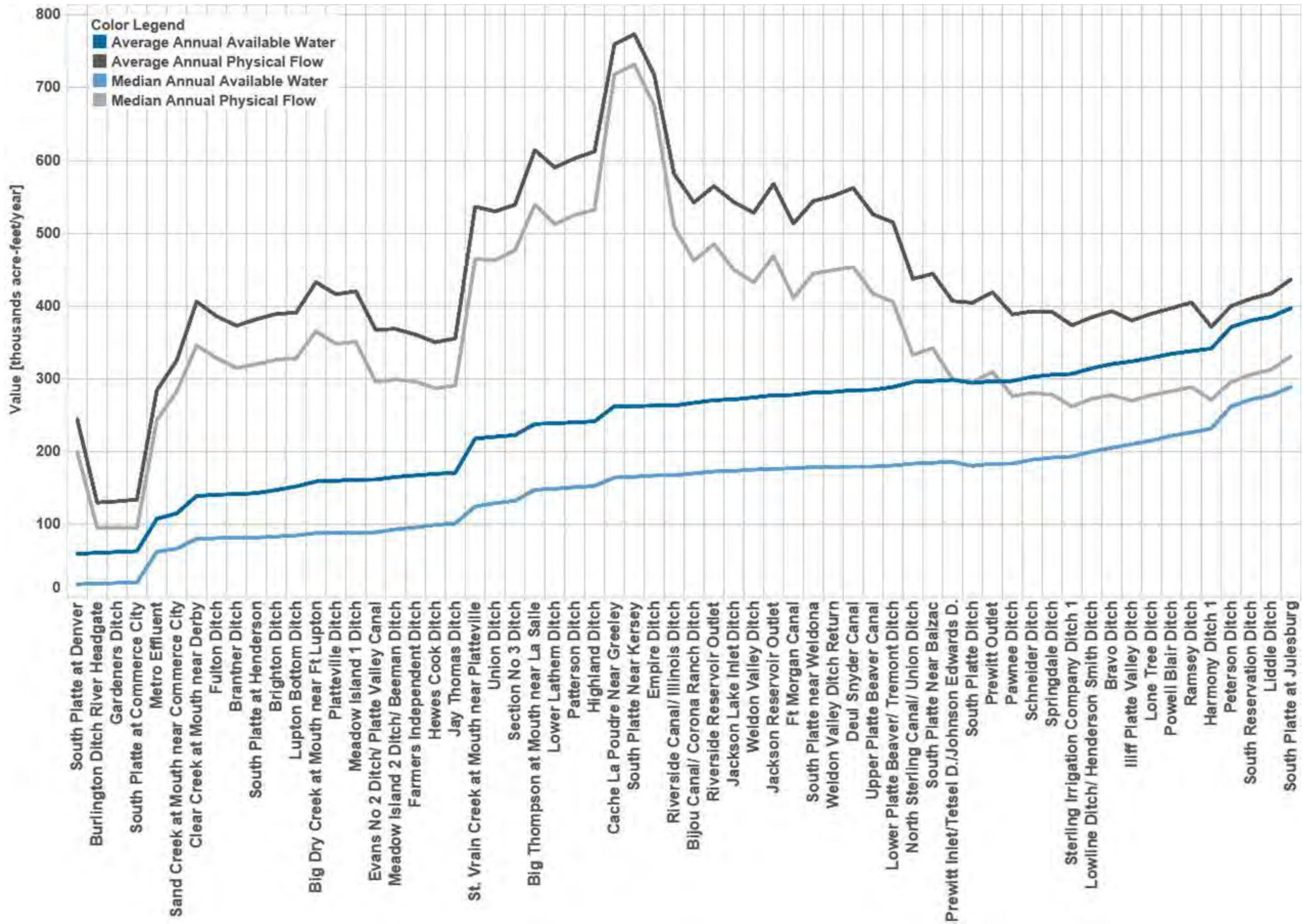



**Figure 6-7. Future Average and Median Physical Flow and Available Water**

## 6.4 DIVERSION CAPACITY CONSTRAINTS ON AVAILABLE WATER

Because nearly all potential SPSS storage options would be located off the mainstem of the South Platte River, effective available water would be constrained by the capacity of the diversion system conveying water from the river to storage. Future daily flows based on the adjusted 1996-2015 hydrology were analyzed to estimate the maximum potential volume of water that could be conveyed to storage as function of diversion capacity from three key points in the SPSS study area: the Kersey gage, the Balzac gage and the Julesburg gage. Results are shown in Table 6-6, and indicate that large diversion and conveyance facilities would be required to capture significant portions of available water when storage is located off-channel. For example, at the Balzac gage a diversion capacity of 650 cfs would be needed to capture an average of 100,000 ac-ft/yr. Capturing 85 percent of available water would require diversion capacities from 450 cfs at Kersey to 800 cfs at Julesburg. These are large diversion capacities, but are within the range of existing diversion structures on the South Platte River.

**Table 6-6. Diversion-Constrained Potential Yield to Off-Channel Storage Site**

| Percentage of Time the Full Daily Streamflow could be Diverted to Storage | Diversion Point | | | | | |
|---|---|---|---|---|---|---|
| | Kersey Gage | | Balzac Gage | | Julesburg Gage | |
| | Diversion Capacity (cfs) | Average Annual Yield (AFY) | Diversion Capacity (cfs) | Average Annual Yield (AFY) | Diversion Capacity (cfs) | Average Annual Yield (AFY) |
| 85 | 450 | 75,300 | 550 | 93,800 | 800 | 162,900 |
| 90 | 700 | 97,600 | 900 | 124,600 | 1,100 | 189,400 |
| 95 | 1,100 | 118,100 | 1,400 | 149,800 | 1,700 | 219,400 |
| 97 | 1,900 | 140,300 | 2,100 | 168,000 | 2,400 | 238,500 |
| 98 | 3,100 | 161,100 | 3,500 | 191,700 | 3,800 | 262,900 |
| 99 | 5,500 | 186,300 | 6,400 | 220,700 | 7,400 | 299,300 |

# 7. DEMANDS

## 7.1 INTRODUCTION

Analysis of SPSS options required an assumption about demands the storage projects would potentially be operated to meet. A simplified approach for estimating water demands was adopted for the SPSS. Because no specific users of SPSS water have been identified, and because many different storage options were investigated, a standardized approach to determining demands for storage scenarios was needed. This approach allowed for a consistent comparison of storage scenarios on the basis of their ability to meet demands in the South Platte Basin.

For the purpose of the SPSS, total potential water demand for future storage projects is defined as the future agricultural and M&I gap or shortage in the lower South Platte Basin, assuming implementation of IPPs. Future demands were used rather than existing demands to match with the use of future condition hydrology for the SPSS supply analysis. The State of Colorado's 2010 Statewide Water Supply Initiative (SWSI 2010) (CDM, 2011) was utilized as the basis for information about the water demands within the SPSS study area.

To simplify the demand analysis, future demand estimates were aggregated by stream reach along the South Platte. From upstream to downstream, the demand reaches utilized for the SPSS were:

- Upstream of the South Platte River at Denver Gage (Upstream of Denver Gage)
- South Platte River at Denver gage to South Platte River Near Kersey gage (Denver to Kersey)
- South Platte River Near Kersey gage to South Platte River at Cooper Bridge near Balzac gage (Kersey to Balzac)
- South Platte River at Cooper Bridge near Balzac gage to South Platte River at Julesburg gage (Balzac to Julesburg)

Detailed documentation of the methods used to estimate demands is provided in **Appendix F**.

## 7.2 DEMAND ESTIMATION METHODS

Estimation of maximum potential demands that could be met by a SPSS storage project were developed using the approach shown in **Figure 7-1**. Derivation of the SPSS agricultural demands was based on the SWSI 2010 analysis of estimated 2050 agricultural demand, which includes assumptions for reduction in irrigated acreage. The future agricultural shortage was assumed to be the maximum potential agricultural demand that could be met by a SPSS option. SWSI 2010 defines agricultural shortage as the difference between the water supply-limited consumptive use and the irrigation water requirement of the irrigated lands.

Agricultural shortages for the recent 10-year historical period were computed by Water District in the SPSS study area. These were then adjusted to 2050 conditions based on the SWSI 2010 assumptions for reduced irrigated acreage. Shortages by Water District were then allocated to the four SPSS demand points.

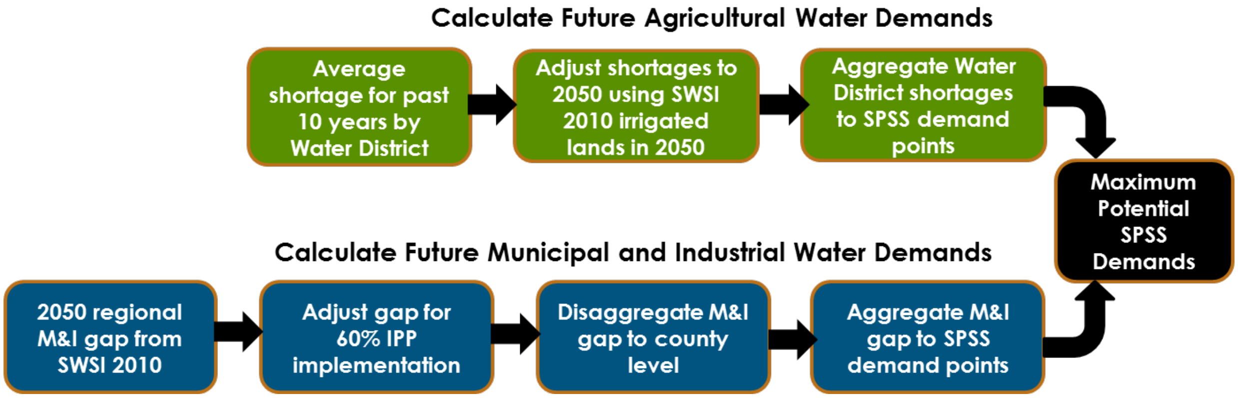



**Figure 7-1. Demand Estimate Approach**

Derivation of the SPSS municipal demands was based on the SWSI 2010 analysis of the 2050 M&I water supply gap. The SPSS adopted the 2050 M&I gap assuming the median demand forecast and 60 percent implementation of IPPs. SWSI 2010 data presented by region was disaggregated to the county level, then re-aggregated at each of the SPSS demand points.

## 7.3 RESULTS OF DEMAND ANALYSIS

Table 7-1 presents the results of the SPSS demand analysis. It lists the maximum potential demand that would be applied to storage options to assess their effectiveness in reducing excess flows at the state line and putting Colorado's water resources to beneficial use. Spatial distribution of the demands is shown in Figure 7-2, which also shows spatial distribution of available water in the SPSS study area.

In addition to total annual demand, the SPSS analysis required a monthly distribution of demand since both M&I and agricultural demands vary substantially throughout the year. M&I weekly demands as a percentage of total annual demand were taken from data available from Aurora Water; this was assumed to be representative of other municipal entities in the South Platte Basin. A monthly agricultural demand pattern was developed from historical data for applied water from both surface and groundwater sources since SPSS water could be used to augment well depletions. The weekly demand patterns for agricultural and M&I demands are shown in Figure 7-3.

The maximum potential demand exceeds the available water supply, particularly if the supply is limited by diversion capacity to off-channel storage projects. Thus the sizing of storage options is supply limited rather than demand limited on a basin-wide basis.

## Table 7-1. Maximum Potential Demand Applied to SPSS Options

| Reach | Ag Future Shortage | | | M&I Future Shortage | | Total |
|---|---|---|---|---|---|---|
| | Water District | Mainstem | Tributary | County | Total | Demand |
| Upstream of Denver Gage | WD8 | | 1,115 | Denver | 18,726 | |
| | WD9 | | 267 | Arapahoe | 40,439 | |
| | | | | Jefferson | 15,215 | |
| | | | | Douglas | 27,545 | |
| | | | | Elbert | 3,516 | |
| | *Reach Total* | - | 1,382 | *Reach Total* | 105,441 | **106,823** |
| Denver to Kersey | WD2 | 71,388 | | Weld | 42,950 | |
| | WD3 | | 65,435 | Adams | 21,847 | |
| | WD4 | | 28,744 | Larimer | 28,122 | |
| | WD5 | | 29,394 | Boulder | 14,828 | |
| | WD6 | | 15,131 | Broomfield | 3,511 | |
| | WD7 | | 90 | | | |
| | *Reach Total* | 71,388 | 138,794 | *Reach Total* | 111,259 | **321,441** |
| Kersey to Balzac | WD1 | 46,644 | | Morgan | 9,486 | |
| | *Reach Total* | 46,644 | - | *Reach Total* | 9,486 | **56,130** |
| Balzac to Julesburg | WD64 | 11,374 | | Logan | 7,114 | |
| | | | | Sedgwick | 0 | |
| | | | | Washington | 0 | |
| | *Reach Total* | 11,374 | - | *Reach Total* | 7,114 | **18,488** |
| **BASIN TOTALS** | | **129,406** | **140,176** | | **233,300** | **502,882** |

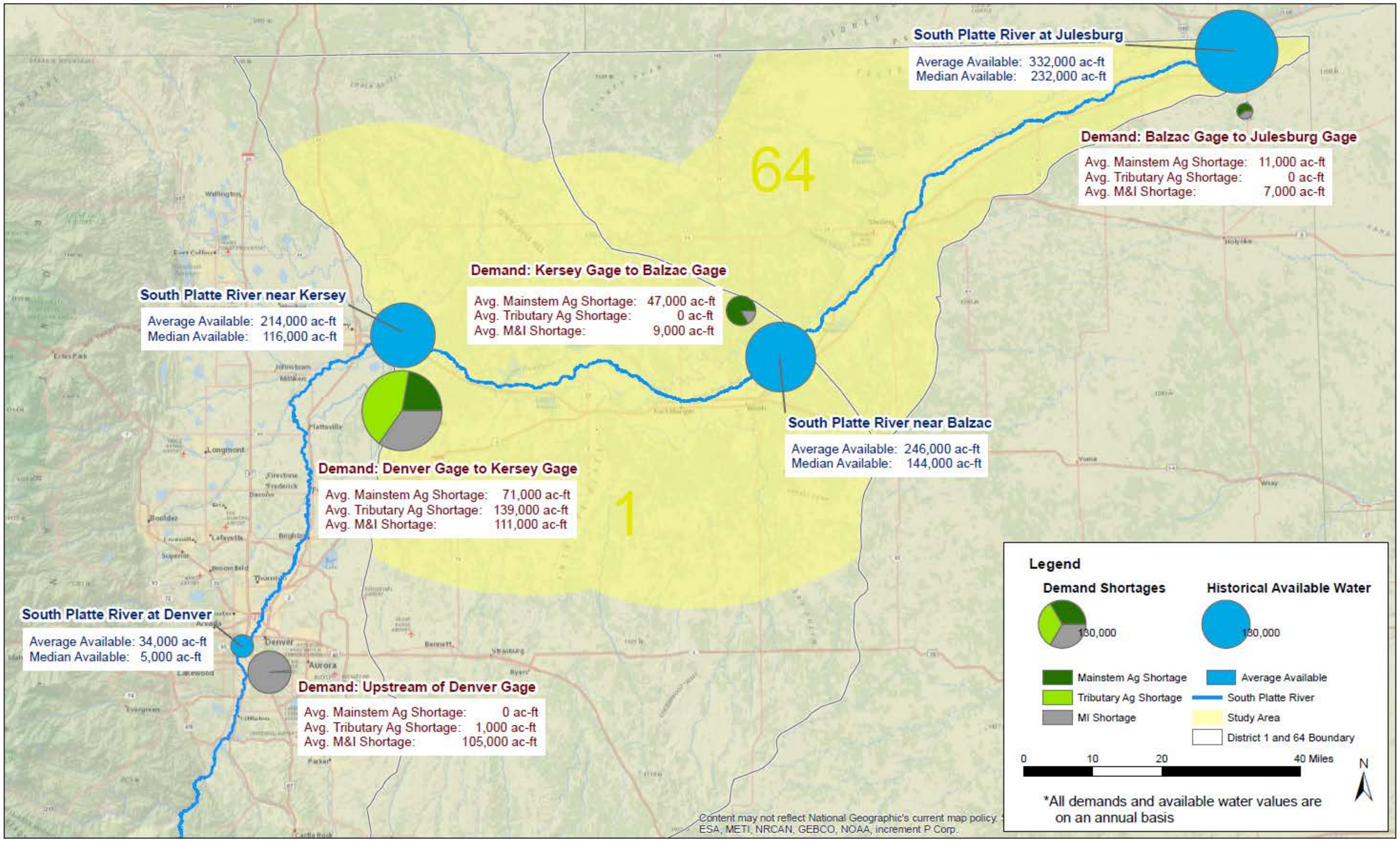



**Figure 7-2. Summary of Available Water and Demands at Key Locations in SPSS Study Area**

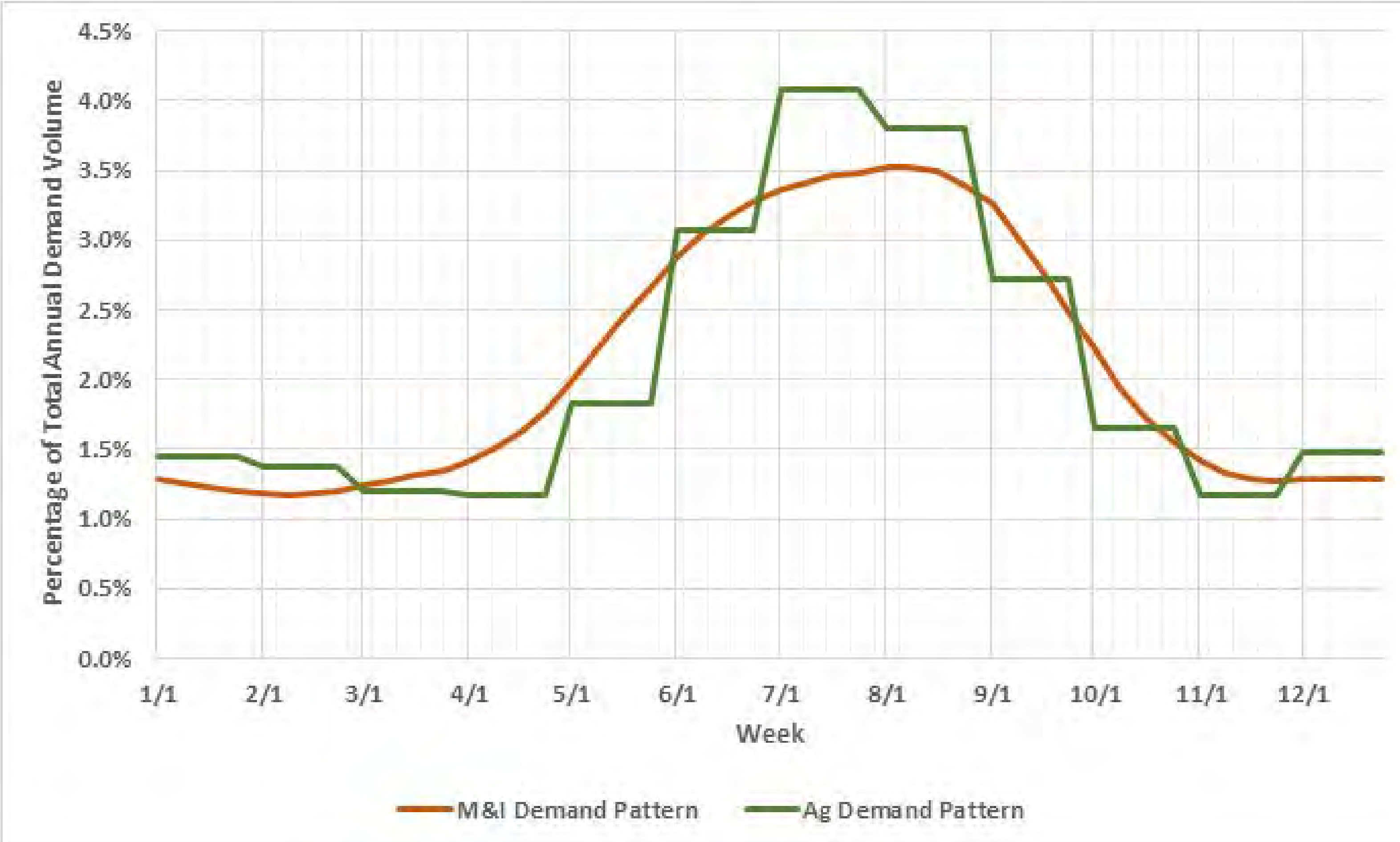



**Figure 7-3. Weekly Distribution of Annual Demand**

# 8. WATER QUALITY

The quality of water available for a new storage project in the lower South Platte Basin could affect the feasibility of putting that water to beneficial use. Similarly, enlarging or rehabilitating existing reservoirs would only be feasible if water quality would be appropriate for the intended uses.

Existing water quality data for stream segments and reservoirs was reviewed and impaired water bodies based on the state's water quality assessment were identified. Results of the water quality review are provided in **Appendix G**.

**Table 8-1** summarizes the results of the water quality review for key parameters. Water diverted for storage in the SPSS study area would be adequate quality for irrigation use, as these sources are currently widely used for agricultural purposes. However, if used directly as a drinking water supply, water from any new SPSS storage project would require a high level of treatment (e.g., reverse osmosis, ion exchange) to remove a number of problematic constituents including arsenic, selenium, sulfate, total dissolved solids, and uranium. This level of treatment would add significant cost and complexity to a storage concept associated with construction of the treatment process itself, disposal of residuals, operational costs, and energy requirements. In addition, groundwater non-degradation policies would require treatment of any water delivered from the South Platte River below Greeley prior to performing aquifer recharge and underground storage to avoid adversely affecting existing groundwater quality.

**Table 8-1. Summary of Water Quality Issues Affecting Storage Options**

| Key Parameter | Assumed Method of Use | Reach Impaired for Use | Potential Treatment Alternatives and Regulatory Needs |
|---|---|---|---|
| Arsenic | *Domestic Water Supply* – Direct feed to WTP | COSPMS01B | High Level Treatment Methods – High Cost<br>Residuals Treatment and/or Disposal – High Cost |
| Dissolved Oxygen | *Agriculture, Aquatic Life, Recreation* – Surface water discharge to receiving water for direct use, augmentation use, or exchange<br>*Domestic Water Supply* – Direct feed to WTP | COSPLS03 (North Sterling Reservoir) | Conventional Treatment Methods – Low Cost |
| E. Coli | *Recreation** – Surface water discharge to receiving water for direct use, augmentation use, or exchange | COSPMS01B | Conventional Treatment Methods – Low Cost |
| Manganese | *Domestic Water Supply* – Direct feed to WTP | COSPMS01B<br>COSPLS01 | Medium Level Treatment Methods – Medium Cost<br>(e.g., green sand filters, enhanced coagulation, etc.) |

| Key Parameter | Assumed Method of Use | Reach Impaired for Use | Potential Treatment Alternatives and Regulatory Needs |
|---|---|---|---|
| pH | *Aquatic Life** – Surface water discharge to receiving water for direct use, augmentation use, or exchange<br>*Domestic Water Supply* – Direct feed to WTP | COSPLS03 (Jackson Reservoir) | Conventional Treatment Methods – Low Cost |
| Selenium | *Domestic Water Supply* – Direct feed to WTP | COSPLS01<br>COSPLS03 (North Sterling Reservoir) | High Level Treatment Methods – High Cost<br>Residuals Treatment and/or Disposal – High Cost |
| Sulfate | *Domestic Water Supply* – Direct feed to WTP | COSPMS01B<br>COSPLS01 | High Level Treatment Methods – High Cost |
| Total Dissolved Solids | *Domestic Water Supply* – Direct feed to WTP | COSPMS01B<br>COSPLS01 | High Level Treatment Methods – High Cost<br>Residuals Treatment and/or Disposal – High Cost |
| Uranium | *Domestic Water Supply* – Direct feed to WTP | COSPLS01 | High Level Treatment Methods – High Cost<br>Residuals Treatment and/or Disposal – High Cost |

*Notes: COSPMS01B - Mainstem of the SPR from confluence with St Vrain Creek to the Weld/Morgan County Line*
*COSPLS01 - Mainstem of the SPR from the Weld/Morgan County line to the CO/NE border*
*High Level Treatment Needs could include reverse osmosis, ion exchange, activated alumina, etc.*
*Residuals Treatment and/or Disposal could include permitted discharge to sewer, deep well injection, evaporation pond, land application, zero liquid discharge, etc.*
** Initial recommendation – obtain legal determination as to whether the use of water constitutes and "exercise of water rights"*

# 9. STORAGE OPTIONS

The SPSS evaluation process involved analyzing storage options (individual reservoir or aquifer storage facilities) and more comprehensive storage concepts or solutions (individual storage options or combinations of storage options integrated with all other infrastructure required to have an operational storage project). Storage options were analyzed first, and the most promising options were incorporated into storage concepts. The overall storage evaluation process is summarized in **Figure 9-1**.

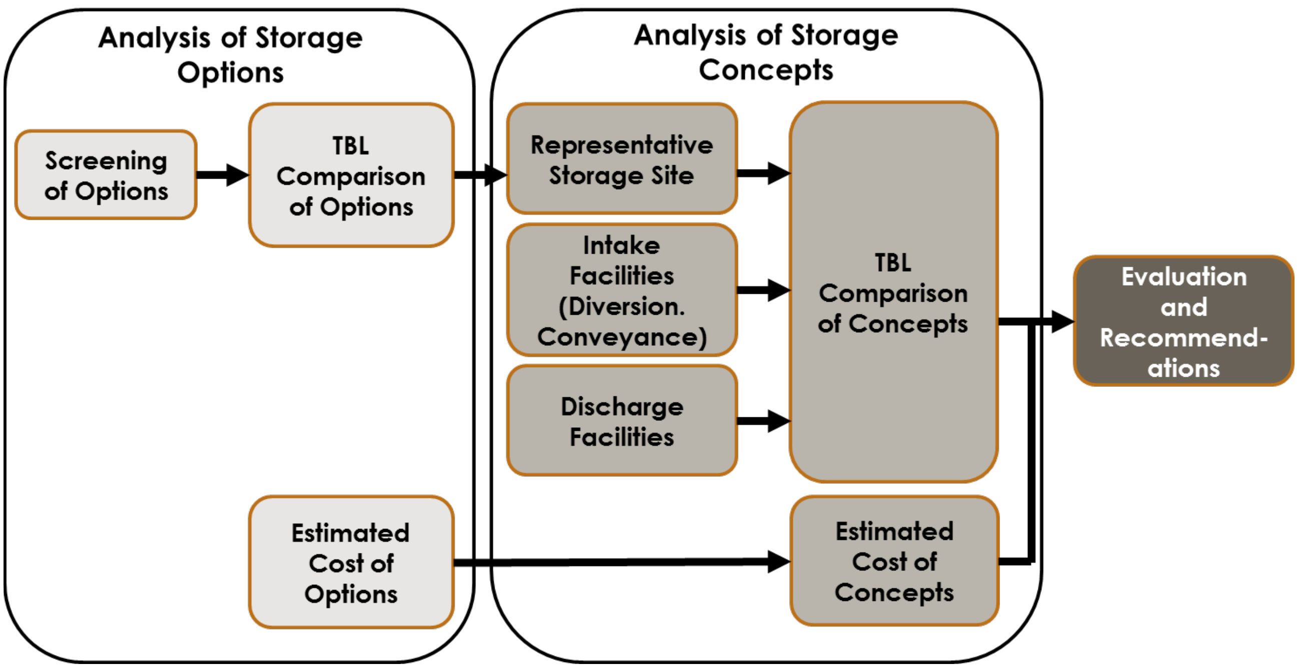



**Figure 9-1. SPSS Storage Evaluation Process Overview**

This section summarizes the process used to identify and evaluate individual storage options for the SPSS. It includes:

- Screening of storage options to eliminate infeasible and clearly inferior options
- Comparison of storage options based on technical and environmental criteria
- Estimation of cost of storage options

A more detailed discussion of the storage option analysis is provided in **Appendix H**. **Section 10.0** describes how individual storage options were incorporated into overall storage concepts for analysis.

Aquifer storage options are different from surface storage options. While many surface storage projects a designed to capture peak flows by diverting high flow rates for short periods of time, aquifer storage projects are limited by recharge capacity and thus cannot directly store high flows. They are often combined with reservoir projects and operated conjunctively so the reservoir can feed water at a managed rate to the recharge area. Aquifer storage is often seen as a supplemental water source rather than a source for peaking or meeting high sustained demands. For this reason they were analyzed separately from surface reservoir options.

## 9.1 SCREENING OF STORAGE OPTIONS

Storage options were screened starting with a long-list resulting from the literature review to eliminate those options with fatal flaws or that did not meet minimum criteria related to SPSS project goals. The objective of this process was not to identify the best storage options, but to eliminate clearly inferior options that would not meet SPSS objectives. The storage option screening process was conducted collaboratively in a workshop attended by members of the South Platte and Metro Basin Roundtables and the Stantec consultant team. Subsequent refinements were made by the consultant team with concurrence of the CWCB, CDWR and Roundtables.

Figure 9-2 summarizes the storage site screening process for surface reservoirs, aquifer storage and gravel pits. Sites were screened out if they were located too far from the South Platte mainstem; did not meet minimum capacity criteria; were clearly inferior to other similar options; or were considered impractical for purposes of SPSS by the Roundtable members. Results of the storage site screening process are shown in Figure 9-3.

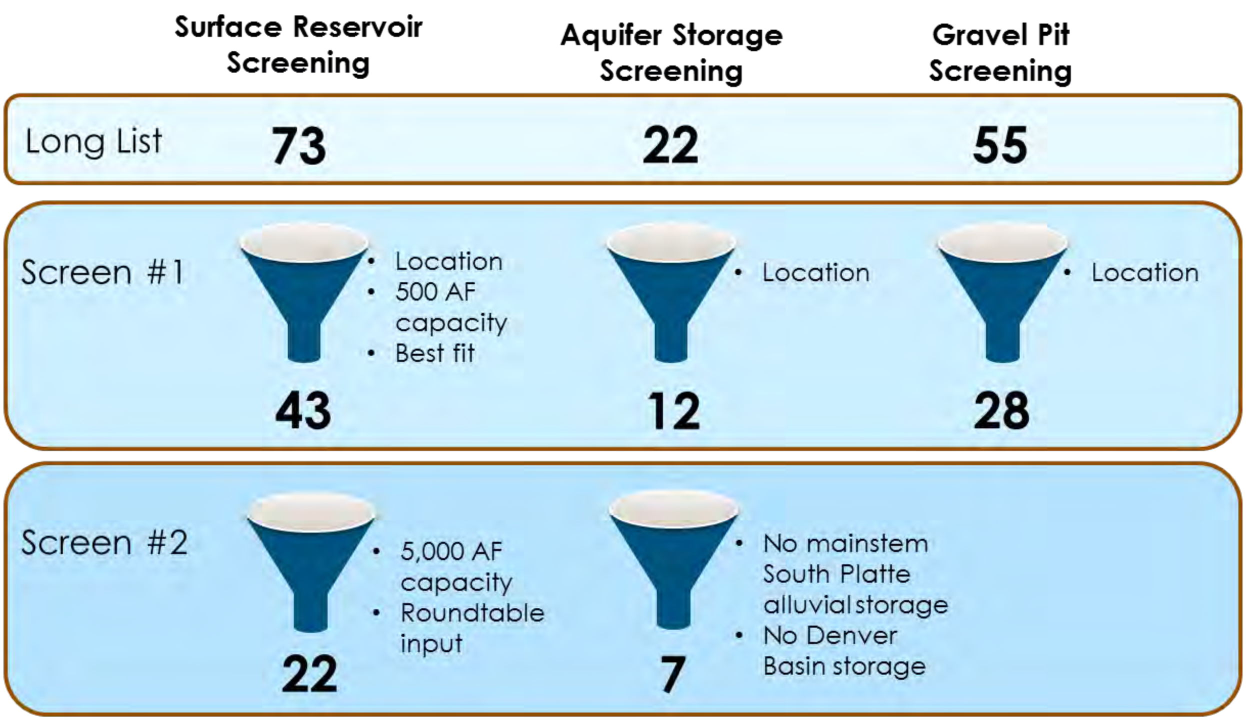



**Figure 9-2. Summary of Storage Site Screening Process**

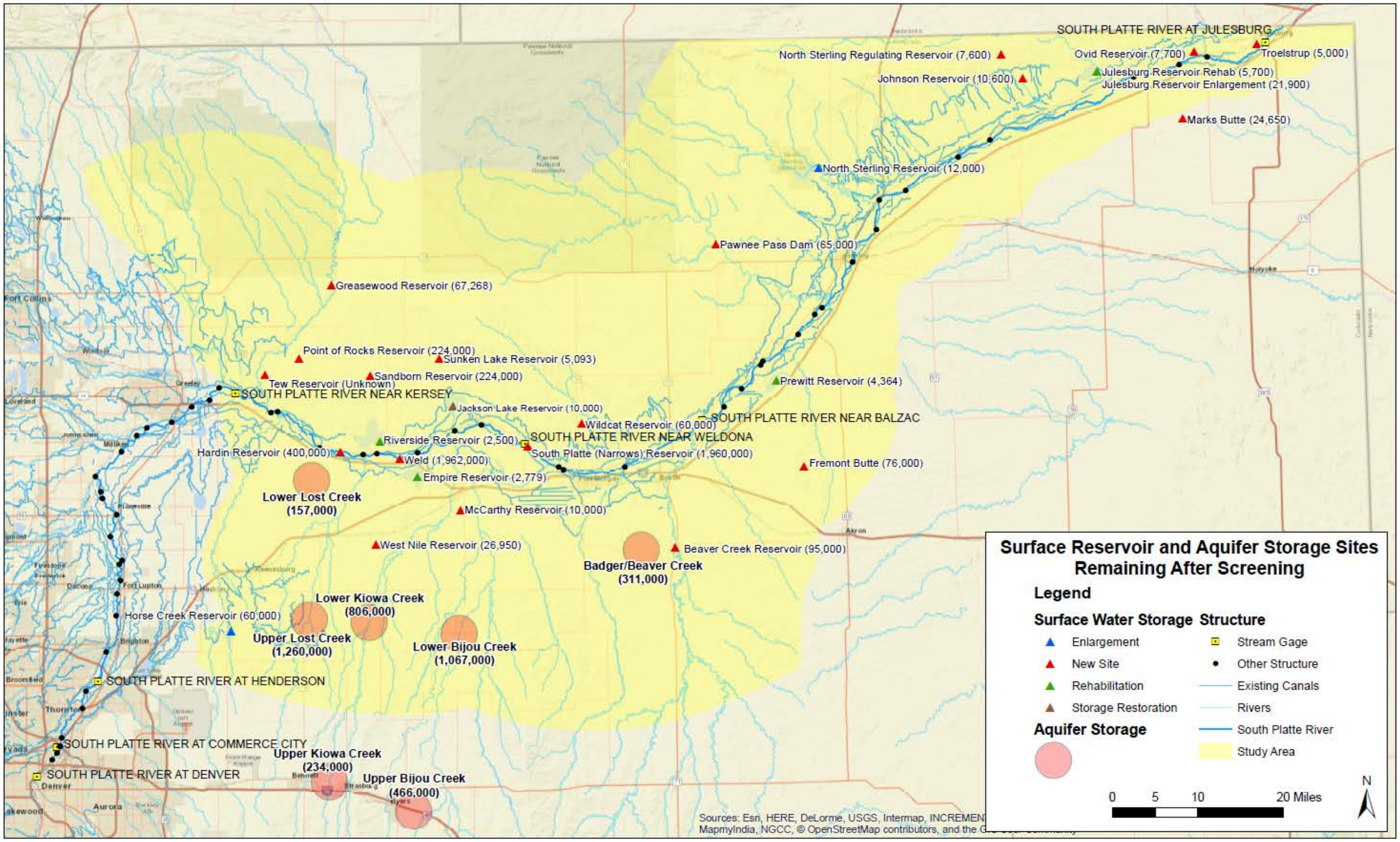



**Figure 9-3. Surface Reservoir and Aquifer Storage Sites Remaining After Screening**

## 9.2 COMPARISON OF STORAGE OPTIONS – SITE EVALUATION FRAMEWORK

Individual SPSS storage options were evaluated and compared based on technical, cost, and environmental factors. Technical and environmental data for all storage options remaining after the initial screening process were collected from the available sources described in **Appendix B**. Data were compiled in a Site Evaluation Framework (SEF) database. Database attributes (parameters, data types) and qualifiers (values, ratings) for the SEF are defined in **Appendix H**.

Where possible, data were collected from previous studies and reports. The SPSS study team used the best available maps, aerial photography and other resources to fill in the database attributes for each storage option. Professional judgment was used where necessary. For each surface reservoir storage option the descriptive data were based on the maximum storage capacity reported for that site in previous reports or based on a feasible dam alignment determined by the consultant team. ASR site characteristics were obtained from previous reports and combined with theoretical conceptual design for recharge and recovery facilities. Database entries for each storage option are shown in **Table 9-1**.

## Table 9-1. Database Entries for Storage Options

| Site Name | Features | | | | | | | | | Benefits | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Partnerships-Consumptive | Partnerships-Non-Consumptive | Regional Integration | Existing Water Quality | Source Water Quality | Construct-ability | Scalability | Use Existing Infrastructure | Ease To Use Existing Infrastructure | Flood Control Benefit | Migratory Bird Habitat | Solution Compatibility |
| Prewitt Reservoir Rehab | Yes | Unknown | Yes | No | Yes | High | Low | Yes | Easy | Low | Yes | Yes |
| Julesburg Reservoir Enlarge | Unknown | Unknown | Yes | Unknown | Yes | High | Low | Yes | Easy | Low | Yes | No |
| Wildcat Reservoir | Yes | Yes | Yes | N/A | Yes | High | Low | Yes | Medium | Low | Yes | Yes |
| South Platte (Narrows) Reservoir | Yes | Unknown | Yes | N/A | Yes | Low | Low | Yes | Easy | High | Yes | Yes |
| Hardin Reservoir | Unknown | Unknown | Yes | N/A | Yes | Low | Low | Yes | Easy | High | Yes | Yes |
| Riverside Reservoir Rehab | Unknown | Unknown | Yes | No | Yes | High | Low | Yes | Easy | Low | Yes | Yes |
| Empire Reservoir Rehab | Unknown | Unknown | Yes | No | Yes | High | Low | Yes | Easy | Low | Yes | Yes |
| Sandborn Reservoir | Unknown | Unknown | Yes | N/A | Yes | High | Low | Yes | Difficult | Low | Yes | Yes |
| Point of Rocks Reservoir | Unknown | Unknown | Yes | N/A | Yes | High | Low | Yes | Medium | Low | Yes | Yes |
| Julesburg Reservoir (Rehab) | Unknown | Unknown | Yes | Unknown | Yes | High | Low | Yes | Easy | Low | Yes | No |
| Jackson Lake Reservoir | Yes | Unknown | Yes | Yes | Yes | High | Low | Yes | Easy | Low | Yes | Yes |
| North Sterling Reservoir Enlarge | Unknown | Unknown | Yes | Yes | Yes | High | Low | Yes | Easy | Low | Yes | No |
| McCarthy Reservoir | Yes | Unknown | Yes | N/A | Yes | High | Low | No | N/A | Low | Yes | Yes |
| Upper Lost Creek | Unknown | Unknown | No | N/A | No | High | Medium | No | N/A | Low | No | Yes |
| Lower Lost Creek | Unknown | Unknown | Yes | No | No | High | Medium | No | N/A | Low | No | Yes |
| Upper Kiowa Creek | Unknown | Unknown | No | N/A | Yes | High | Medium | No | N/A | Low | No | Yes |
| Lower Kiowa Creek | Unknown | Unknown | Yes | Yes | Yes | High | Medium | No | N/A | Low | No | Yes |
| Upper Bijou Creek | Unknown | Unknown | No | N/A | Yes | High | Medium | No | N/A | Low | No | Yes |
| Lower Bijou Creek | Unknown | Unknown | Yes | Unknown | Unknown | High | Medium | No | N/A | Low | No | Yes |
| Badger/Beaver Creek | Unknown | Unknown | No | No | No | High | Medium | No | N/A | Low | No | Yes |
| Ovid Reservoir | Unknown | Unknown | Yes | N/A | Yes | High | Low | Yes | Medium | Low | Yes | No |
| Johnson Reservoir | Unknown | Unknown | Yes | N/A | Yes | High | Low | Yes | Medium | Low | Yes | No |
| North Sterling Regulating Res | Unknown | Unknown | Yes | N/A | Yes | High | Low | Yes | Difficult | Low | Yes | No |
| Troelstrup | Unknown | Unknown | Yes | N/A | Yes | High | Low | Yes | Medium | Low | Yes | No |
| Pawnee Pass Dam | Unknown | Unknown | Yes | N/A | Yes | High | Low | Yes | Difficult | Medium | Yes | Yes |
| Greasewood Reservoir | Unknown | Unknown | Yes | N/A | Yes | High | Low | No | N/A | Medium | Yes | Yes |
| Sunken Lake Reservoir | Unknown | Unknown | Yes | N/A | Yes | High | Low | No | N/A | Low | Yes | Yes |
| West Nile Reservoir | Unknown | Unknown | Yes | N/A | Yes | High | Low | No | N/A | Low | Yes | Yes |
| Fremont Butte | Yes | Unknown | Yes | N/A | Yes | High | Low | No | N/A | High | Yes | Yes |
| Beaver Creek Reservoir | Unknown | Unknown | Yes | N/A | Yes | High | Low | No | N/A | Medium | Yes | Yes |

| Site Name | Environmental | | | | | | | Permitting | |
|---|---|---|---|---|---|---|---|---|---|
| | National Wetland Inventory | Critical Habitat -ESA | Wildlife Habitat Impact | Wildlife Species Impact | Migratory Bird Impact | Bald Eagle Nests Impacts | Oil And Gas Wells | Federal Nexus | SPWRAP Potential |
| Prewitt Reservoir Rehab | Medium | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| Julesburg Reservoir Enlarge | Medium | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| Wildcat Reservoir | Medium | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| South Platte (Narrows) Reservoir | High | No | Negative | Negative | Negative | Low | None | Yes | No |
| Hardin Reservoir | High | No | Negative | Negative | Negative | High | High | Yes | No |
| Riverside Reservoir Rehab | Medium | No | Neutral | Neutral | Neutral | High | Low | Yes | Yes |
| Empire Reservoir Rehab | Medium | No | Neutral | Neutral | Neutral | High | Low | Yes | Yes |
| Sandborn Reservoir | Low | No | Negative | Negative | Negative | Low | Low | Yes | Yes |
| Point of Rocks Reservoir | Low | No | Negative | Negative | Negative | Low | High | No | Yes |
| Julesburg Reservoir (Rehab) | High | No | Neutral | Neutral | Neutral | Low | None | Yes | Yes |
| Jackson Lake Reservoir | Low | No | Negative | Negative | Neutral | Medium | None | Yes | Yes |
| North Sterling Reservoir Enlarge | Medium | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| McCarthy Reservoir | Low | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| Upper Lost Creek | Low | No | Neutral | Neutral | Neutral | Low | None | Yes | No |
| Lower Lost Creek | Low | No | Neutral | Neutral | Neutral | Low | Low | No | No |
| Upper Kiowa Creek | Low | No | Neutral | Neutral | Neutral | Low | None | Maybe | No |
| Lower Kiowa Creek | Low | No | Neutral | Neutral | Neutral | Low | None | Yes | No |
| Upper Bijou Creek | Low | No | Neutral | Neutral | Neutral | Low | None | Maybe | No |
| Lower Bijou Creek | Medium | No | Neutral | Neutral | Neutral | Low | None | Yes | No |
| Badger/Beaver Creek | Low | No | Neutral | Neutral | Neutral | Low | Low | Yes | No |
| Ovid Reservoir | High | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| Johnson Reservoir | Low | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| North Sterling Regulating Res | Low | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| Troelstrup | High | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| Pawnee Pass Dam | Medium | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| Greasewood Reservoir | Low | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| Sunken Lake Reservoir | Medium | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| West Nile Reservoir | Low | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| Fremont Butte | Low | No | Negative | Negative | Negative | Low | None | Yes | Yes |
| Beaver Creek Reservoir | High | No | Neutral | Neutral | Neutral | Low | None | Yes | Yes |

The information in the SEF was used to select the representative storage sites for modeling each storage concept as described in **Section 10.0** of this report. Representative sites were the sites that provided the best balance of technical feasibility and size while avoiding difficult environmental and social impacts to the extent possible. While the representative sites were selected as the "best fit" among the potential sites in each portion of the SPSS study area, further study could determine that other sites are as good or better. The data in the SEF can provide the starting point for future studies if desired.

Criteria and data from the SEF were used to compare short-listed storage sites using a simple scoring system. The purpose of the scoring system was to provide a means of identifying the more feasible storage options. At this level the comparison of sites is not a precise assessment, and results should be used only to identify overall trends or large differences between options.

**Appendix H** lists numerical values assigned to each of the qualifiers for the attributes. Assigning values to the qualifiers allowed for calculation of a triple bottom line evaluation score for each option.

Evaluation of alternatives using a triple bottom line scoring system with multiple criteria required assumptions for the weight of each of the criteria. For this analysis three weighting scenarios were tested:

- Equal Weights; all criteria received an equal weight of 1.
- Technical Weights; all criteria related to technical feasibility of the storage option (e.g., scalability, constructability, ability to use existing infrastructure) were given a weight of 3 and all other criteria were given a weight of 1.
- Environmental Weights; all criteria related to environmental parameters (e.g., wetlands, habitat impacts, permittability) were given a weight of 3 and all other criteria were given a weight of 1.

**Table 9-2** summarizes the results of the triple bottom line site evaluation process applied to the storage options for the three criteria weighting scenarios. The table shows the numerical score for the storage options separated by storage category. Because each type of storage project is different, it is most appropriate to compare scores within each category. In addition, the average of the scores was computed across the 3 weighting scenarios for each storage option to assess how the sites performed across all weightings. This is shown in **Table 9-3**, which again is separated by storage category. **Figure 9-4** shows the range of scores for combined surface reservoirs and aquifer storage sites for each of the weighting scenarios as well as the maximum possible score for each scenario.

## Table 9-2. Summary of Storage Site Evaluation Scores for Different Criteria Weighting Scenarios

| Name | Storage Category | Site Score-Equal Weighting | Site Score-Feasibility Weighting | Site Score-Environmental Weighting |
|---|---|---|---|---|
| **Range of Possible Scores (Min / Max)** | | **0 / 20.5** | **0 / 43.5** | **0 / 37.5** |
| **New Reservoirs** | | | | |
| Beaver Creek Reservoir | New Site | 8.5 | 18.5 | 12.5 |
| Fremont Butte | New Site | 7.5 | 18.5 | 7.5 |
| Greasewood Reservoir | New Site | 6.5 | 16.5 | 6.5 |
| Hardin Reservoir | New Site | 6 | 20 | 0 |
| Johnson Reservoir | New Site | 7 | 21 | 7 |
| McCarthy Reservoir | New Site | 6 | 16 | 6 |
| North Sterling Reg Res | New Site | 7 | 21 | 7 |
| Ovid Reservoir | New Site | 6.5 | 21.5 | 4.5 |
| Pawnee Pass Dam | New Site | 7 | 19 | 6 |
| Point of Rocks Reservoir | New Site | 8.5 | 21.5 | 10.5 |
| Sandborn Reservoir | New Site | 7 | 19 | 7 |
| South Platte (Narrows) Res | New Site | 7.5 | 22.5 | 3.5 |
| Sunken Lake Reservoirs | New Site | 6.5 | 18.5 | 5.5 |
| Troelstrup | New Site | 6.5 | 21.5 | 4.5 |
| West Nile Reservoir | New Site | 5.5 | 14.5 | 5.5 |
| Wildcat Reservoir | New Site | 9 | 26 | 8 |
| **Modified Existing Reservoirs** | | | | |
| Jackson Lake Reservoir | Rehabilitation | 9.5 | 25.5 | 10.5 |
| Julesburg Reservoir (Enlrg) | Enlargement | 8 | 25 | 8 |
| Julesburg Reservoir (Rehab) | Rehabilitation | 10.5 | 27.5 | 15.5 |
| North Sterling Reservoir | Enlargement | 7 | 22 | 6 |
| Prewitt Reservoir | Rehabilitation | 9 | 26 | 8 |
| Riverside Reservoir | Rehabilitation | 10 | 25 | 13 |
| Empire Reservoir | Rehabilitation | 10 | 25 | 13 |
| **Aquifer Storage** | | | | |
| Badger/Beaver Creek | Aquifer | 9.5 | 24.5 | 13.5 |
| Lower Bijou Creek | Aquifer | 10.5 | 28.5 | 13.5 |
| Lower Kiowa Creek | Aquifer | 10 | 26 | 12 |
| Lower Lost Creek | Aquifer | 11.5 | 28.5 | 17.5 |
| Upper Bijou Creek | Aquifer | 8.5 | 20.5 | 11.5 |
| Upper Kiowa Creek | Aquifer | 8.5 | 20.5 | 11.5 |
| Upper Lost Creek | Aquifer | 10 | 26 | 14 |

## Table 9-3. Average of Scores across Three Weighting Scenarios for Reservoir Storage Options

| Storage Options Sorted by Average Score | Storage Category | Average of Scores for 3 Weighting Scenarios (1) |
|---|---|---|
| **New Reservoirs** | | |
| Wildcat Reservoir | New – Off Channel | 14.3 |
| Point of Rocks Reservoir | New – Off Channel | 13.5 |
| Beaver Creek Reservoir | New – Off Channel | 13.2 |
| Johnson Reservoir | New – Off Channel | 11.7 |
| North Sterling Regulating Reservoir | New – Off Channel | 11.7 |
| Fremont Butte | New – Off Channel | 11.2 |
| South Platte (Narrows) Reservoir | New - Mainstem | 11.2 |
| Sandborn Reservoir | New – Off Channel | 11.0 |
| Ovid Reservoir | New – Off Channel | 10.8 |
| Troelstrup | New – Off Channel | 10.8 |
| Pawnee Pass Dam | New – Off Channel | 10.7 |
| Sunken Lake Reservoir | New – Off Channel | 10.2 |
| Greasewood Reservoir | New – Off Channel | 9.8 |
| McCarthy Reservoir | New – Off Channel | 9.3 |
| Hardin Reservoir | New – Mainstem | 8.7 |
| West Nile Reservoir | New – Off Channel | 8.5 |
| **Modified Existing Reservoirs** | | |
| Julesburg Reservoir (Rehabilitation) | Rehabilitation | 17.8 |
| Riverside Reservoir | Rehabilitation | 16.0 |
| Empire Reservoir | Rehabilitation | 16.0 |
| Jackson Lake Reservoir | Rehabilitation | 15.2 |
| Prewitt Reservoir | Rehabilitation | 14.3 |
| Julesburg Reservoir (Enlargement) | Enlargement | 13.7 |
| North Sterling Reservoir | Enlargement | 11.7 |
| **Aquifer Storage** | | |
| Lower Lost Creek | Aquifer | 19.2 |
| Lower Bijou Creek | Aquifer | 17.5 |
| Upper Lost Creek | Aquifer | 16.7 |
| Lower Kiowa Creek | Aquifer | 16.0 |
| Badger/Beaver Creek | Aquifer | 15.8 |
| Upper Bijou Creek | Aquifer | 13.5 |
| Upper Kiowa Creek | Aquifer | 13.5 |

*(1) Range of possible averaged scores is 0 – 34*

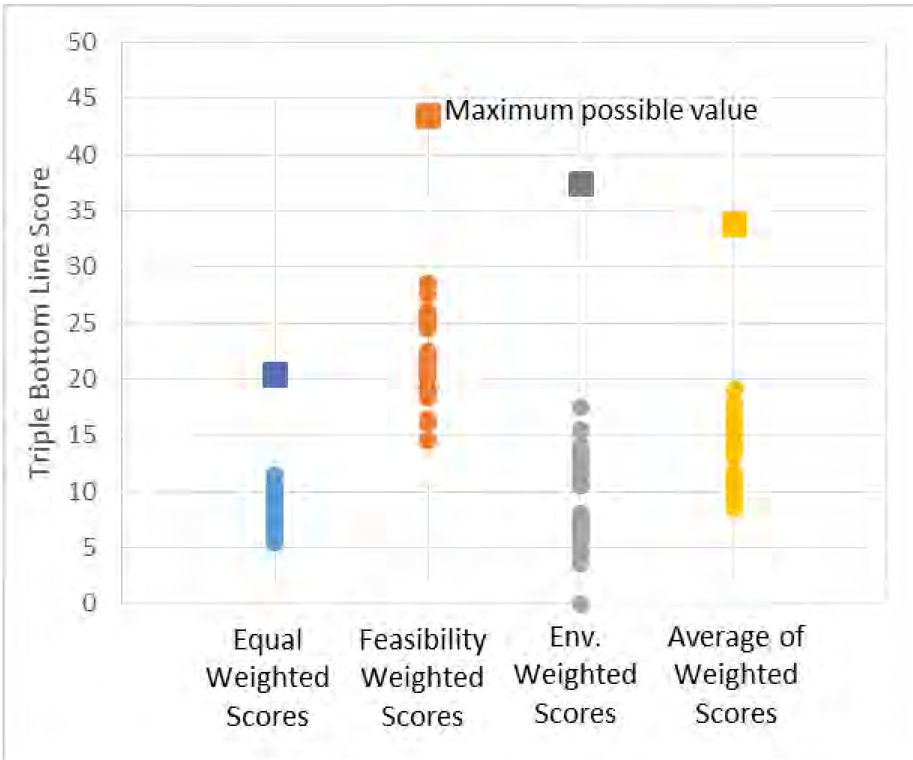



**Figure 9-4. Range of Storage Site Scores for Different Weighting Scenarios**

Results of the multi-criteria comparison of sites can be summarized as follows:

- Sites that tend to rise to the top of the scoring process tend to do so regardless of the weights assigned to the criteria. Similarly, sites that tend to fall to the bottom of the scoring process tend to do so regardless of the weights assigned to the criteria. This is helpful in that the relative scoring of most sites is fairly independent of the weight assigned to the criteria in the SEF.
- As expected, the on-channel storage options (Narrows Reservoir and Hardin Reservoir) score poorly relative to most other options.
- Of the new off-channel reservoir options, the sites with the most promise appear to be Wildcat, Point of Rocks, Beaver Creek, Johnson, North Sterling Regulating, and Sandborn.
- Of the aquifer storage sites, Lower Lost Creek and Lower Bijou Creek score better than the other sites because of their closer proximity to the South Platte (simplifying diversions into storage and releases back to the river) and closer proximity to the major demand centers at Denver and Kersey.
- Scores are clustered over a relatively narrow range compared to the maximum possible score for each weighting scenario, and no storage options had a score close to the maximum possible score. Differences among storage options are small, and at this level of analysis the triple bottom line scoring process should not be used to eliminate options.

At this level of analysis, the storage option scoring process is very approximate and is based on conceptual information and considerable professional judgment. Significant information about individual sites was unknown at this stage. Refinement of site specific data could change scores of options significantly. In addition, sites were scored without regard for how they could be used in a specific solution that could be formulated by a specific water user. When considering how storage sites would be incorporated into a particular alternative and integrated into the operations of a particular water user, results for the scoring process could vary considerably from this generic approach.

## 9.3 STORAGE COST ESTIMATES

Conceptual (ACEE Class V) construction cost estimates were prepared for the remaining surface reservoir sites and for two of the aquifer storage sites with the most potential for SPSS storage. Details of the cost estimating process for dams and other infrastructure are contained in **Appendix I**. Where possible cost estimates from past studies were adopted for this study and were escalated to 2017 dollars using accepted construction cost indexes. For new sites or sites for which no data were available, unit costs ($/ac-ft) were estimated based on unit costs of other reservoir storage projects in the SPSS study area.

Surface reservoir costs are summarized in **Table 9-4**. These include costs for permitting, design, land acquisition and construction. The reservoirs with the lowest unit cost are the most cost-effective in terms of storage provided per dollar spent. For new surface reservoirs, unit cost is generally inversely correlated with capacity such that the largest reservoirs have the lowest unit cost. This is shown in **Figure 9-5**; data in the figure include design and construction but not permitting costs. Enlarged or rehabilitated existing reservoirs have more variable unit costs because the type of work required to achieve the additional storage varies considerably from site to site.

## Table 9-4. Summary of Surface Reservoir Costs

| Dam Type/Name | Storage Capacity (ac-ft) | Estimated 2017 Cost ($ million) | Unit Cost ($/ac-ft) |
|---|---|---|---|
| **New Site** | | | |
| Sandborn Reservoir | 224,000 | $131 | $580 |
| West Nile Reservoir | 26,950 | $59 | $2,100 |
| McCarthy Reservoir | 10,000 | $27 | $2,500 |
| South Platte (Narrows) Reservoir | 1,960,000 | $145 | $74 |
| Wildcat Reservoir | 60,000 | $79 | $1,300 |
| Pawnee Pass Dam | 75,000 | $254 | $3,400 |
| Fremont Butte | 76,000 | $74 | $980 |
| North Sterling Regulating Reservoir | 7,600 | $38 | $5,000 |
| Johnson Reservoir | 10,600 | $24 | $2,300 |
| Ovid Reservoir | 7,700 | $24 | $3,100 |
| Troelstrup | 5,000 | $19 | $3,700 |
| Beaver Creek | 95,000 | $66 | $690 |
| **Enlargement** | | | |
| North Sterling Reservoir Enlargement | 12,000 | $22 | $1,800 |
| Julesburg Reservoir Enlargement | 21,900 | $46 | $2,100 |
| **Rehabilitation** | | | |
| Empire Reservoir Rehab | 2,779 | $14 | $5,000 |
| Prewitt Reservoir Rehab | 4,364 | $5.5 | $1,300 |
| Julesburg Reservoir Rehab | 5,700 | $31 | $5,400 |
| Jackson Lake Reservoir Rehab | 10,000 | $37 | $3,700 |
| Riverside Reservoir Rehab | 2,500 | $13 | $5,200 |

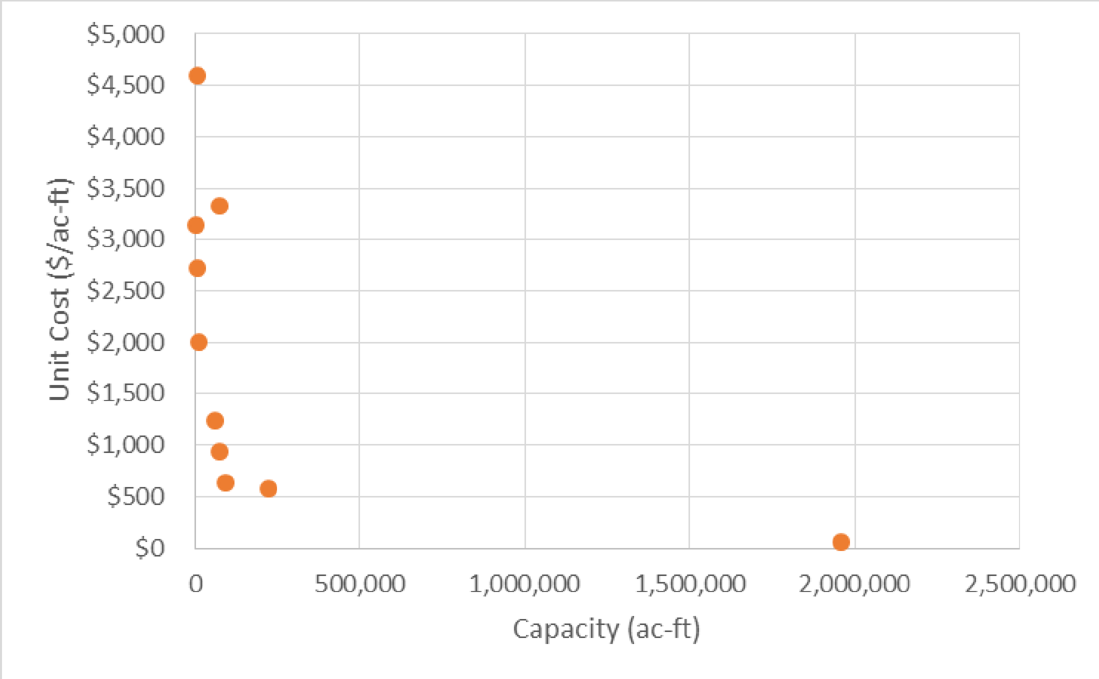



**Figure 9-5. Unit Cost of Surface Storage vs Capacity for New Reservoirs**

Aquifer storage costs were based on conceptual designs for infiltration basin recharge and recovery within an alluvial aquifer. Conceptual designs included components required to recharge and recover water at a site, but not the conveyance to and from the site.

Aquifer storage and recovery concept costs are more correlated to recharge and recovery rates than total storage volumes. Because of this, Table 9-5 presents the same total cost estimate for Lower Lost Creek Basin and Badger/Beaver Basin. These costs were developed on a unit basis so future cost estimates can be scaled to different recharge and recovery scenarios.

**Table 9-5. Aquifer Storage and Recovery Costs**

| Storage Concept | Storage Capacity (ac-ft) | Recharge Rate (ac-ft per month) | Recovery Rate (ac-ft per month) | Estimated 2017 Cost ($ million) | Unit Cost ($/ac-ft/month) |
|---|---|---|---|---|---|
| Lower Lost Creek Aquifer | 157,000 | 5,000 | 4,000 | $39 | $9,750 |
| Beaver/Badger Aquifer | 311,000 | 5,000 | 4,000 | $39 | $9,750 |

The aquifer storage cost estimates were based on SPSS delivery and demand scenarios with 10,000 ac-ft of gravel pit regulating storage near the river diversion (see discussion of concepts in the next section). Aquifer storage concepts were modeled with a capacity of 5,000 ac-ft per month of inflow/recharge and 4,000 ac-ft per month of outflow/recovery. It is possible that these scenarios would not represent achievable rates of alluvial aquifer recharge and recovery for all alluvial ASR sites, but these rates were used to provide a reasonable scale for ASR site components and associated costs. It was assumed that land availability and hydrogeologic conditions would not constrain site construction or operations for recharge or recovery. Comparison to surface water storage options is challenging because of fundamental differences in how ASR sites would be constructed and operated.

## 9.4 SUMMARY OF STORAGE OPTION ANALYSIS

The analysis of storage options was necessarily high level at this stage of analysis, but supports the following conclusions.

- Many feasible surface and aquifer storage options exist in the lower South Platte Basin.
- Cost of surface reservoir storage varies widely, and is very dependent on the specific site being considered and its size based on the needs of the particular application. Nonetheless, many potentially cost-effective reservoir storage options exist in the study area.
- Aquifer storage projects are more limited by recharge and recovery rates rather than storage volume. Typical aquifer storage projects are designed as supplemental supply sources, not as projects to recharge large volumes of water diverted during peak spring snowmelt periods. This results in lower firm yield, and does not attempt to maximize use of potential storage capacity as occurs with surface reservoirs. However, a related benefit is that aquifer storage projects are relatively low cost and can be scaled up over time (not constructed all at once). These unique characteristics make aquifer storage projects difficult to compare to surface water storage projects.
- Factors besides cost such as environmental impacts, permittability, land requirements, infrastructure conflicts, etc. will be important in evaluating specific storage options. These would need to be reviewed in the context of a particular storage project to determine how they could affect project feasibility.
- Based on the high level evaluation in this study it is not recommended that any potential storage options be eliminated from further consideration. However, mainstem dams may prove infeasible due to insurmountable permitting obstacles.
- Mainstem dam options (e.g., Narrows and Hardin sites) are technically feasible and cost-effective but would face significant new permitting challenges and present extensive social challenges related to property acquisition and landowner impacts.

# 10. STORAGE CONCEPTS

Storage sites cannot be evaluated in a vacuum, but must be integrated with assumed basin water supply, demand and operations to assess their potential effectiveness. The SPSS used the term “storage concept” or “storage solution” to describe how individual storage options would be tied to the overall basin operations in the South Platte River. Conceptual storage solutions were generalized approaches to developing additional storage of South Platte River water in the SPSS study area below Greeley.

Storage concepts were organized based on the reach of the lower South Platte River in which a storage project would be located, the reach from which water would be diverted, and whether storage would be achieved in a surface reservoir or groundwater basin. Each concept was required to have at least one actual storage site identified in the inventory of storage options described in **Section 2.0**. Storage concepts consisted of a specific storage option, an approach to capture water from the South Platte River, and an approach to deliver water to meet demands.

Aquifer storage concepts were fit to the aquifer recharge and recovery capacities described previously. For purposes of comparison with similar surface storage concepts, alternate aquifer storage concepts were also evaluated with similar intake and discharge assumptions, even though in most cases designing and operating aquifer storage projects under those conditions would be extremely challenging.

Surface reservoir storage concepts were modeled using a simplified MODSIM water resources model of the SPSS study area developed for this project. The features of storage concepts and the assumptions used to model them are described below. Aquifer storage options were not simulated in the same way because they would typically be used in conjunction with surface reservoirs and not as stand-alone projects; modeling of surface-groundwater conjunctive use concepts was beyond the scope of this study.

While hundreds of possible storage concepts could be envisioned in the lower South Platte Basin, a manageable number of representative storage concepts was selected to investigate the range of possible storage opportunities in the region.

## 10.1 SELECTION OF STORAGE CONCEPTS

The following eight representative storage concepts were selected for analysis. Evaluating these concepts will give the state an indication of the range of alternatives, feasibility issues, costs, etc. associated with a new storage project in the SPSS study area.

1. Mainstem Storage – surface reservoir on the mainstem of the South Platte River
2. Upper Basin Storage – surface storage with a reservoir and river diversion between Greeley and the South Platte River near Weldona stream gage
3. Mid Basin Storage North – surface storage with a reservoir and river diversion on the north side of the river between the South Platte River near Weldona stream gage and the South Platte River near Balzac stream gage
4. Mid Basin Storage South – surface storage with a reservoir and river diversion on the south side of the river between the South Platte River near Weldona stream gage and the South Platte River near Balzac stream gage
5. Lower Basin Storage – surface storage with a reservoir and river diversion downstream of the South Platte River near Balzac stream gage
6. Existing Reservoir Improvements – enlargements or rehabilitations of existing reservoirs anywhere in the study area
7. Groundwater Storage Basin West – groundwater aquifer storage and recovery in a groundwater basin in the western portion of the study area
8. Groundwater Storage Basin East – groundwater aquifer storage and recovery in a groundwater basin in the eastern portion of the study area

## 10.2 DEFINITION OF COMPONENTS ASSOCIATED WITH STORAGE CONCEPTS

In order to analyze the relative benefits of the identified storage concepts, the common components necessary to implement the concepts were defined at a conceptual level. These components are described below and include storage, diversion, intake, and outlet infrastructure. Standard assumptions were adopted for surface storage concepts and another set of standard assumptions were adopted for groundwater storage concepts so as to avoid biasing the results. No optimization or other special consideration was given to any of the storage concepts.

### 10.2.1. Storage Components

Table 10-1 lists the specific surface and groundwater storage options remaining after the previously described screening process and connects them with each storage concept. Representative storage sites used for analysis are highlighted in bold.

## Table 10-1. Specific Storage Options Linked to Generalized Storage Solution Concepts

| Storage Solution Concepts | Potential Storage Sites and Maximum Capacities |
|---|---|
| Mainstem Storage | **South Platte (Narrows) Reservoir Site (1.960,000 ac-ft)**<br>Hardin Reservoir Site (400,000 ac-ft) |
| Upper Basin Storage | **Sandborn Reservoir Site (224,000 ac-ft)**<br>Point of Rocks Reservoir Site (224,000 ac-ft)<br>Sunken Lake Reservoir Site (5,093 ac-ft)<br>Greasewood Reservoir Site (67,268 ac-ft)<br>Jackson Lake Reservoir Rehabilitation (10,000 ac-ft) |
| Mid Basin Storage North | **Wildcat Reservoir Site (60,000 ac-ft)**<br>Pawnee Pass Reservoir Site (75,000 ac-ft) |
| Mid Basin Storage South | **Beaver Creek Reservoir Site (95,000 ac-ft)**<br>Fremont Butte Reservoir Site (75,000 ac-ft)<br>West Nile Reservoir Site (26,950 ac-ft)<br>McCarthy Reservoir Site (10,000 ac-ft) |
| Lower Basin Storage | **Julesburg Reservoir Enlargement/Rehabilitation (27,600 ac-ft)**<br>**Ovid Reservoir Site (7,700 ac-ft)**<br>**Troelstrup Reservoir Site (5,000 ac-ft)**<br>North Sterling Reservoir Enlargement (12,000 ac-ft)<br>North Sterling Regulation Reservoir (7,600 ac-ft)<br>Johnson Reservoir (10,600 ac-ft) |
| Existing Reservoir Improvements | **Julesburg Reservoir Enlargement/Rehabilitation (27,600 ac-ft)**<br>**North Sterling Reservoir Enlargement (12,000 ac-ft)**<br>**Prewitt Reservoir Rehabilitation (4,364 ac-ft)**<br>**Riverside Reservoir Rehabilitation (2,500 ac-ft)**<br>**Jackson Lake Reservoir Rehabilitation (10,000 ac-ft)**<br>Empire Reservoir Rehabilitation (2,779 ac-ft) |
| Groundwater Basin Storage West | Upper Lost Creek Aquifer (1,260,000 ac-ft)<br>**Lower Lost Creek Aquifer (157,000 ac-ft)**<br>Upper Kiowa Creek Aquifer (234,000 ac-ft)<br>Lower Kiowa Creek Aquifer (806,000 ac-ft)<br>Upper Bijou Creek Aquifer (466,000 ac-ft)<br>Lower Bijou Creek Aquifer (1,067,000 ac-ft) |
| Groundwater Basin Storage East | **Beaver/Badger Aquifer (311,000 ac-ft)** |

*Note: Representative storage sites used for analysis are highlighted in bold.*

Representative storage options were selected for use in each of the storage concepts. This allowed realistic elevation-area-capacity data, evaporation data, and diversion and delivery configurations to be used in the simulations. The study team performed a best-fit evaluation to select a representative storage option for each storage concept. The best-fit option was selected based on data in the Site Evaluation Framework described previously, including physical, environmental and social attributes of the candidate reservoir and groundwater sites in each region of the SPSS study area.

**Table 10-1** highlights the representative storage options selected for simulating each storage concept. The locations of these representative storage options are shown in **Figure 10-1**. **Figures 10-2** through **Figures 10-9** present maps of the representative storage options used for each storage concept, and the location of conceptual inlet-outlet facilities (intake pipelines, use of existing irrigation canals, or both).

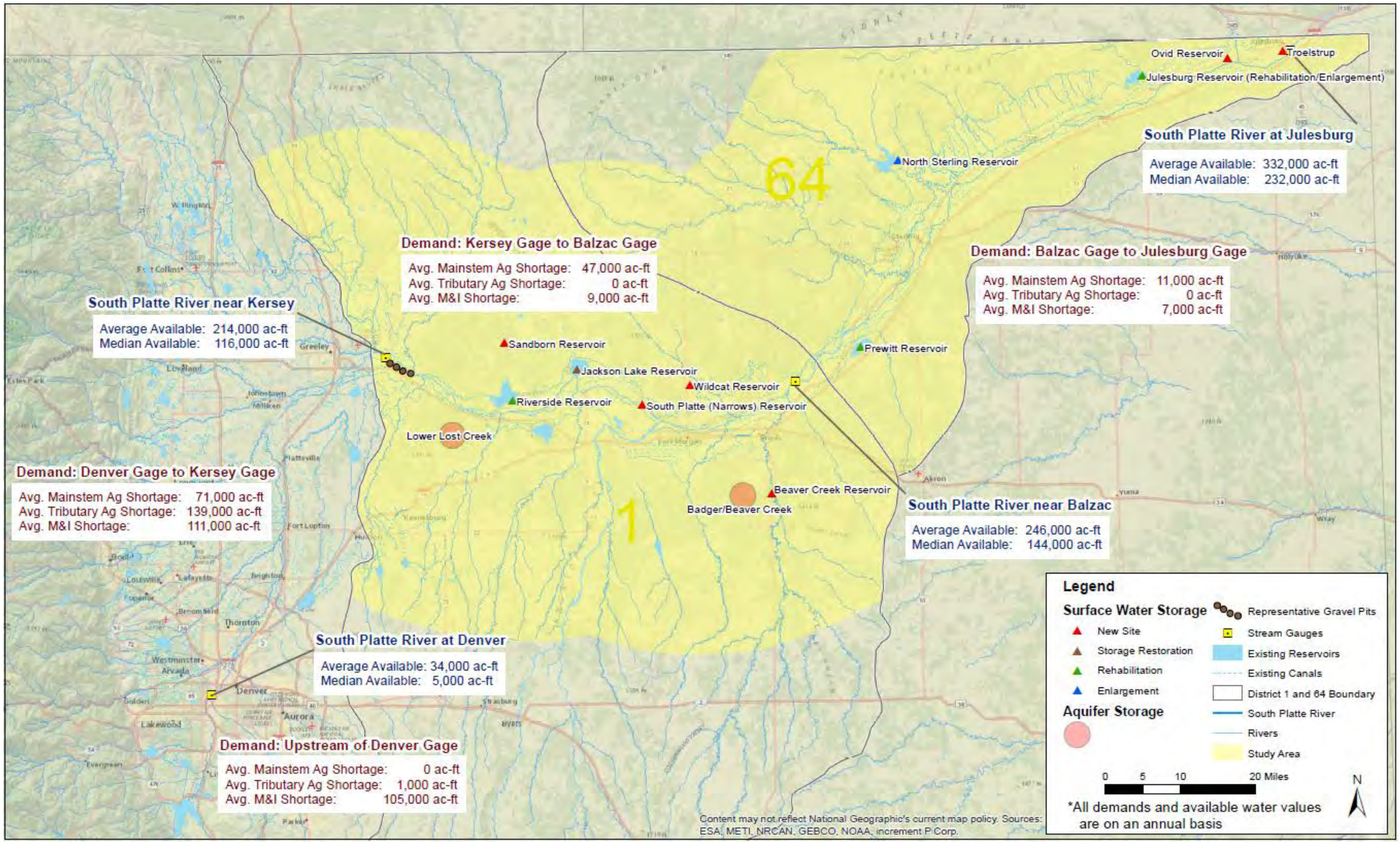



**Figure 10-1. Representative Storage Options Used to Model Storage Concepts**


**Figure 10-2. Upper Basin Storage Conceptual Design for Sandborn Reservoir**

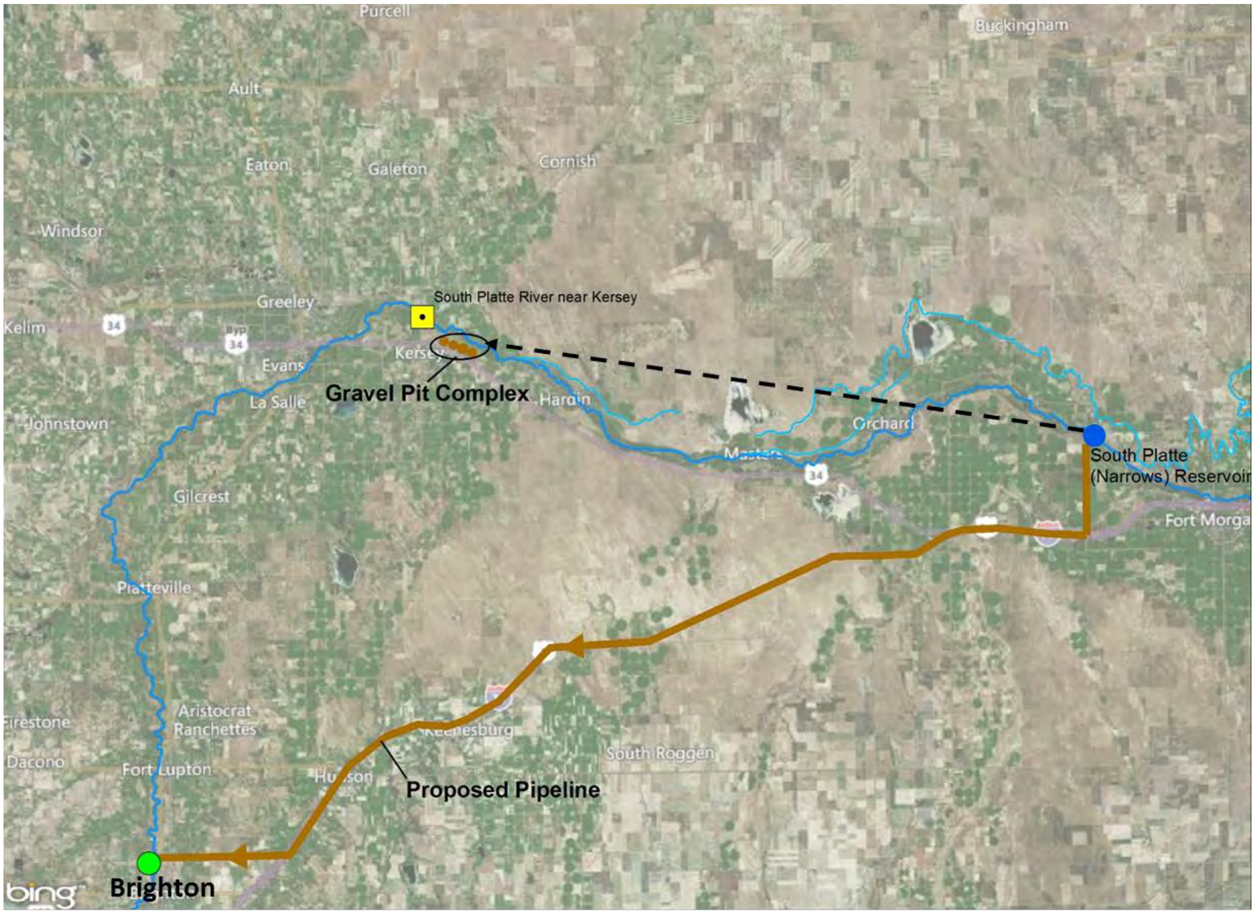



**Figure 10-3. Mainstem Storage Conceptual Design for South Platte (Narrows) Reservoir**

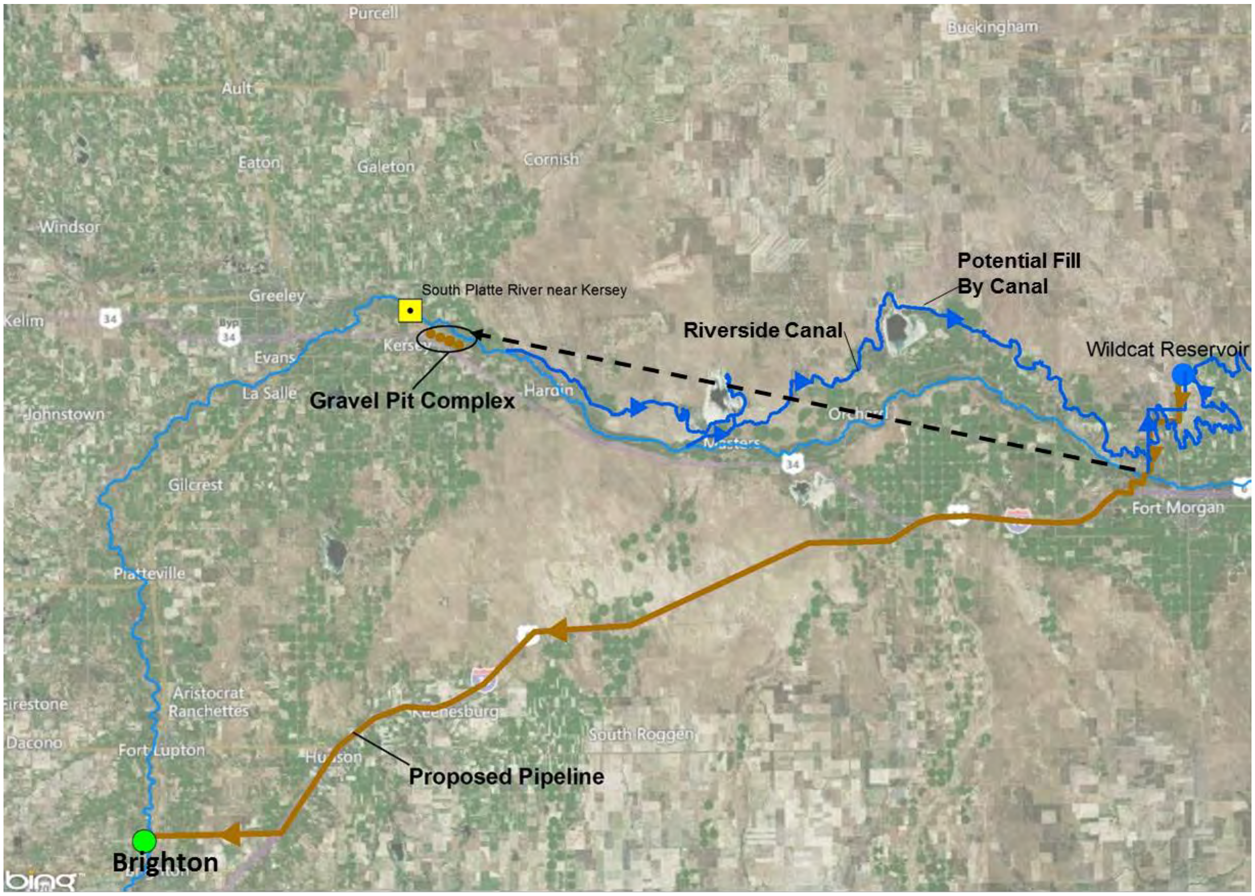



Figure 10-4. Mid Basin North Conceptual Design for Wildcat Reservoir

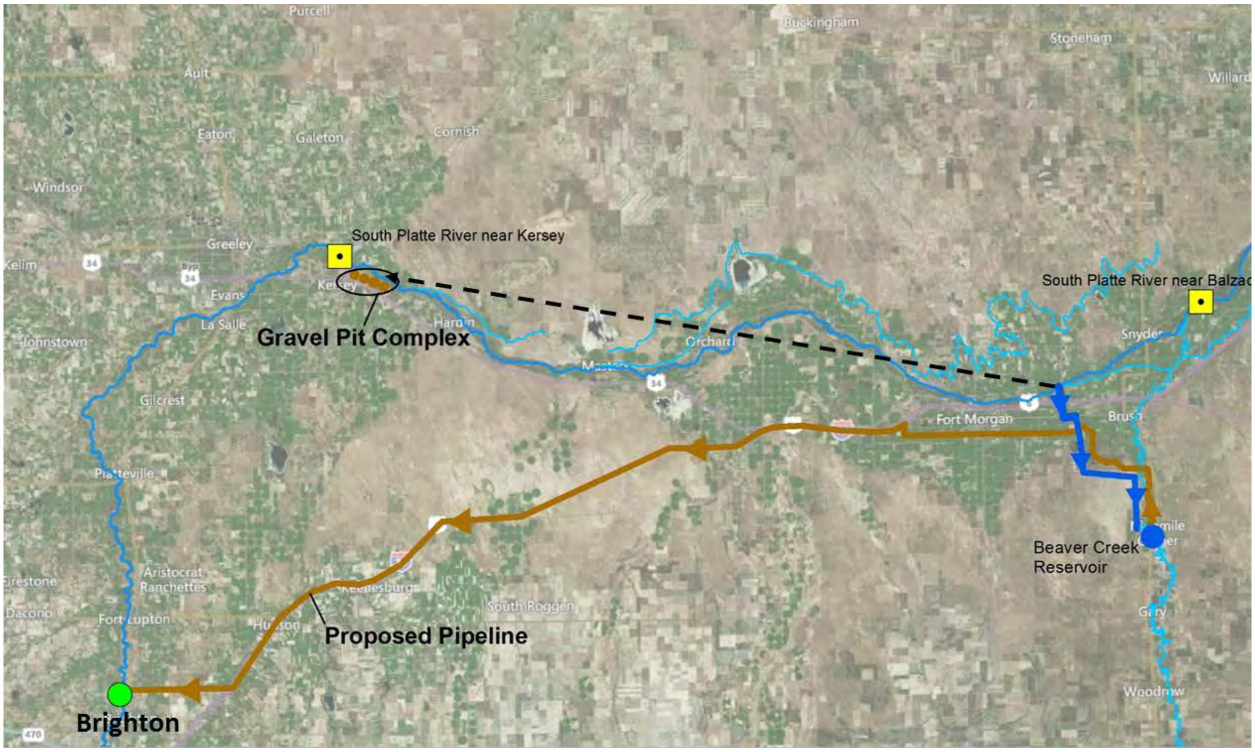



**Figure 10-5. Mid Basin South Conceptual Design for Beaver Creek Reservoir**

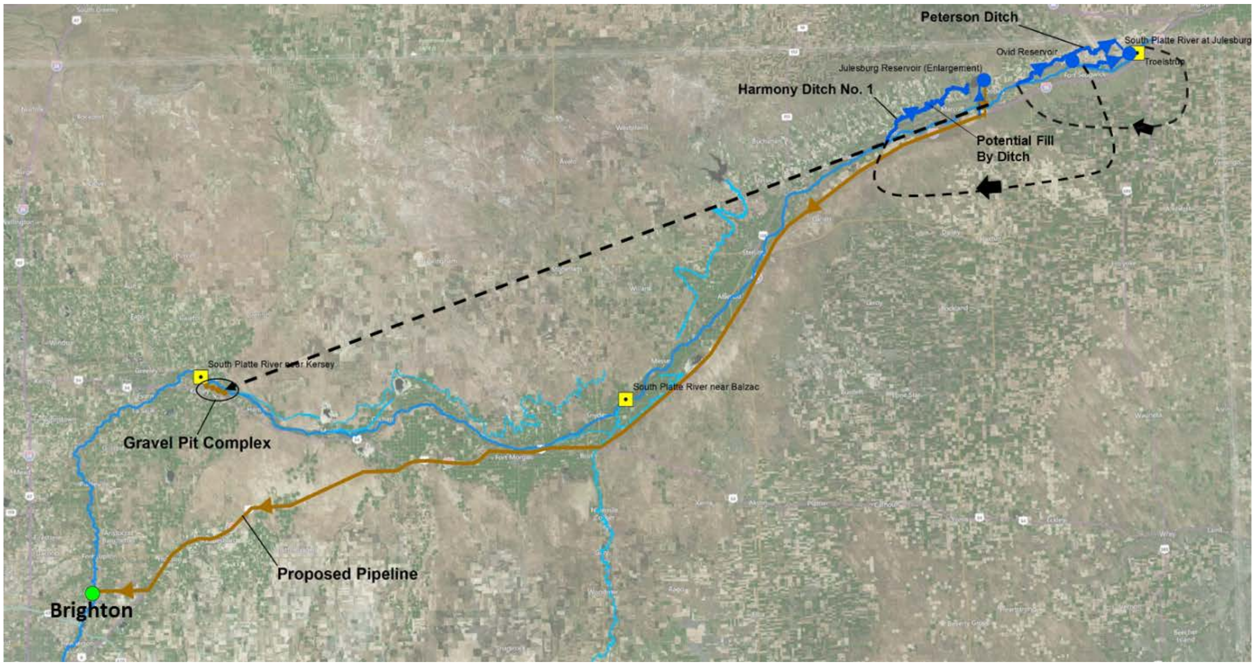



**Figure 10-6. Lower Basin Storage Conceptual Design for Julesburg, Ovid, Troelstrup Reservoirs**


**Figure 10-7. Existing Reservoir Improvements Conceptual Design for Julesburg, North Sterling, Prewitt, Jackson Lake, and Riverside Reservoirs**


**Figure 10-8. Groundwater Storage Basin West Conceptual Design for Lower Lost Creek Basin**

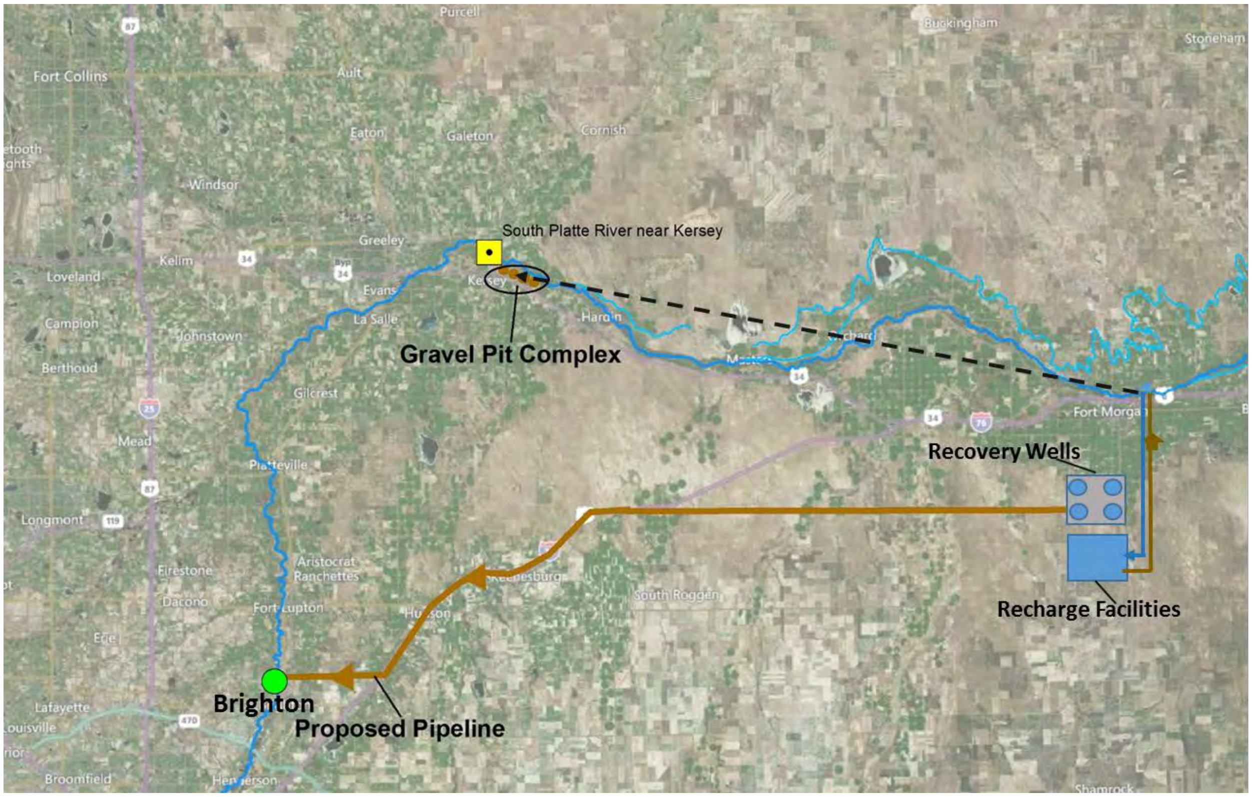



**Figure 10-9. Groundwater Basin East Conceptual Design for Badger/Beaver Creek Basin**

### 10.2.2. Surface Reservoir Concept Components

#### 10.2.2.1 River Diversion and Intake Components

With the exception of the Mainstem Storage concept, all concepts require diversion of water from the South Platte River and conveyance to an off-channel storage facility. For any off-channel storage option, the water supply yield would be constrained by the capacity of the diversion and conveyance facilities used to fill the reservoir. Based on review of historical diversion data and conceptual engineering analysis of potential conveyance options, standard assumptions were made for analyzing storage concepts. All storage concepts included the following diversion and intake components.

- *A new 800 cfs (520 mgd) diversion structure on the South Platte River at a location close to the storage option.* This is close to the maximum historical river diversion and balances size and cost of the structure against frequency of bypassing potentially divertable flows due to limited diversion capacity (see **Section 6.4**). Available divertable flow in the South Platte River would exceed this capacity about 8-15 percent of the time, depending on the location.
- *A 10,000 ac-ft gravel pit complex at the diversion point.* This would allow the capacity of the intake conveyance facilities to be sized at 50 percent of the river diversion capacity. This was an estimated size for regulating storage; it was not simulated in the modeling of storage concepts or optimized.
- A new 96-inch pipeline and system of pump stations from the diversion structure to the reservoir or aquifer recharge area with a capacity of 400 cfs (260 mgd). It is possible that existing irrigation diversion structures and canals could be used to fill new storage sites depending on their location and available capacity at the time SPSS water rights would be in priority. Because of the great uncertainty around use of existing irrigation systems for new storage when the owner/operator is not defined, this study assumed new infrastructure would be required.

#### 10.2.2.2 Outlet Components

For purposes of comparing SPSS storage concepts, it was assumed that any storage project would be operated to meet demands in three ways: (1) make releases to the South Platte and exchange up to Kersey to meet demands in the Northern Front Range area; (2) make releases to the South Platte River to meet demands downstream of the discharge point; and (3) make releases to a new pipeline to Brighton to meet demands in the Denver Metro/Northern Front Range area. To make these releases each storage concept included the same standard outlet components:

- Release of water back to the South Platte in the same pipeline used to fill the reservoir (bi-directional pipeline), with an unconstrained capacity.
- 100 mgd pipeline to Brighton. A capacity of 100 mgd (150 cfs) was selected because it is similar to the ultimate capacity of the Prairie Waters pipeline that delivers water from the Brighton area to Aurora and WISE participants.
- A 20,000 ac-ft gravel pit complex near Kersey to serve as the exchange-to point for the exchange alternative. The size of this storage was not optimized but was standard for all storage concepts.

### 10.2.3. Aquifer Storage Concept Components

The ASR site components were conceptually designed to recharge alluvial aquifers through surface infiltration basins with downgradient recovery wells. The ASR site components included associated instrumentation/controls, conveyance piping, and site excavation costs. ASR sites will also require similar intake components (diversion structure, gravel pit storage, pipeline) and outlet components (pipeline, gravel pit storage), as those described above.

## 10.3 ASSUMED OPERATIONS FOR STORAGE CONCEPT ANALYSIS

In order to simulate operation of each surface reservoir storage concept to estimate the water supply yield it could produce, a MODSIM operations model was constructed for the Lower South Platte River. The model used the infrastructure components described in the previous section. This section describes the other input data and assumptions used to create the MODSIM model and perform that analysis.

### 10.3.1. Hydrology

The MODSIM operations model used the daily estimate of available water under future river conditions for the period 1996-2015 from the Point Flow Model. The estimates of future available water account for effects of full use of reusable water by Denver Water and Aurora Water; IPPs from Colorado's Water Plan; and decreed but unexercised exchanges that would not have been reflected in the historical data in the Point Flow Model.

### 10.3.2. Demands

The same demands were applied to each storage concept, regardless of where it was located in the SPSS study area. This provided a standard basis of comparison for all the storage concepts. The maximum potential demands as well as their temporal distribution through the year were described in **Section 6.0** based on the SWSI gap analysis for the lower South Platte Basin.

All storage concepts were simulated to concurrently meet the three demand scenarios according to the following logic.

1. Priority 1: Exchange to Kersey. Water was exchanged to the assumed 20,000 ac-ft gravel pit complex at Kersey to meet the M&I and agricultural demands aggregated at the Kersey gage. Demands at the Kersey gage represent M&I and agricultural shortages for areas primarily east and north of this point. It is recognized that infrastructure would be required to deliver water from Kersey to M&I or agricultural customers upstream of this point. That infrastructure has not been conceptualized and has not been included in the SPSS costs described in this report.
2. Priority 2: Release to River. Water was released back to the South Platte River to meet downstream agricultural and municipal demands. This would include use of the SPSS water to meet augmentation commitments.
3. Priority 3: Pipe to Brighton. Water delivered by pipeline to the Brighton area could meet demands for municipal customers upstream of the Denver gage and municipal and agricultural customers upstream of the Kersey gage. This was given the lowest priority among the demand scenarios because it would have the highest capital and operating costs. It is recognized that infrastructure would be required to deliver water from Brighton to M&I or agricultural customers upstream of this point. That infrastructure has not been conceptualized and has not been included in the SPSS costs described in this report.

### 10.3.3. System Losses

Losses in pipelines and pump stations were set at 5 percent of the flow conveyed. Net evaporation at all the reservoir sites was set at 34 inches/year, based on a typical value for the lower South Platte Basin.

### 10.3.4. Groundwater Storage Options

To simplify the initial comparison of options, all groundwater storage options were assumed to be operated in an aquifer storage and recovery mode in which recharge would occur in surface infiltration basins and recovery would occur through a gallery of extraction wells.

The primary assumptions used to simulate groundwater storage options were developed based on review of available documentation for hydrogeologic characteristics and are listed in **Table 10-2**. Year-to-year carryover storage was allowed as it would be in a surface reservoir. Deliveries from the river were assumed to occur from new river diversions and dedicated pipelines including10,000 ac-ft of regulating storage (e.g., gravel lakes), similar to operation of the surface storage options.

### 10.3.5. Reservoir Operations

Reservoir storage could be operated in many different ways depending on the needs of the owners. Conceptually, water from storage could be:

- used as a base supply with a constant amount taken every year;
- used as a supplemental dry year supply with water withdrawn only in drought periods;
- used as a primary supply with water taken whenever it is available; or
- used as a mitigation supply to augment diversions from other sources.

### Table 10-2. Aquifer Storage Modeling Assumptions

| Characteristic | Lower Lost Creek Basin | Badger/Beaver Basin |
|---|---|---|
| Storage Capacity (ac-ft) | 157,000 | 311,000 |
| Storage per Acre (ac-ft/ac) | 5.7 | 4.4 |
| Maximum Inflow (ac-ft/month) | 5,000 | 5,000 |
| Maximum Outflow (ac-ft/month) | 4,000 | 4,000 |
| Dominion and Control / Residence Time | Challenging | Challenging |
| Multi-year Storage | Challenging | Challenging |
| Infiltration Rate (ft/day) | 1.0 | 1.0 |
| Extraction Well Capacity (gpm) | 500 | 500 |
| Approximate Well Count | 60 | 60 |
| Losses in Aquifer (% of inflow) | 10 | 10 |

Because SPSS reservoir ownership is unknown and the demands the reservoir could be operated to meet are unknown, a standard operating approach was adopted for each storage concept such that the performance of the concepts could be compared against the same set of conditions. Two operating approaches were considered.

1. Firm Yield Analysis. Firm yield is the maximum yield that could be delivered in every year, for all years of the simulation. In this approach the firm yield for each concept was determined by varying the total demand on a trial-and-error basis until the maximum demand that could be met in every year was determined.
2. As-Available Analysis. This approach estimated the yield that could be delivered if the water would be taken from the river into storage whenever available and delivered from storage to a demand center whenever there is demand. It assumes SPSS water would the primary supply for the user and would be taken whenever it is available.

Results from simulations of storage concepts using both approaches to reservoir operations were investigated to assure that the selection of a particular operating assumption would not bias the comparison of storage concepts.

## 10.4 STORAGE CONCEPT WATER SUPPLY ANALYSIS RESULTS

### 10.4.1. Basic Firm Yield Analysis

The firm yield for each of the storage concepts was estimated for the maximum capacity of the representative storage options. Results are shown in Table 10-3. As an example of the firm yield simulations, Figure 10-10 shows a plot of daily MODSIM model results for the Upper Basin – Sandborn Reservoir simulation. The figure shows the demand met on a daily basis by a 224,000 ac-ft reservoir diverting from the Upper Basin portion of the SPSS study area. The firm yield is met on almost every day of the simulation; the shortages are due to the tolerance in the iterative routine used to estimate firm yield in the MODSIM model. The plot shows the reservoir emptying during the critical drought in the model period.

**Table 10-3. Storage Concept Firm Yield for Maximum Capacity of Representative Storage Sites**

| Storage Concept | Representative Storage Site(s) | Reservoir Capacity (ac-ft) | Firm Yield with Pipeline to Brighton (ac-ft/yr) | Firm Yield without Pipeline to Brighton (ac-ft/yr) |
|---|---|---|---|---|
| Mainstem Storage | South Platte (Narrows) | 1.960,000 | 62,000 | 47,000 |
| Upper Basin Storage | Sandborn | 224,000 | 22,000 | 20,000 |
| Mid Basin Storage North | Wildcat | 60,000 | 9,000 | 7,000 |
| Mid Basin Storage South | Beaver Creek | 95,000 | 11,000 | 8,000 |
| Lower Basin Storage | Julesburg, Ovid, Troelstrup | 40,300 | 24,000 | 24,000 |
| Existing Reservoir Improvements | Riverside, Jackson, Prewitt, Julesburg, North Sterling | 56,464 | 17,000 | 15,000 |

Figure 10-11 plots the demand locations receiving deliveries of firm yield for each of the storage concepts. Recall that the Kersey demand is met through a combination of exchange and pipeline deliveries, the Denver demand is met through pipeline deliveries alone, and the Balzac and Julesburg demands are met by direct releases to the South Platte. Kersey demands receive the majority of the firm yield for most concepts. Exchanges have the highest priority in the model when attempting to satisfy demands, so those are exercised first and remaining water is released to the river or piped to Brighton. For concepts with some or all of the storage in the lower basin (Lower Basin Storage, Existing Reservoir Improvements), direct releases are the primary mechanism for meeting demands because of the constraints of limited exchange potential. Different reservoir operation assumptions would give different results for distribution of demands being met; for this analysis, the total firm yield is the most important parameter for comparing storage concepts.

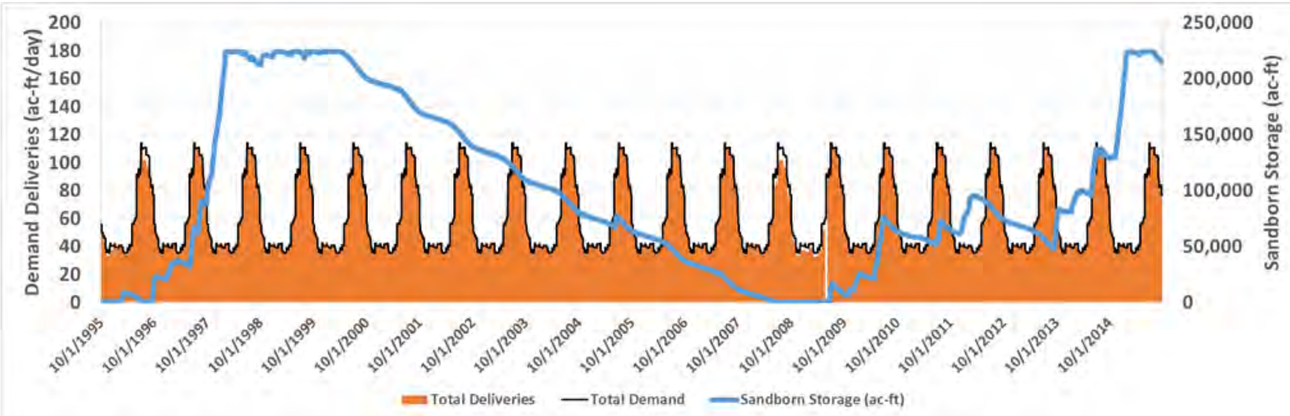



**Figure 10-10. Demand Met and Storage Contents for Sandborn Reservoir Firm Yield Analysis**

It is noted that any concept in which water is exchanged or piped to Brighton would benefit greatly from terminal storage at the delivery point. As noted previously, this SPSS analysis did not evaluate infrastructure needed to store or convey water beyond Kersey or Brighton.

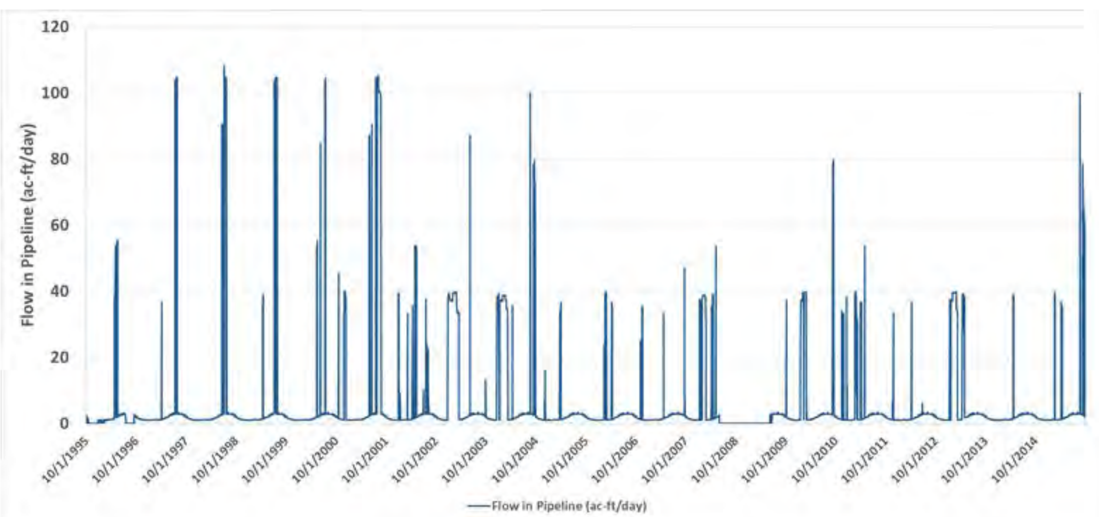

*Note: Groundwater storage concepts were simulated based on sizing to capture large peak flows from South Platte River for purposes of comparing to surface reservoirs. Feasible recharge constraints would produce much smaller firm yields.*

**Figure 10-11. Distribution of Firm Yield to Demand Points for Storage Concepts with Maximum Capacity of Representative Storage Site**

The results depicted in Figure 10-11 show that for the firm yield simulation most storage concepts do not utilize the Brighton Pipeline to meet demands at the Denver demand node because they do not have water remaining after the higher priority demands are satisfied. This raises the question of how much the Brighton Pipeline is being used in the simulations. The water delivered in the Brighton Pipeline can meet demands at the Denver demand node but can also be discharged to the South Platte River to meet demands at the Kersey demand node that could not be met through exchanges due to limited exchange potential. **Table 10-4** summarizes the average annual water conveyed in the Brighton Pipeline for each surface reservoir concept. The Mainstem Storage concept makes significant the most use of the Brighton Pipeline. **Figure 10-12** is a plot of the daily flow in the Brighton Pipeline for the firm yield simulation of the Upper Basin storage concept with Sandborn Reservoir. This shows that the pipeline is used at a high flow rate only infrequently. As shown later in this section, this pipeline is a very expensive infrastructure component. For comparison the firm yields without the pipeline are shown in **Table 10-3**.

### Table 10-4. Average Flow through Brighton Pipeline for Firm Yield Simulations

| Solution Name | Representative Storage Site(s) | Average Annual Flow through Pipeline to Brighton (AF/Y) |
|---|---|---|
| Mainstem Storage | Narrows | 15,000 |
| Upper Basin Storage | Sandborn | 2,000 |
| Mid Basin Storage North | Wildcat | 2,000 |
| Mid basin Storage South | Beaver Creek | 3,000 |
| Lower Basin Storage | Julesburg, Ovid, Troelstrup | 0 |
| Existing Reservoir Improvements | Riverside, Jackson, Prewitt, Julesburg, North Sterling | 2,000 |




### Figure 10-12. Daily Flow in Brighton Pipeline for Upper Basin Storage Concept (Sandborn Reservoir) Firm Yield Simulation

### 10.4.2. Firm Yield Sensitivity Analyses

A firm yield sensitivity analysis was performed in which selected alternative sizes of storage capacity for certain storage concepts were simulated to assess the effect of capacity on firm yield.

***Mainstem Storage Concept.*** Table 10-5 and Figure 10-13 compare firm yield at the South Platte (Narrows) Dam site for reservoir capacities of 1,960,000 ac-ft, 500,000 ac-ft and 250,000 ac-ft. Results show firm yield is strongly correlated to reservoir capacity. Although the storage efficiency (storage-to-yield ratio) is better for the smaller reservoir, in general bigger is better for the mainstem dam sizes investigated.

**Table 10-5. Mainstem Storage Concept Sensitivity Analysis Results**

| Reservoir Capacity (ac-ft) | Firm Yield (ac-ft/yr) | Storage:Yield Ratio |
|---|---|---|
| 1,960,000 | 61,700 | 16:1 |
| 500,000 | 38,000 | 13:1 |
| 250,000 | 20,300 | 12:1 |

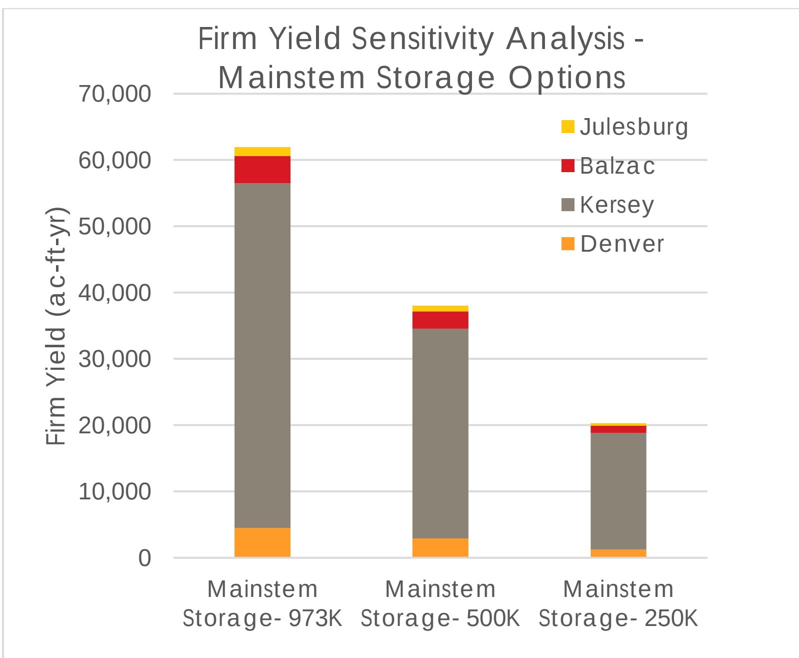



**Figure 10-13. Mainstem Storage Concept Sensitivity Analysis Results**

***Mid Basin Storage Concept.*** A larger storage capacity than the two identified Mid Basin sites was simulated to estimate potential benefits from additional storage in this region. A 150,000 ac-ft capacity was simulated at the Wildcat Reservoir location. Results are shown in Table 10-6. A larger storage capacity provides a significant increase in firm yield in this region even with off-channel storage options. Because of the high variability in annual flow the storage:yield ratio is better for smaller reservoir sizes.

### Table 10-6. Mid Basin Concept Sensitivity Analysis

| Storage Site | Capacity (ac-ft) | Firm Yield (ac-ft/yr) | Storage:Yield Ratio |
|---|---|---|---|
| Wildcat | 60,000 | 9,300 | 6:1 |
| Beaver Creek | 95,000 | 10,700 | 9:1 |
| Wildcat | 150,000 | 17,200 | 9:1 |

***Aquifer Storage vs Surface Storage.*** To compare relative benefits of surface storage and aquifer storage for similar operations, the Upper Basin Storage Concept using Sandborn Reservoir was simulated with a capacity of 150,000 ac-ft, and the Groundwater Basin West aquifer storage option was simulated with the Lost Basin ASR capacity of 157,000 ac-ft. To be comparable to the surface reservoir options, in this case the Lost Creek Basin concept was expanded such that the inflow/outflow facilities would be similar to those used for surface reservoirs; this would not only require the large intake and delivery pipelines and pump stations but also extremely large recharge basins and extraction wellfields.  Results are shown in Table 10-7. The ASR concept gives a higher firm yield and better storage:yield ratio for essentially the same storage capacity. This is likely due primarily to the elimination of evaporation losses in the aquifer storage concept (although the simulation does include some groundwater losses).  However, it is noted that designing and operating an aquifer storage project in this manner on such a large scale would be extremely challenging and may be infeasible.

### Table 10-7. Surface Storage vs Aquifer Storage Comparison in Upper Basin

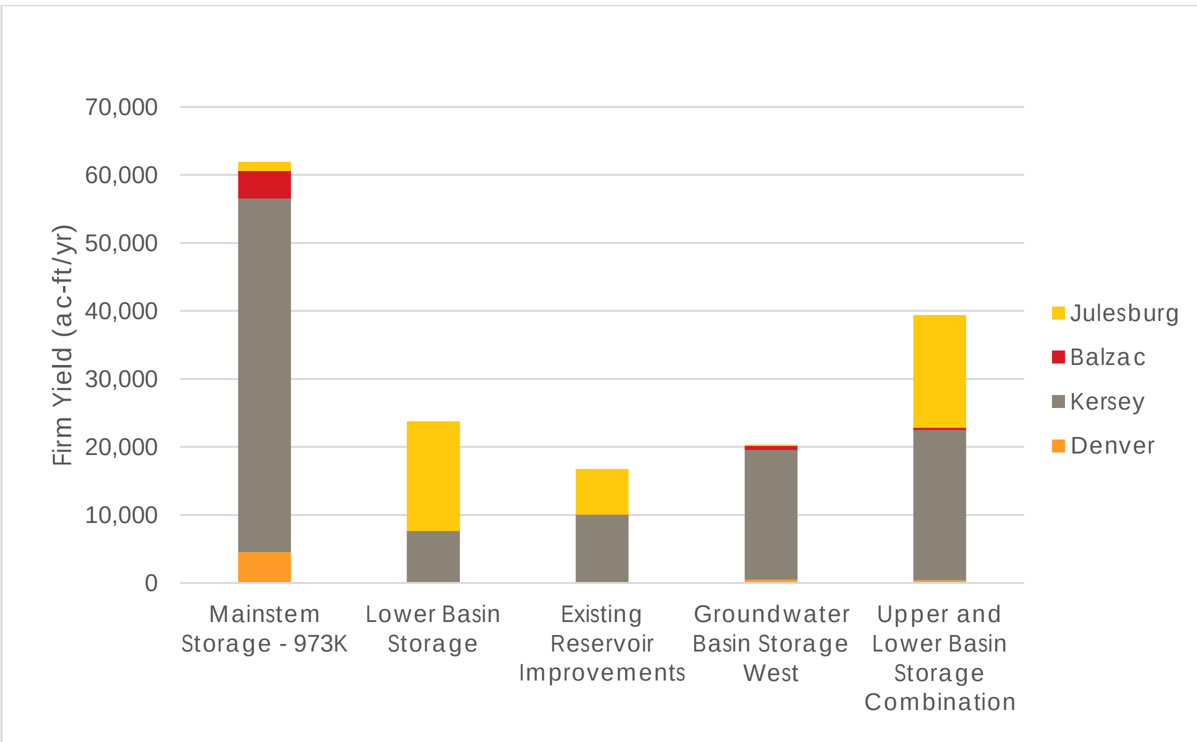
| Storage Option | Capacity (ac-ft) | Firm Yield (ac-ft/yr) | Storage:Yield Ratio |
|---|---|---|---|
| Upper Basin Surface Storage | 224,000 | 22,200 | 10:1 |
| Upper Basin Surface Storage | 150,000 | 16,200 | 9:1 |
| Upper Basin Aquifer Storage | 157,000 | 20,100 | 8:1 |

*Note: Recharge and extraction capacities would be extremely large in this concept compared to most ASR projects in Colorado and may be infeasible.*

***Combination of Upper Basin + Lower Basin Concepts.*** Benefits of combining an Upper Basin project with a Lower Basin project were investigated by simulating a combination of Lost Creek ASR in the Upper Basin with the three surface reservoirs in the Lower Basin Storage concept. Results are shown in Table 10-8 and Figure 10-14. The benefits are significant; firm yield of this combination is exceeded only by the large Mainstem Dam concept.

## Table 10-8. Firm Yield for Combined Upper and Lower Basin Storage Concepts

| Storage Concept | Storage Options Simulated | Total Capacity (ac-ft) | Firm Yield (ac-ft/yr) | Storage:Yield Ratio |
|---|---|---|---|---|
| Lower Basin Storage Alone | Julesburg Enlargement/ Rehabilitation, Ovid, Troelstrup | 40,300 | 23,500 | 2:1 |
| Upper Basin Storage Alone | Lower Lost Creek ASR | 157,000 | 20,100 | 8:1 |
| Combined Upper and Lower Basin Storage | All of above | 197,300 | 39,200 | 5:1 |




*Note: Groundwater basin concepts with displayed in this chart were sized to capture peak flows from the South Platte River. Yield is greater than simulated for the more feasible aquifer storage concepts.*

**Figure 10-14. Comparison of Firm Yield for Combined Upper and Lower Basin Storage Concept with Other Concepts**

### 10.4.3. As-Available Analysis of Storage Concepts

As noted previously, actual operations of any of the SPSS storage concepts are unknown because the ownership is unknown. Reservoir owners could choose to operate their storage in something other than a firm yield approach. To test the sensitivity of the comparison of storage concepts to operating assumptions, two other operational scenarios were simulated that assumed the storage would be operated to meet as much demand as possible whenever that demand occurred. These scenarios varied only in the amount of demand applied to the storage reservoirs.

- Scenario 1 – Demand on the reservoir was set to the total demand estimated based on the future M&I and agricultural South Platte Basin gap at the four demand centers as described in **Section 7.0** (annual demand = 502,900 AFY).
- Scenario 2 – Gap demand was scaled-back to force reservoirs to hold more water in storage during wet periods (annual demand = 97,000 AFY).

Modeling results are summarized in **Table 10-9** for the maximum potential capacities at each of the representative storage sites for the SPSS storage concepts. The average annual deliveries under this kind of operating assumption are much higher than the firm yields shown in **Table 10-3**. However, the reliability (percentage of days the full applied demand was completely satisfied) was very low. For the Upper Basin Storage simulation in **Figure 10-15**, the reliability is only 1 percent. For the Mainstem Storage concept the reliability is higher – 9 percent – because the storage volume is larger and there are no constraints in diversion and intake capacities. (Recall firm yield has a reliability of 100 percent.) **Figure 10-15** also shows that the storage is rarely used because demands are so high water is moved directly from the river to the demand centers. The simulation of this type of operation does not highlight the value of storage, but does demonstrate that there is a large amount of available water in the river to meet high demands on a very infrequent basis.

## Table 10-9. Yield of Storage Concepts Based on As-Available Operations

| Solution Name | Representative Storage Site(s) | Reservoir Capacity (AF) | Full Gap Demand (502,882 AFY) – Average Annual Delivery (AF/Y) | Scaled Demand (97,000 AFY) – Average Annual Delivery (AF/Y) |
|---|---|---|---|---|
| Mainstem Storage | Narrows | 1,960,000 | 118,000 | 81,000 |
| Upper Basin Storage | Sandborn | 224,000 | 74,000 | 48,000 |
| Mid Basin Storage North | Wildcat | 60,000 | 82,000 | 43,000 |
| Mid Basin Storage South | Beaver Creek | 95,000 | 85,000 | 46,000 |
| Lower Basin Storage | Julesburg, Ovid, Troelstrup | 40,300 | 129,000 | 48,000 |
| Existing Reservoir Improvements | Riverside, Jackson, Prewitt, Julesburg, North Sterling | 56,464 | 143,000 | 59,000 |

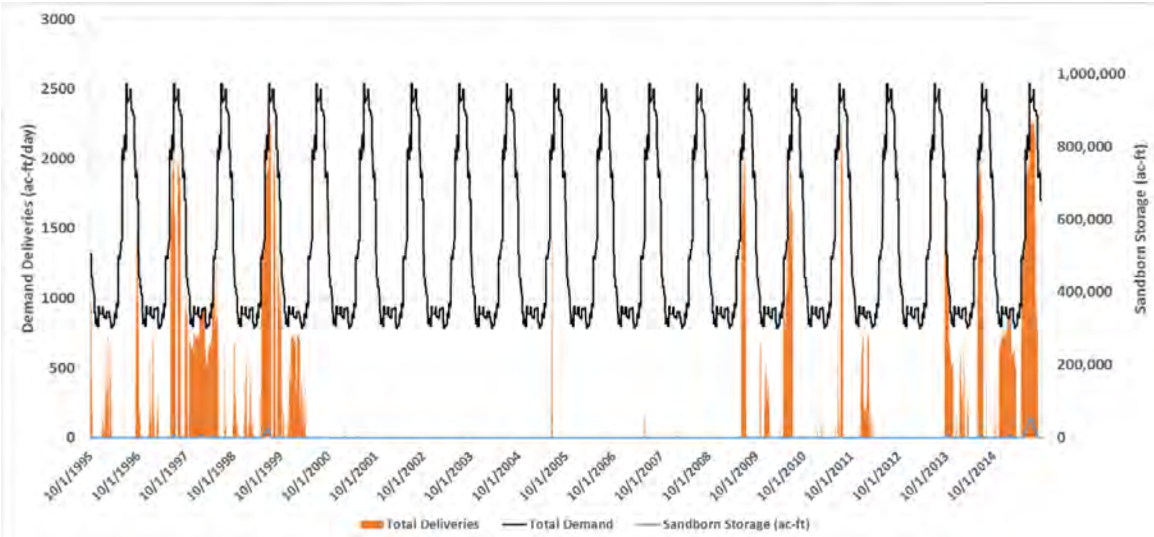



**Figure 10-15. Simulation of Sandborn Reservoir with Full Gap Demand Applied in As-Available Operation Mode**

Simulation of the scaled-back demands is summarized for each concept in Table 10-9, and is displayed for the Upper Basin (Sandborn) concept in Figure 10-16. The scaled-back demands are 97,000 ac-ft/yr compared to 502,900 ac-ft/yr for the full gap demands. Average annual deliveries are less than for the full gap scenario (because less water is demanded) and the benefits of storage are more evident. In addition, Figure 10-16 shows that the reliability for this condition is approaching 50 percent, which is much better than when the full gap demands were applied.

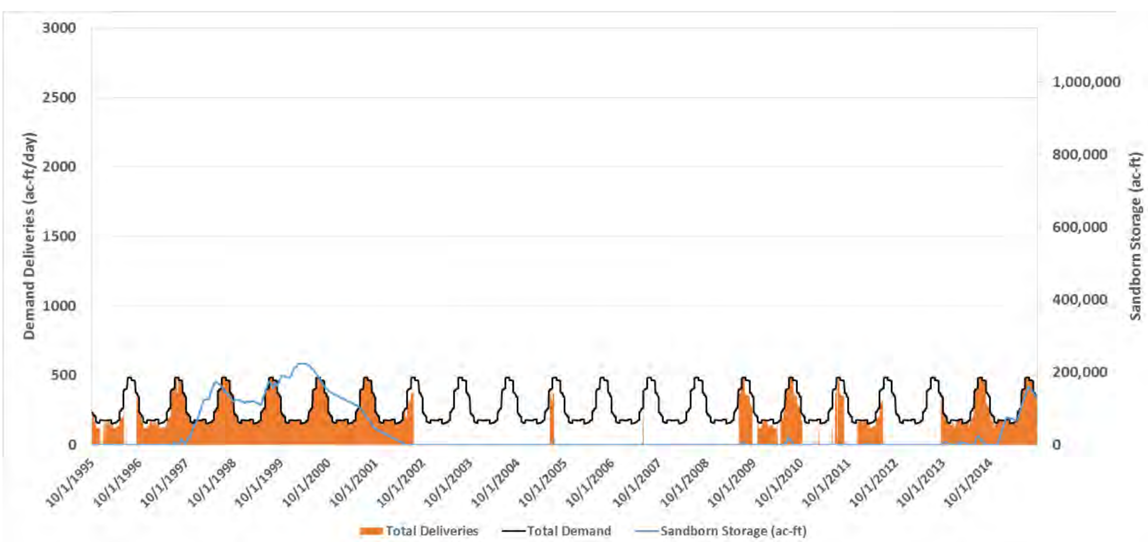



**Figure 10-16. Simulation of Sandborn Reservoir with Scaled-Back Demand Applied in As-Available Operation Mode**

## 10.5 SUMMARY OF STORAGE CONCEPT SIMULATIONS

The key findings of the storage concept simulation analysis are as follows.

1. The Firm Yield results are the most useful for this analysis and have an easier message to convey. Thus the firm yield results will be used to draw conclusions.
2. Firm yields of 9,000 ac-ft/yr to 62,000 ac-ft/yr were estimated for the representative storage concepts analyzed for this study.
3. Not surprisingly, the large mainstem reservoir has the best performance. Smaller mainstem reservoirs have significantly less firm yield and are comparable to other off-channel options.
4. Aquifer storage projects are more limited by recharge and recovery rates rather than storage volume. Typical aquifer storage projects are designed as supplemental supply sources, not as projects to recharge large volumes of water diverted during peak spring snowmelt periods. This results in lower firm yield, and does not attempt to maximize use of potential storage capacity as occurs with surface reservoirs. However, a related benefit is that aquifer storage projects are relatively low cost and can be scaled up over time (not constructed all at once). These unique characteristics make aquifer storage projects difficult to compare to surface water storage projects.
5. Average annual available water under future conditions varies from about 160,000 ac-ft/yr at Greeley to about 290,000 ac-ft/yr at Julesburg. Firm yields are much less than these values even for the large storage options due to the significant year-to-year variability in streamflow. Substantially more storage would be required to significantly increase firm yields from the alternatives.
6. Storage options lower in the basin tend to be more efficient (better storage:yield ratio) because there is more water available. This is biased by the fact that the lower basin concepts simulated in this study have multiple storage buckets and hence multiple inlets, so there is more diversion capacity, but the additional water is still an important factor in performance of storage options.
7. A combination of upper basin and lower basin storage concepts rivals the large mainstem dam for firm yield benefits.
8. No feasible storage concepts or reasonable combinations of concepts are capable of putting all the available flow in the lower South Platte River to beneficial use. Therefore as a general principle, more storage will always be "better" in this region in terms of maximizing available supply for basin water users.
9. Because nearly all concepts require off-channel storage and diversion from the South Platte River, intake capacity constraints can be important and there are benefits to having multiple off-channel storage projects to minimize these effects.

## 10.6 SUMMARY OF COSTS BY STORAGE CONCEPT

Conceptual (ACEE Class V) cost estimates were prepared for the surface reservoir storage concepts including components for storage (maximum size), intake system (new 800 cfs diversion structure, new 10,000 ac-ft gravel pit, new 400 cfs bi-directional conveyance system), and delivery system (conveyance system to Brighton, 20,000 ac-ft Kersey gravel pits). Aquifer storage concept costs were estimated based on the assumptions described earlier with recharge capacities of 5,000 ac-ft/month and extraction wellfield capacities of 4,000 ac-ft/month.

Table 10-10 summarizes capital costs for SPSS storage concepts. These costs are based on the largest feasible storage capacity for the surface reservoir, and the assumed modest size of an ASR project. No alignment studies or cost optimization were performed for this analysis. It is noted that cost estimates assume construction of all new intake and delivery system components; the ability to utilize existing diversion structures or irrigation canals to some degree for certain storage options would reduce the estimated cost. Use of SPSS water directly for M&I purposes at any of the demand centers in the analysis would require advanced water treatment; the cost of facilities to provide this treatment is not included in the storage concept costs. Storage concept costs do not include O&M costs for items such as energy for pumping or maintenance and replacement of mechanical equipment. Energy costs could be significant for pumpback components and aquifer storage and recovery projects.

**Table 10-10. Summary of Storage Concept Costs for Maximum Representative Storage Site Including Pipeline to Brighton**

| Storage Concept (Representative Site) | Storage Capacity (ac-ft) | Storage Cost ($M) | Intake System Cost ($M) (Diversion, Gravel Pits, Pipes, Pump) | Delivery System Cost ($M) (Pipe to Brighton, Kersey Gravel Pits) | Total Storage Concept Cost ($M) | Firm Yield (AFY) | Total Unit Cost ($/AFY) |
|---|---|---|---|---|---|---|---|
| ***Surface Reservoir Storage Concepts*** | | | | | | | |
| Mainstem Dam (Narrows) | 1,960,000 | $145 | - | $380 | $525 | 62,000 | $8,500 |
| Upper Basin Storage (Sandborn) | 224,000 | $131 | $168 | $322 | $621 | 22,000 | $28,000 |
| Mid Basin Storage North (Wildcat) | 60,000 | $79 | $141 | $433 | $652 | 9,000 | $72,000 |
| Mid Basin Storage South (Beaver) | 95,000 | $66 | $407 | $437 | $910 | 11,000 | $83,000 |
| Existing Reservoirs | 40,300 | $121 | $221 | $322 | $664 | 17,000 | $39,000 |
| Lower Basin Storage | 56,464 | $118 | $92 | $826 | $1,037 | 24,000 | $43,000 |

| Storage Concept (Representative Site) | Storage Capacity (ac-ft) | Storage Cost ($M) | Intake System Cost ($M) (Diversion, Gravel Pits, Pipes, Pump) | Delivery System Cost ($M) (Pipe to Brighton, Kersey Gravel Pits) | Total Storage Concept Cost ($M) | Firm Yield (AFY) | Total Unit Cost ($/AFY) |
|---|---|---|---|---|---|---|---|
| ***Groundwater Storage Concepts*** | | | | | | | |
| Groundwater Storage West (Lost Creek) | 157,000 | $39 | $238 | $ 158 | $435 | 8,400 | 52,000 |
| Groundwater Storage East (Badger/Beaver) | 311,000 | $39 | $160 | $270 | $469 | 8,000 | 59,000 |

*Note: Aquifer storage concepts are smaller than surface reservoir concepts, consistent with common existing projects.*

As described in the discussion of storage concept modeling results, the pipeline to Brighton is used infrequently when it has lowest priority after exchanges and releases to the river have been performed. This pipeline is a very expensive component of any storage concept in the lower South Platte River. **Table 10-11** shows storage concept costs without the pipeline to Brighton. It is noted that without the pipeline the performance of any storage concept is very dependent on exchange potential in the South Platte River. While exchange potential was simulated in the reaches below Kersey, many factors could reduce this exchange potential in the future. In addition, the exchange potential between Kersey and Denver is very limited, and substantial demands at the Denver location could only be met using direct conveyance.

**Table 10-11. Summary of Storage Concept Costs for Maximum Potential Storage Site without Pipeline to Brighton**

| Storage Concept (Representative Site) | Storage Capacity (ac-ft) | Storage Cost ($M) | Intake System Cost ($M) (Diversion, Gravel Pits, Pipes, Pump) | Delivery System Cost ($M) (Kersey Gravel Pits) | Total Storage Concept Cost ($M) | Firm Yield (AFY) | Total Unit Cost ($/AFY) |
|---|---|---|---|---|---|---|---|
| ***Surface Reservoir Storage Concepts*** | | | | | | | |
| Mainstem Dam (Narrows) | 1,960,000 | $145 | - | $45 | $190 | 58,000 | $ 3,300 |
| Upper Basin Storage (Sandborn) | 224,000 | $131 | $168 | $45 | $344 | 21,000 | $26,000 |
| Mid Basin Storage North (Wildcat) | 60,000 | $79 | $141 | $45 | $265 | 9,000 | $29,000 |
| Mid Basin Storage South (Beaver) | 95,000 | $66 | $407 | $45 | $518 | 11,000 | $47,000 |
| Existing Reservoirs | 40,300 | $121 | $221 | $45 | $387 | 17,000 | $23,000 |
| Lower Basin Storage | 56,464 | $118 | $92 | $45 | $255 | 24,000 | $11,000 |
| ***Aquifer Storage Concepts*** | | | | | | | |
| Groundwater Storage West (Lost Creek) | 157,000 | $39 | $238 | $45 | $322 | 8,400 | $38,000 |
| Groundwater Storage East (Badger/Beaver) | 311,000 | $39 | $160 | $45 | $244 | 8,000 | $31,000 |

*Note: Aquifer storage concepts are smaller than surface reservoir concepts, consistent with common existing projects.*

## 10.7 COMPARISON OF STORAGE CONCEPTS

The SEF for the SPSS contains many attributes that apply to the overall solutions and storage concepts. Many of the storage concept attributes are based on the specific criteria listed in HB 16-1256 for evaluating SPSS alternatives. Others were developed by the study team to assist in comparing the storage concepts on a relative basis.

Table 10-12 shows the attribute values for the eight SPSS storage concepts considered in this study. It also lists the cumulative scores for each storage concept when numerical values are assigned to the attribute qualifiers (e.g., 1.0, 0.5, 0). For many of the attributes, particularly those associated with the HB 16-1256 criteria, the storage concepts have very similar performance. They were formulated to meet demands in a variety of locations in the basin and thus have similar capabilities of providing water supply benefits listed in HB 16-1256. The storage concepts relying on reservoirs lower in the South Platte basin (e.g., Lower Basin Storage, Existing Storage) have lower scores due to the relatively greater difficulty in providing water supply and flood management benefits for large portions of the basin when storage is located downstream.

It is noted that this comparison is based on the storage concepts and representative storage sites simulated in the MODSIM model. For the SPSS analysis it was necessary to select a limited number of concepts for analysis. Many variations of these concepts would be feasible, including use of different storage options, increased storage capacity, and different operating assumptions. Variations in these storage concept definitions could result in substantial differences in scores exceeding the variability in the scores in **Table 10-12**. Furthermore, none of the concepts or individual site designs were optimized at this level because ownership of storage projects is not known. Results in this table should be used only for a high-level comparison of storage concepts. The fact that the comparison produces fairly similar scores for all of the storage concepts suggests that none should be eliminated based on this analysis.

It was not possible to monetize project benefits at this level of analysis to support a numerical benefit-cost comparison of storage concepts. Information in **Table 10-11**and **Table 10-11** allows for qualitative comparisons of benefits and costs of the limited number of storage concepts analyzed in this study. Storage concepts developed to meet the needs of specific water users could have very different costs and benefits based on their particular application and the ability to optimize size and performance to meet the specific project needs.

## Table 10-12. Site Evaluation Framework Attribute Values for Storage Concepts

| Attribute | Description | Mainstem Dam | Upper Basin Storage | Mid Basin Storage - North | Mid Basin Storage - South | Lower Basin Storage | Existing Storage | Aquifer Storage West | Aquifer Storage East | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Water Supply Gap Solution | The storage solution could capture water to meet demands in the basin. | High | Medium | Low | Medium | Medium | Medium | Medium | Medium | Based on firm yield |
| Reduce TransBasin Diversions | The storage solution could yield additional supplies from in-basin sources, reducing the need for future transbasin diversions. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Any in-basin yield substitutes for transbasin diversions |
| Multiple Users Supply | The storage solution could supply water to various municipal, industrial, environmental, and agricultural water users in the basin. | High | High | High | High | Low | Medium | High | Medium | Upstream is good. Far downstream with no pipeline is bad. |
| Augmentation Plan Operation Enhancement | The storage solution could be used to optimize the operation of existing or future augmentation plans. | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Any storage concept can release to river so all those above Lower Basin could be operated for augmentation |

| Attribute | Description | Mainstem Dam | Upper Basin Storage | Mid Basin Storage - North | Mid Basin Storage - South | Lower Basin Storage | Existing Storage | Aquifer Storage West | Aquifer Storage East | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Aquifer Recharge Operations | The storage solution is an aquifer recharge facility, directly delivers water to aquifer recharge facilities, or facilitates conjunctive use. | Medium | Medium | Medium | Medium | Low | Medium | High | High | Lower Basin would be below aquifer recharge facilities |
| ATM Partnership | A storage solution would have available storage for temporary leased water to be stored to help the ATM operations and partnerships. | High | High | High | High | High | High | High | High | All could do this |
| Exchange Potential Enhancement | The storage solution adds storage capacity for interim storage or "leap-frogging" exchanges, or could add streamflows that would increase exchange potential in the river. | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes for all except Lower Basin |
| Recreation Benefit | The storage solution would increase recreational opportunities. | Positive | Positive | Positive | Positive | Positive | Neutral | Neutral | Neutral | Positive for new surface sites; neutral for GW and existing storage sites |

| Attribute | Description | Mainstem Dam | Upper Basin Storage | Mid Basin Storage - North | Mid Basin Storage - South | Lower Basin Storage | Existing Storage | Aquifer Storage West | Aquifer Storage East | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Enhance Streamflow | The storage solution could deliver water to downstream users via natural channels, enhancing stream flow. | Medium | High | High | High | Medium | Medium | High | High | All could release to South Platte; some could release to tribs |
| Compact Compliance | The storage solution could increase low flows at the state line and reduce frequency of compact calls. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | All would do this |
| Increase Ag Production | The storage solution could help meet the agricultural demand gap in the basin. | Low | Low | Low | Low | High | Low | Low | Low | |
| Reduce Buy&Dry | The storage solution could yield additional M&I supplies from in-basin sources, reducing the pressure to buy Ag water rights. | High | Medium | Low | Medium | Medium | Medium | Medium | Medium | Based on firm yield and applicability to potential M&I users |

| Attribute | Description | Mainstem Dam | Upper Basin Storage | Mid Basin Storage - North | Mid Basin Storage - South | Lower Basin Storage | Existing Storage | Aquifer Storage West | Aquifer Storage East | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Delivery Water Quality | The storage solution would deliver raw water requiring advance treatment to achieve primary and/or secondary drinking water standards. | Low | Low | Low | Low | Low | Low | Low | Low | All water in SPSS study area would need advanced treatment for potable use |
| Permitting Feasibility | The potential permitting feasibility of site and solution. | Low | Medium | Medium | Medium | Medium | High | High | High | On channel is worst; existing dams and GW are best |
| Water Rights | Measure of the perceived ease in obtaining the water rights/decrees required to operate the solution. | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Set all to medium. All will have some issues. |
| Combined Permitting | Captures the potential increase in permitting complexity for the solutions compared to storage sites alone. | Same | Same | Same | More | More | More | Same | More | Used "More" for concepts requiring longer pipelines to Brighton |
| Estimated Permit Timeline | The probability that permits would be secured quickly. | Low | Medium | Medium | Medium | Medium | High | Medium | Medium | Mainstem dam is longest. Modifications to existing reservoirs is shortest. |

| Attribute | Description | Mainstem Dam | Upper Basin Storage | Mid Basin Storage - North | Mid Basin Storage - South | Lower Basin Storage | Existing Storage | Aquifer Storage West | Aquifer Storage East | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Combined Impact | Captures the potential increase in environmental impacts for the solutions compared to individual sites alone. | More | More | More | More | More | More | More | More | All require facilities outside the storage footprint |
| River Reach | River reach where the solution is predominantly located. | Kersey-Balzac | Kersey-Balzac | Kersey-Balzac | Kersey-Balzac | Balzac-Julesburg | Balzac-Julesburg | Kersey-Balzac | Balzac-Julesburg | |
| Meet Demands | Ability of a solution to meet demands, either upstream or downstream | US and DS | US and DS | US and DS | US and DS | US and DS | US and DS | US and DS | US and DS | All concepts were formulated to meet demands throughout Basin |
| **Total Score (Unweighted)** | | **11.5** | **12** | **11** | **11** | **8** | **10** | **12** | **10.5** | |

## 10.8 BENEFICIAL USE OF COLORADO'S AVAILABLE SOUTH PLATTE WATER

The ability of the simulated storage concepts to put Colorado's South Platte River water to beneficial use is summarized in **Table 10-13**. This analysis used future hydrology, and shows that while a significant amount of water that would otherwise leave Colorado could contribute to in-state beneficial uses, considerably more storage would be required to use all the state's available South Platte water resources. A plot of daily flows at the state line for the Upper Basin Storage Concept is shown in **Figure 10-17**. Similar plots for all of the storage concepts are contained in **Appendix J**.

**Table 10-13. Water Leaving the State under Future Hydrology for Simulated Storage Concepts**

| Storage Concept | Average Annual Water Leaving State (ac-ft) | Median Annual Water Leaving State (ac-ft) | Percentage of Available Water Contributing to Beneficial Use (1) |
|---|---|---|---|
| No Storage | 343,000 | 249,000 | - |
| Mainstem Storage | 169,000 | 150,000 | 51% |
| Upper Basin Storage | 279,000 | 210,000 | 19% |
| Mid Basin Storage North | 272,000 | 196,000 | 21% |
| Mid Basin Storage South | 269,000 | 192,000 | 22% |
| Lower Basin Storage | 193,000 | 78,000 | 44% |
| Existing Reservoir Improvements | 173,000 | 100,000 | 50% |
| Groundwater Basin Storage West (sized and operated similar to surface reservoirs) | 280,000 | 213,000(2) | 18% |
| Groundwater Basin Storage East (sized and operated similar to surface reservoirs) | 271,000 | 196,000(2) | 21% |

*(1) Includes evaporation losses and other losses which would not be beneficial uses.*
*(2) Assumes maximum size to capture peak spring runoff. Actual projects would be smaller and leave more water at the state line.*

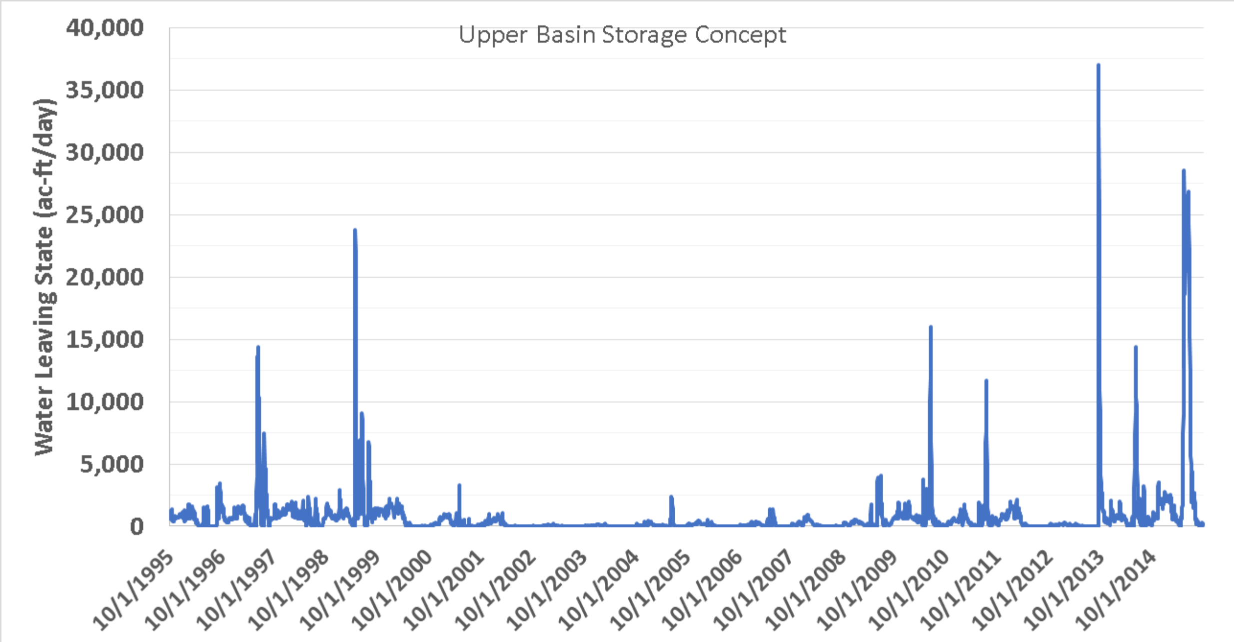



**Figure 10-17. Timeseries of Water Leaving the State for Upper Basin Storage Concept under Future Hydrology**

# 11. CONCLUSIONS AND RECOMMENDATIONS

## 11.1 CONCLUSIONS

### 11.1.1. Available Water, Demand and Water Quality

The following conclusions relate to available water in the SPSS study area.

1. A large supply of water is available for beneficial use in the lower South Platte Basin. Between 1996 and 2015, an annual median of approximately 293,000 ac-ft/yr of water was delivered to Nebraska in excess of the South Platte Compact. Excess available water varied between 10,000 ac-ft/yr and 1,904,000 ac-ft/yr over this period.
2. Under future conditions, average annual water available for diversion to a new storage project would vary from approximately 214,000 ac-ft/yr at Kersey to 332,000 ac-ft/yr at Julesburg. Median annual available water would vary from approximately 116,000 ac-ft/yr at Kersey to 232,000 ac-ft/yr at Julesburg, highlighting the influence of a few high runoff years on streamflow statistics in the South Platte Basin.
3. Annual streamflows in the study area are characterized by a few very high flow years. A large mainstem dam or several off-stream dams with large diversion structures would be required to capture a large portion of the available streamflow.
4. Available water at Kersey is much less than at Julesburg due to return flows in the lower basin. A large lower basin reservoir(s) would be required as part of a storage scheme to capture a large portion of available flow upstream of the state line.
5. Because the vast majority of storage options are located off the main South Platte River channel, physically available water is constrained by the diversion capacity and the capacity of conveyance facilities from the river to the storage reservoir. Large diversion and conveyance structures would be needed to capture and convey water from the river to off-channel storage. At the Balzac gage near the middle of the SPSS study area, a diversion capacity of 550 cfs would be needed to capture 85 percent of the available water.
6. Future water shortages in the lower South Platte Basin based on the water supply gap estimated in SWSI 2010 are significant, and exceed the estimated available water in the future. Annual municipal and agricultural demands that could potentially be served by water from a SPSS storage project total over 502,000 ac-ft/yr for the Denver Metro Area, the Northern Front Range Region, and the lower South Platte basin below Greeley.
7. Water quality throughout the SPSS study area is adequate for agricultural use but would require advanced water treatment for direct municipal use.

### 11.1.2. Storage Options and Concepts

Conclusions related to the SPSS analysis of storage opportunities in the lower South Platte Basin are summarized as follows.

1. Many off-channel storage options are feasible and can be combined in a wide variety of water supply concepts.
2. Firm yields of 9,000 ac-ft/yr to 62,000 ac-ft/yr were estimated for the representative storage concepts analyzed for this study.
3. Capital costs for storage concepts range from $7,400 to $78,200/ac-ft/yr, exclusive of treatment costs, with a pipeline to Brighton. Without the pipeline to Brighton the concept costs range from $3,300 to $47,000/ac-ft/yr exclusive of treatment costs. The upper end of this range greatly exceeds the cost of recent water development projects in Colorado.
4. Not surprisingly, a large mainstem reservoir has the best performance in terms of putting the state's water to beneficial use. However, permitting obstacles may be insurmountable.
5. Aquifer storage projects are more limited by recharge and recovery rates rather than storage volume. Typical aquifer storage projects are designed as supplemental supply sources, not as projects to recharge large volumes of water diverted during peak spring snowmelt periods. This results in lower firm yield, and does not attempt maximize use of potential storage capacity as occurs with surface reservoirs. However, a related benefit is that aquifer storage projects are relatively low cost and can be scaled up over time (not constructed all at once). These unique characteristics make aquifer storage projects difficult to compare to surface water storage projects.
6. Storage options lower in the basin tend to be more efficient (better storage:yield ratio) because there is more water available. However they are further from the main demand centers.
7. Combinations of storage options working conjunctively can provide significantly more benefit than individual options. A combination of upper basin and lower basin storage concepts rivals the large mainstem dam option for firm yield benefits. However, there will be reduction in efficiency as the number of projects goes up, and even with multiple storage project a large amount of available water would leave Colorado.
8. No feasible storage concepts or reasonable combinations of concepts are capable of putting all the available flow in the lower South Platte River to beneficial use. This is shown in **Table 11-1**. Therefore as a general principle, more storage will always be "better" in this region in terms of maximizing available supply for basin water users.

## Table 11-1. Water Leaving the State under Future Hydrology for Simulated Storage Concepts

| Storage Concept | Median Annual Water Leaving State (ac-ft) | Percentage of Available Water Contributing to Beneficial Use (1) |
|---|---|---|
| No Storage | 249,000 | - |
| Mainstem Storage | 150,000 | 51% |
| Upper Basin Storage | 210,000 | 19% |
| Mid Basin Storage North | 196,000 | 21% |
| Mid Basin Storage South | 192,000 | 22% |
| Lower Basin Storage | 78,000 | 44% |
| Existing Reservoir Improvements | 100,000 | 50% |
| Groundwater Basin Storage West | 213,000(2) | 18% |
| Groundwater Basin Storage East | 196,000(2) | 21% |

*(1) Includes evaporation losses and other losses which would not be beneficial uses*
*(2) Assumes maximum size to capture peak spring runoff. Actual projects would be smaller and leave more water at the state line.*

10. Because nearly all concepts require off-channel storage and diversion from the South Platte River, intake capacity constraints can be important and there are benefits to having multiple off-channel storage projects to minimize the effects of these constraints.
11. Enlargements and rehabilitations of existing reservoirs tend to score higher than new reservoirs in the multi-criteria ranking process.
12. Triple bottom line scores for the storage sites analyzed in this study were fairly similar at this level of analysis without specific information on how the sites would be used in a water supply strategy; thus the triple bottom line scoring process should not be used to eliminate options at this time.
13. Any of the storage concepts could be candidates for further study in the future under the right circumstances. However, concepts with more storage higher in the basin generally offer a greater potential for benefits and could be more attractive to a broader variety of potential participants.
14. Multiple large storage projects, including one low in the basin, would be required to capture a substantial amount of the available water above the state line.
15. Even a combination of conjunctively operated storage projects would not be capable of addressing the majority of the combined overall M&I and agricultural water supply gaps in the South Platte Basin.

## 11.2 RECOMMENDATIONS

The SPSS team developed the following recommendations for future work.

1. Better estimates of future hydrology should be developed to refine the anticipated available water under future basin operations. Completion of the South Platte Decision Support System would facilitate further hydrologic and operational studies.
2. Exchanges will be important to making storage work cost effectively for many applications. A more robust method of estimating future exchange potential may be needed to refine this important aspect of the analysis.
3. Site-specific and owner-specific analyses will be needed when particular project opportunities are identified in the future. The work in the SPSS is a starting point for more specific alternative investigations, but substantial additional analysis will be required to test the feasibility of specific storage options based on points of diversion, intake systems, and methods of operating to meet demands.
4. Aquifer storage and recovery projects will require site specific aquifer characterization and pilot testing. Pilot testing and preliminary design can begin at a relatively low cost due to the scalability of ASR systems.
5. Using existing irrigation canals to fill storage sites could significantly reduce infrastructure costs for some concepts. Partnerships with irrigation companies and available canal capacities should be investigated further.
6. Cooperative storage projects with multiple users, multiple components and multiple purposes would have the best chance of success. The state, Roundtables and water users should continue to explore opportunities for cooperative multi-use storage projects in the lower South Platte Basin.
7. Gravel pit storage opportunities were not considered in detail in this study. Gravel pits have been used extensively for storage along the South Platte River upstream of Greeley. An investigation of gravel pit storage opportunities downstream of Greeley may be warranted.
8. Use of water from SPSS storage projects directly for M&I use would require advanced water treatment. Recharge into aquifer storage would also require treatment. Additional investigation is required into the feasibility of available advanced treatment processes on water quality from the study area, particularly in the further downstream reaches of the South Platte River.
9. Investigation is warranted into how storage could support future implementation of alternative transfer method (ATM) projects per recommendations in the South Platte Basin Implementation Plan. Most or even all ATM project would need storage to increase yield and project efficiency. Investigation is needed into how new storage projects could be utilized in combination with ATMs to efficiently store and deliver available water as well as water provided from ATM projects. This combination could potentially make both new storage and ATM projects more feasible and help meet the water supply gaps in the basin.
10. Future storage projects would have an impact on Colorado's water obligation to the PRRIP. Membership in SPWAP in addition to coordination with the State of

Colorado and SPWAP would be necessary to comply with all PRRIP mitigation requirements for new South Platte water storage projects. Further investigation into SPWRAP effects of new storage projects is recommended.

11. This study did not simulate conjunctive operation of a large surface storage project with an ASR project. Benefits of conjunctive use should be investigated.
12. This study did not evaluate potential supplies or storage opportunities upstream of Kersey on the South Platte River or Poudre River. Extending the water availability study and the investigation of potential storage options upstream of Kersey on the South Platte River and Cache la Poudre River should be considered.

# 12. REFERENCES

CDM. Statewide Water Supply Initiative. Prepared for Colorado Water Conservation Board and Colorado Department of Natural Resources. January 2011.

Colorado Water Conservation Board. Colorado's Water Plan. 2015.

HDR/West Sage. South Platte Basin Implementation Plan. Prepared for South Platte and Metro Basin Roundtables. 2015

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# APPENDIX A – HB 16-1256

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Second Regular Session
Seventieth General Assembly
STATE OF COLORADO

**INTRODUCED**

LLS NO. 16-0630.01 Jennifer Berman x3286

**HOUSE BILL 16-1256**

**HOUSE SPONSORSHIP**

**Brown,** Humphrey, Priola, Roupe, Nordberg, Windholz, Everett, Lundeen, Klingenschmitt, Thurlow, Wist, Sias, Dore, DelGrosso, Leonard, Willett, Van Winkle, Wilson, Rankin, Arndt, Becker J., Conti, Coram, Landgraf, Navarro, Saine, Singer, Vigil

**SENATE SPONSORSHIP**

**Sonnenberg,**

**House Committees**
Agriculture, Livestock, & Natural Resources
Appropriations

**Senate Committees**

## A BILL FOR AN ACT

**CONCERNING A STUDY REGARDING THE CREATION OF ADDITIONAL WATER STORAGE IN THE SOUTH PLATTE RIVER BASIN.**

### Bill Summary


*(Note: This summary applies to this bill as introduced and does not reflect any amendments that may be subsequently adopted. If this bill passes third reading in the house of introduction, a bill summary that applies to the reengrossed version of this bill will be available at http://www.leg.state.co.us/billsummaries.)*

**Section 1** of the bill requires the Colorado water conservation board (board), in collaboration with the state engineer, to conduct or commission a hydrology study of the South Platte river basin to determine, for each of the previous 20 years, the amount of water that has been delivered to Nebraska from the river in excess of the amount required under the South Platte river compact. The study must also

include a list of locations that have been identified as possible sites for the construction of a reservoir along the mainstem and tributaries of the South Platte river between Greeley, Colorado, and Julesburg, Colorado. For each listed location, the study must include information on the amount of water that could have been stored in a reservoir at the site, a list of any property that the federal bureau of reclamation or another government agency has purchased for construction of the site, an estimate of the cost to construct a reservoir at the site, and a cost-benefit analysis for constructing a reservoir at the site. The board, in collaboration with the state engineer, is required to provide a report summarizing the study to the committees of reference in the house of representatives and the senate that have jurisdiction over natural resources matters.

**Section 2** transfers $250,000 from the severance tax perpetual base fund to the Colorado water conservation board construction fund on July 1, 2016.

---

*Be it enacted by the General Assembly of the State of Colorado:*

**SECTION 1.** In Colorado Revised Statutes, 37-60-115, **add** (11) as follows:

**37-60-115. Water studies - rules - repeal.** (11) **South Platte river storage study - report - repeal.** (a) **Legislative declaration.** (I) THE GENERAL ASSEMBLY HEREBY FINDS THAT:

(A) COLORADO'S WATER PLAN IDENTIFIES INCREASED WATER STORAGE AS AN IMPORTANT GOAL AND SETS FORTH AN OBJECTIVE TO ATTAIN AN ADDITIONAL FOUR HUNDRED THOUSAND ACRE FEET OF WATER STORAGE IN COLORADO BY 2050; AND

(B) IN 2015, MORE THAN TWO MILLION ACRE FEET OF WATER THAT WERE DELIVERED TO NEBRASKA BY THE SOUTH PLATTE RIVER COULD HAVE BEEN STORED AND USED IN COLORADO.

(II) THE GENERAL ASSEMBLY FURTHER DETERMINES THAT WATER STORAGE PROVIDES NUMEROUS BENEFITS, INCLUDING:

(A) AN INCREASED ABILITY TO ADDRESS COLORADO'S PREDICTED FUTURE WATER SUPPLY GAPS;

(B) PROVIDING AQUIFER RECHARGE;

(C) REDUCING THE NEED TO IMPORT WATER FROM ONE WATER BASIN TO ANOTHER WATER BASIN THROUGH A TRANSBASIN DIVERSION;

(D) REDUCING RELIANCE ON THE PRACTICE OF BUYING AGRICULTURAL WATER RIGHTS AND DRYING UP THE AGRICULTURAL LAND SERVED BY THE WATER RIGHTS;

(E) RECREATIONAL BENEFITS;

(F) FLOOD CONTROL;

(G) INCREASING PRODUCTION BY ALLOWING AGRICULTURAL PUMPING OF WELLS, WHICH WILL LOWER THE WATER LEVELS IN AREAS WHERE WELLS HAVE BEEN SHUT OFF DUE TO HIGH GROUNDWATER LEVELS;

(H) INCREASED MUNICIPAL, INDUSTRIAL, AND AGRICULTURAL WATER SUPPLY; AND

(I) INCREASED AGRICULTURAL PRODUCTION.

(III) THEREFORE, THE GENERAL ASSEMBLY DECLARES THAT A STUDY SHOULD BE CONDUCTED TO IDENTIFY POSSIBLE WATER STORAGE SITES ALONG THE SOUTH PLATTE RIVER BASIN.

(b) THE BOARD, IN COLLABORATION WITH THE STATE ENGINEER, SHALL CONDUCT OR COMMISSION A HYDROLOGY STUDY OF THE SOUTH PLATTE RIVER BASIN TO ESTIMATE, FOR EACH OF THE PREVIOUS TWENTY YEARS, THE VOLUME OF WATER THAT:

(I) HAS BEEN DELIVERED TO NEBRASKA IN EXCESS OF THE AMOUNT REQUIRED TO BE DELIVERED BY THE SOUTH PLATTE RIVER COMPACT, ARTICLE 65 OF THIS TITLE; AND

(II) COULD HAVE OTHERWISE BEEN STORED IN THE LOWER SOUTH PLATTE RIVER BASIN.

(c) THE STUDY MUST INCLUDE A LISTING OF THE LOCATIONS THAT

HAVE BEEN IDENTIFIED AS POSSIBLE SITES FOR THE CONSTRUCTION OF A NEW RESERVOIR ON THE MAINSTEM AND TRIBUTARIES OF THE SOUTH PLATTE RIVER BETWEEN GREELEY, COLORADO, AND JULESBURG, COLORADO.

(d) FOR EACH POSSIBLE SITE IDENTIFIED PURSUANT TO PARAGRAPH (c) OF THIS SUBSECTION (11), THE STUDY MUST INCLUDE:

(I) AN ESTIMATE OF THE VOLUME OF WATER THAT COULD HAVE BEEN STORED ANNUALLY;

(II) USING RELEVANT RECORDS TO WHICH THE PERSONS CONDUCTING THE STUDY MAY ACCESS, INCLUDING RECORDS OF THE FEDERAL BUREAU OF RECLAMATION AND OTHER FEDERAL AGENCIES, A LISTING OF ANY PROPERTY THAT THE FEDERAL BUREAU OF RECLAMATION OR OTHER GOVERNMENT AGENCY HAS PURCHASED FOR CONSTRUCTION OF THE SITE;

(III) AN ESTIMATE OF THE COST TO CONSTRUCT A RESERVOIR AT THE SITE, INCLUDING THE ESTIMATED COSTS OF OBTAINING NECESSARY PERMITS AND ACQUIRING PROPERTY; AND

(IV) A COST-BENEFIT ANALYSIS FOR CONSTRUCTING A RESERVOIR AT THE SITE, INCLUDING CONSIDERATION OF POTENTIAL ENVIRONMENTAL, FINANCIAL, AND LEGAL CONSTRAINTS AND POTENTIAL BENEFITS, INCLUDING:

(A) ADDRESSING COLORADO'S PREDICTED FUTURE WATER SUPPLY GAPS;

(B) PROVIDING AQUIFER RECHARGE;

(C) REDUCING THE NEED TO IMPORT WATER INTO THE SOUTH PLATTE RIVER BASIN FROM OTHER WATER BASINS;

(D) REDUCING RELIANCE ON THE PRACTICE OF BUYING

AGRICULTURAL WATER RIGHTS AND DRYING UP THE AGRICULTURAL LAND SERVED BY THE WATER RIGHTS;

(E) RECREATIONAL BENEFITS;

(F) FLOOD CONTROL;

(G) INCREASING PRODUCTION BY ALLOWING AGRICULTURAL PUMPING OF WELLS, WHICH WILL LOWER THE WATER LEVELS IN AREAS WHERE WELLS HAVE BEEN SHUT OFF DUE TO HIGH GROUNDWATER LEVELS;

(H) INCREASED MUNICIPAL, INDUSTRIAL, AND AGRICULTURAL WATER SUPPLY;

(I) INCREASED AGRICULTURAL PRODUCTION; AND

(J) ANY OTHER BENEFIT.

(e) THE BOARD, IN COLLABORATION WITH THE STATE ENGINEER, SHALL:

(I) COMPLETE THE STUDY AS EXPEDITIOUSLY AS PRACTICABLE, BUT NOT LATER THAN NOVEMBER 30, 2016; AND

(II) ON OR BEFORE JANUARY 20, 2017, PROVIDE A REPORT SUMMARIZING THE STUDY TO THE COMMITTEES OF REFERENCE IN THE HOUSE OF REPRESENTATIVES AND THE SENATE WITH JURISDICTION OVER NATURAL RESOURCES.

(f) THE BOARD MAY ACCEPT AND EXPEND GIFTS, GRANTS, AND DONATIONS FOR THE PURPOSES OF THIS SUBSECTION (11), BUT THE IMPLEMENTATION OF THIS SUBSECTION (11) IS NOT DEPENDENT ON THE RECEIPT OF GIFTS, GRANTS, AND DONATIONS. THE BOARD SHALL TRANSMIT ALL MONEY RECEIVED THROUGH GIFTS, GRANTS, OR DONATIONS TO THE STATE TREASURER, WHO SHALL CREDIT THEM TO THE COLORADO WATER CONSERVATION BOARD CONSTRUCTION FUND CREATED IN SECTION 37-60-121.

(g) THIS SUBSECTION (11) IS REPEALED, EFFECTIVE JULY 1, 2018.

**SECTION 2.** In Colorado Revised Statutes, 39-29-109, **amend** (2) introductory portion; and **add** (2) (a) (XV) as follows:

**39-29-109. Severance tax trust fund - created - administration - distribution of money - repeal.** (2) State severance tax receipts shall be credited to the severance tax trust fund as provided in section 39-29-108. Except as otherwise set forth in section 39-29-109.5, all income derived from the deposit and investment of the ~~moneys~~ MONEY in the fund shall be credited to the fund. At the end of any fiscal year, all unexpended and unencumbered ~~moneys~~ MONEY in the fund ~~remain therein~~ REMAINS IN THE FUND and shall not be credited or transferred to the general fund or any other fund. All ~~moneys~~ MONEY in the fund ~~are~~ IS subject to appropriation by the general assembly for the following purposes:

(a) **The severance tax perpetual base fund.** (XV) NOTWITHSTANDING ANY PROVISION OF THIS PARAGRAPH (a) TO THE CONTRARY, ON JULY 1, 2016, THE STATE TREASURER SHALL TRANSFER TWO HUNDRED FIFTY THOUSAND DOLLARS FROM THE FUND TO THE COLORADO WATER CONSERVATION BOARD CONSTRUCTION FUND, CREATED IN SECTION 37-60-121 (1) (a), C.R.S., FOR USE BY THE COLORADO WATER CONSERVATION BOARD, CREATED IN SECTION 37-60-102, C.R.S., TO IMPLEMENT THE SOUTH PLATTE RIVER WATER STORAGE STUDY PURSUANT TO SECTION 37-60-115 (11), C.R.S.

**SECTION 3. Safety clause.** The general assembly hereby finds, determines, and declares that this act is necessary for the immediate preservation of the public peace, health, and safety.

# APPENDIX B – LITERATURE REVIEW TM

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# HB 1256 - South Platte Storage Study (SPSS)

MWH now part of Stantec

TECHNICAL MEMORANDUM

| | | | |
|---|---|---|---|
| To: | Joe Frank, Andy Moore | From: | Samantha Mauzy, Enrique Triana and Chip Paulson |
| | Lower South Platte Water Conservancy District, Colorado Water Conservation Board | | MWH Now Part of Stantec |
| Subject: | **South Platte Storage Opportunities Literature Review** | Date: | March 13, 2017 |

## INTRODUCTION AND BACKGROUND

The South Platte Storage Study (SPSS) was initiated as a result of House Bill 16-1256 titled "South Platte Storage Study." HB16-1256, signed into law by the Governor on June 9th, 2016, authorizes the Colorado Water Conservation Board (CWCB), in collaboration with the State Engineer (SEO), and the South Platte Basin and Metro Roundtables, to identify multi-purpose water storage options along the lower South Platte River to capture flows leaving the state in excess of the legally required amounts. These water storage possibilities will include new reservoirs, the enlargement/rehabilitation of existing reservoirs, and alternative storage mechanisms (e.g., underground storage).

The first task of the SPSS project is a literature review of storage studies in the South Platte River basin. The objective of the literature review is to identify and document previously studied storage sites and catalog opportunities for additional expansion, partnerships and multiuse possibilities.

Storage opportunities in the South Platte basin have been studied by a variety of different agencies, including the State and individual water users. Some of these past studies sought to address broad regional water needs (e.g., the South Platte Basin Implementation Plan), while others were conducted by individual water users to meet their own storage needs. In some cases, those storage opportunities are part of water users' long term plans and are included in the State Water Plan as Identified Projects and Processes (IPP). In other cases, storage opportunities were ruled out by the water user that studied them because they did not meet the needs of the water user. These storage opportunities previously ruled out have been included herein because they could be an opportunity for others.

This technical memorandum presents the results of the SPSS Literature Review. It contains an overview of potential storage sites identified thus far. It outlines the sources that have been reviewed and how the identified sites have been categorized. A working draft of this technical memorandum was distributed and presented to interested parties on January 12, 2017. The feedback, comments, and clarifications received were incorporated into this version of the memorandum.

## SOURCES OF INFORMATION

The sources reviewed for this study are shown in Table 1. Pertinent information for storage sites was extracted from these reports and databases. HB 16-1256 asked for a review of previously identified storage sites throughout the South Platte Basin. Reports covering areas throughout the basin were reviewed, but the emphasis was on storage options in the designated SPSS study area between Greeley and the state line.

## Table 1. Information Sources Used in the Literature Review

| Source Name | Entity | Author | Year |
|---|---|---|---|
| 2015 South Platte Basin Implementation Plan | South Platte Basin Roundtable | HDR/ West Sage | 2015 |
| 2015 South Platte Basin Surface Water Availability Analysis - Appendix G | South Platte Basin Roundtable | MWH/ HDR | 2015 |
| Active Construction DRMS Permits Shapefile from State of Colorado | | | 2017 |
| Addendum No. 2 to Definite Plan Report | US Bureau of Reclamation | | 1983 |
| Analysis of managed aquifer recharge for retiming streamflow in an alluvial river | Journal of Hydrology | Michael J. Ronayne, Jason A. Roudebush, John D. Stednick | 2016 |
| Artificial Aquifer Recharge in the Colorado Portion of the Ogallala Aquifer | Colorado Water Resources Research Institute | Robert Longenbaugh, Donald Miles, Earl Hess, James Rubingh | 1984 |
| Artificial Recharge of Ground Water in Colorado - A Statewide Assessment | Colorado Geological Survey | Ralf Topper, Peter E. Barkmann, David A. Bird, and Matthew A. Sares | 2004 |
| Cache la Poudre Water and Hydropower Resources Management Study | Colorado Water Resources and Power Development Authority | Harza Engineering Company | 1987 |
| CDSS Reservoirs GIS Shapefile, Division 1 | | | 2017 |
| Chatfield Reservoir Reallocation Final Integrated Feasibility Report and Environmental Impact Statement | | US Army Corps of Engineers | 2013 |
| Colorado Water Conservation Board SB-193 Underground Water Storage Study | Colorado Water Conservation Board | | 2007 |
| Colorado's Water Plan | Colorado Water Conservation Board | Colorado Water Conservation Board | 2015 |
| Final Draft Alternative Descriptions for Moffat Collection System EIS | Denver Water | MWH | 2005 |
| GIS Dam Site Inventory from State of Colorado | | | |
| Legal and Institutional Opportunities for Aquifer Recharge and Storage in Colorado --An Interactive Forum | | Aqua Engineering, Inc., El Paso County Water Authority | 2008 |
| Lost Creek Basin Aquifer Recharge and Storage Study | Lost Creek Ground Water Management District | Colorado Geological Survey | 2011 |
| Multi-Basin Water Supply Investigation | Northern Colorado Water Conservancy District | Black and Veatch | 2006 |
| Northern Integrated Supply Project Final Technical Memorandum 5D: Existing Reservoirs with Enlargement and Rehabilitation Potential | Northern Colorado Water Conservancy District | MWH | 2004 |
| Northern Integrated Supply Project Phase II Alternative Evaluation | Northern Colorado Water Conservancy District | MWH | 2004 |
| Northern Integrated Supply Project Technical Memorandum 5E Upper Saint Vrain Yield Analysis | Northern Colorado Water Conservancy District | MWH | 2004 |
| Ovid Reservoir and Dam Preliminary Design Report | | Applegate Group | 2003 |

| Source Name | Entity | Author | Year |
|---|---|---|---|
| Pawnee Creek Flood Control Project - Phase 1 Project Scoping Report | | W. W. Wheeler and Associates | 2011 |
| Preliminary Conceptual Plan for Proposed Pawnee Pass Dam and Reservoir in Logan County Colorado | Platte River Hydrologic Research Center | Charles Leaf | |
| River Water Management and Storage Sites | Colorado Water Conservation Board | GEI Consultants | 2001 |
| SB06-193 Underground Water Storage Study | Colorado Water Conservation Board | Camp Dresser and McKee Inc. | 2007 |
| SPSS Project - CCWCD Interview Notes | Colorado Water Conservation Board | MWH | 2016 |
| Statewide Water Supply Initiative Technical Memoranda | Colorado Water Conservation Board | | 2010 |
| Windy Gap Firming Project, Alternative Plan Formulation Report | Northern Colorado Water Conservancy District | Boyle Engineering Corporation | 2003 |

## STORAGE SITE CLASSIFICATION

Storage sites found in the literature review were separated into three (3) main categories: surface storage sites; aquifer storage sites; and gravel pit sites. Gravel pit storage was separated from the surface storage category because of the way gravel pit storage is evaluated herein. For the purpose of this study, gravel pit storage is evaluated based on general geographic location, not as individual sites.

### SURFACE STORAGE SITES

Surface storage sites were classified into four (4) sub-categories to help identify opportunities for this project. Sub-categories for surface storage opportunities were enlargements of existing reservoirs, identified new reservoir sites, existing reservoirs with rehabilitation potential, and existing reservoirs with storage restoration potential. These categories are defined in Table 2.

**Table 2. Surface Storage Category Definitions**

| Category | Description |
|---|---|
| **Enlargement** | This group includes existing reservoirs that have been previously studied to determine feasibility of an enlargement. If available, information such as enlarged capacity and enlargement feasibility from previous enlargement studies was captured for use in this investigation. |
| **New Site** | These are locations where a new surface storage facility could be feasible. Information such as potential reservoir capacity and feasibility from previous studies is usually available. |
| **Rehabilitation** | These sites are existing reservoirs that have a storage restriction imposed by the State of Colorado Dam Safety Branch. By rehabilitating the dams at these locations, the storage restrictions could be removed and additional storage would then become available. |
| **Storage Restoration** | Locations in this category include existing reservoirs that have reduced storage capacity due to sedimentation. Storage capacity at these sites could be recovered by dredging the sediment and disposing it. |

Storage sites identified as IPPs in the State Water Plan are included in the inventory. Although the water users promoting these IPPs might be planning to use all the potential storage capacity, there may be opportunities for further enlargements of these reservoirs to incorporate the needs of additional partners. Additional analysis will need to be performed to determine if IPP sites can potentially be enlarged for the purpose of this study. Storage projects identified in other studies that were screened out for that project purpose could still be feasible for this study. If available, the reasons for sites being screened out in previous studies were compiled in this literature review.

Sites included in the GIS Dam Site Inventory Shapefile from the State of Colorado that were not included in the comprehensive CDSS Division 1 Reservoirs Shapefile of existing sites were categorized as *Potential New Sites*. The potential for reservoir sites in this category within the SPSS study area to meet needs of this study will have to be evaluated in detail later in the project.

### AQUIFER STORAGE SITES

This group of storage sites includes options that use deep confined or shallow unconfined aquifers to store water. For this summary these sites are represented by a single point on a map, but in reality aquifer storage could occur over a broad area in the aquifer porous space underground. These options will require points of recharge and extraction that will be analyzed when formulating the storage concepts later in the project.

### GRAVEL PIT STORAGE

Gravel pit storage sites were separated from the surface water storage category because they will be treated differently than the larger surface reservoir options in this study. The individual gravel pit storage options are small and will not be considered for long term storage on their own; however, groups of individual gravel pits in the same general area could be combined into a larger storage complex that could provide sufficient capacity to meet the needs of this study. In addition, these sites may be used to support other storage solutions, for example by providing temporary storage to hold exchange water until it can be exchanged further upstream. For purposes of this storage site inventory, gravel pit locations were mapped separately from other surface reservoir options so locations of possible gravel pit complexes can be considered later in the project.

## SUMMARY OF REVIEWED STORAGE SITES

The potential surface storage sites in the South Platte River Basin cataloged in this literature review are listed in Table 3, and potential aquifer storage sites are presented in Table 4. *Additional Storage* represents the estimated volume that the site could contribute to new storage in the basin (i.e., excluding existing storage for enlargement, rehabilitation and restoration options). Readily available information was collected and summarized for storage options in the entire South Platte Basin. Information was not verified, but was taken directly from previous studies or inventories. Additional information will be developed for sites within the SPSS study area that are candidates for including in this study in future phases of the work.

*Potential for Consumptive Partnerships* and *Potential for Non-Consumptive Partnerships* are key factors in determining which sites have potential to be considered for this project as an option to develop additional storage in the basin. A site with Potential Consumptive Partnerships refers to future storage concepts for which the current reservoir owner could consider opportunities to split both financial costs and additional storage space at the site with other water users for consumptive water uses. A site with potential non-consumptive partnerships refers to a storage opportunity for which the current owner could consider cooperating with additional entities to split financial costs, providing non-consumptive use benefits (i.e. recreation, wildlife habitat, etc.). This factor is important because, although it may be physically feasible to enlarge or rehabilitate an existing reservoir, without cooperation from the current owner and a commitment to make a portion of the additional storage space available to the State or other water users the additional storage capacity would not benefit this project. Similarly for a new reservoir, if the water user proposing it intends to develop the full site capacity for its own purposes then there would be no opportunity to acquire storage for purposes of the SPSS. Limited information on potential partnership opportunities was obtained through the literature review and therefore this information is incomplete; it will be refined for reservoir options in the SPSS study area as the project progresses and the number of candidate sites is reduced through the screening process.

Figure 1 shows the location of the cataloged surface storage sites for the entire South Platte Basin. It includes potential new reservoir sites and existing reservoirs that could be enlarged, rehabilitated, or restored. Figure 2 shows potential new, enlarged, rehabilitated and restored surface storage sites in the SPSS study area. Figure 3 shows the cataloged aquifer storage options in the South Platte Basin; Figure 4 shows the same information for the SPSS study area. Locations indicated on the map are representative of the general aquifer locations; aquifer spatial boundaries are not depicted.

Figure 5 and Figure 6 show active sand, gravel, sand and gravel, or construction borrow material mines in Division 1 and the SPSS study area, respectively. These sites are color-coded according to the current post-mining use designation. Those with the designation “developed water resources” have been identifies as sites that will be reclaimed for the purpose of water storage use after mining is completed. Note that there is potential for mines not designated as “developed water resources” to change designation after mining is completed, so all permitted gravel mining operations are shown.

A total of 70 surface storage options (excluding gravel pits) and 22 aquifer storage options were found in the SPSS study area through the Literature Review. Individual surface storage options in the study area vary from 3 ac-ft to 1,962,000 ac-ft of additional storage capacity, and include sites on the South Platte mainstem, on primary tributaries, and in tributary drainage areas. The inventory includes:

- Fifty-nine (59) new reservoir sites
- Six (6) existing reservoir enlargements
- Four (4) existing reservoir rehabilitations

- One (1) existing reservoir restoration
- Twenty-two (22) aquifer storage options
- Fifty-five (55) permitted gravel mining sites

Some of these options are similar (e.g., different nearby reservoir sites on the same tributary) and may be filtered into a single option in the next step of the storage site evaluation.

The next phase of the work will include assessing the storage options in the study area and developing a long-list of options that warrant further study based on their size, location, ownership, permitability, and other attributes.

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| Primary Source: 2015 South Platte Basin Implementation Plan | | | | | | | | |
| 114 | Box Creek Reservoir | New Site | 25,000 | Unknown | Unknown | Yes | | |
| 137 | Consolidated Mutual Water District Reservoir Construction | New Site | | Unknown | Unknown | Yes | | |
| 194 | Corral Creek A | New Site | 9,000 | Unknown | Unknown | | Yes | |
| 250 | Corral Creek B | New Site | 2,500 | Unknown | Unknown | | Yes | |
| 247 | Cottonwood Creek | New Site | 4,000 | Unknown | Unknown | | Yes | |
| 197 | Gerk | New Site | 5,000 | Unknown | Unknown | | Yes | |
| 107 | Greeley Flatiron Reservoir | New Site | 3,100 | Unknown | Unknown | | | Enlarged capacity is combined Greeley Flatiron and Overland Trail and 25th Ave Lakes |
| 189 | Harmony Ditch West | New Site | 10,000 | Unknown | Unknown | | Yes | |
| 248 | Hawk Springs | New Site | 3,500 | Unknown | Unknown | | Yes | |
| 110 | Highway 93 Lakes | New Site | 500 | Unknown | Unknown | Yes | | |
| 89 | Jackson Lake Reservoir | Storage Restoration | 10,000 | Yes | Unknown | | Yes | Potential partnerships to recapture storage by dredging (front range city, oil/gas industry, or State Parks Dept.) Info updated 2/21/17 based on email communication with Cynthia Lefever (fmrico@outlook.com) |
| 199 | Johnson Lake Enlargement | Enlargement | 5,400 | Unknown | Unknown | | Yes | |
| 198 | Johnson Lake West | New Site | 3,500 | Unknown | Unknown | | Yes | |
| 188 | Johnson Reservoir | New Site | 10,600 | Unknown | Unknown | | Yes | |
| 97 | Little Thompson Reservoir | New Site | 305,000 | Unknown | Unknown | | | |

### Table 3. Potential Surface Storage Sites in the South Platte Basin

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 138 | New Storage Projects (Northglenn) | New Site | 1,500 | Unknown | Unknown | Yes | | |
| 193 | North Sterling Regulating Reservoir | New Site | 7,600 | Unknown | Unknown | | Yes | |
| 249 | Ramsey Draw | New Site | 2,900 | Unknown | Unknown | | Yes | |
| 133 | Reuter Hess Reservoir Enlargement | Enlargement | 14,810 | Unknown | Unknown | Yes | | |
| 187 | Sedgwick | New Site | 2,230 | Unknown | Unknown | | Yes | |
| 246 | Site A | New Site | 1,580 | Unknown | Unknown | | Yes | |
| 195 | Skinner Draw | New Site | 5,400 | Unknown | Unknown | | Yes | |
| 190 | Sterling Lateral East | New Site | 4,900 | Unknown | Unknown | | Yes | |
| 191 | Sterling Lateral South | New Site | 6,600 | Unknown | Unknown | | Yes | |
| 192 | Sterling Lateral West | New Site | 6,900 | Unknown | Unknown | | Yes | |
| 196 | Troelstrup | New Site | 5,000 | Unknown | Unknown | | Yes | |
| 134 | Union (Calkins) Reservoir Enlargement | Enlargement | 1,770 | Unknown | Unknown | Yes | | >5 residences impacted |
| Primary Source: CDSS Reservoirs GIS Shapefile, Division 1 | | | | | | | | |
| 427 | A C Rupp Reservoir No 2 | New Site | 22 | Unknown | Unknown | | | |
| 431 | Alma Reservoir | New Site | | Unknown | Unknown | | | |
| 367 | Bakerville Reservoir 1 | New Site | 70 | Unknown | Unknown | | | |
| 368 | Bakerville Reservoir 2 | New Site | 80 | Unknown | Unknown | | | |
| 370 | Bald Mountain Reservoir | New Site | 110,000 | Unknown | Unknown | | | |
| 364 | Ball Placer Reservoir | New Site | 110 | Unknown | Unknown | | | |
| 489 | Barnes Park Pond Reservoir | New Site | | Unknown | Unknown | | | |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 340 | Behrmann Reservoir | New Site | 2,869 | Unknown | Unknown | | | |
| 507 | Bickling Reservoir | New Site | | Unknown | Unknown | | | |
| 277 | Bijou Valley D & R Sys A | New Site | 487 | Unknown | Unknown | | Yes | |
| 474 | Bokelman Reservoir 1 | New Site | 345 | Unknown | Unknown | | | |
| 414 | Boksmati Reservoir | New Site | | Unknown | Unknown | | | |
| 484 | Boomerang Reservoir 1 | New Site | 581 | Unknown | Unknown | | | |
| 485 | Boomerang Reservoir 2 | New Site | 481 | Unknown | Unknown | | | |
| 462 | Brinkmann-Woodward Reservoir | New Site | | Unknown | Unknown | | | |
| 331 | Buckhorn Reservoir | New Site | 1,190 | Unknown | Unknown | | | |
| 312 | Cache La Poudre Forebay | New Site | 55,000 | Unknown | Unknown | | | |
| 499 | Carbon Valley Water Storage Cell Reservoir | New Site | 1,600 | Unknown | Unknown | | | |
| 394 | Centennial Lake | New Site | 680 | Unknown | Unknown | | | |
| 458 | Centennial Ponds | New Site | 2,172 | Unknown | Unknown | | | |
| 369 | Centennial Reservoir | New Site | 110,000 | Unknown | Unknown | | | |
| 509 | Central City Chase Gulch Reservoir | New Site | | Unknown | Unknown | | | |
| 490 | Cgrw Investments Pond Reservoir | New Site | | Unknown | Unknown | | | |
| 358 | Clear Creek Reservoir 2 | New Site | 30 | Unknown | Unknown | | | |
| 359 | Clear Creek Reservoir 3 | New Site | 65 | Unknown | Unknown | | | |
| 360 | Clear Creek Reservoir 4 | New Site | 55 | Unknown | Unknown | | | |
| 430 | Columbine Reservoir | New Site | | Unknown | Unknown | | | |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 432 | Como Reservoir 2 | New Site | 7,900 | Unknown | Unknown | | | |
| 444 | Corliss No 1 Reservoir | New Site | | Unknown | Unknown | | | |
| 436 | Couch Aug Pond D | New Site | | Unknown | Unknown | | Yes | |
| 479 | Cpnmd Reservoir 1 | New Site | 5,500 | Unknown | Unknown | | | |
| 281 | D T Reservoir 1 | New Site | 138 | Unknown | Unknown | | Yes | |
| 279 | D T Reservoir 2 | New Site | 112 | Unknown | Unknown | | Yes | |
| 280 | D T Reservoir 3 | New Site | 125 | Unknown | Unknown | | Yes | |
| 393 | Dancing Deer Pond | New Site | | Unknown | Unknown | | | |
| 354 | Donald Reservoir | New Site | 264 | Unknown | Unknown | | | |
| 361 | Douglas Mountain Reservoir 2 | New Site | 525 | Unknown | Unknown | | | |
| 288 | Dover Reservoir | New Site | | Unknown | Unknown | | Yes | |
| 273 | Duke Pond | New Site | | Unknown | Unknown | | | |
| 421 | Eagle Rock Park Reservoir | New Site | 7 | Unknown | Unknown | | | |
| 453 | East Reservoir Complex | New Site | 45,761 | Unknown | Unknown | | | |
| 466 | East Wabash Underground Storage Structure | New Site | 101 | Unknown | Unknown | | | |
| 422 | Eitel North Dam | New Site | 1 | Unknown | Unknown | | | |
| 423 | Eitel South Dam | New Site | 10 | Unknown | Unknown | | | |
| 460 | Emj Squaw Pass Upper Reservoir No 1 | New Site | 3 | Unknown | Unknown | | | |
| 470 | Emj Squaw Pass Upper Reservoir No 2 | New Site | 2 | Unknown | Unknown | | | |
| 505 | Everist No 2 Reservoir | New Site | 10,163 | Unknown | Unknown | | | |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 506 | Everist No 3 Reservoir | New Site | 1,767 | Unknown | Unknown | | | |
| 374 | Everist Reservoir | New Site | 990 | Unknown | Unknown | | | |
| 304 | Ferguson Reservoir | New Site | | Unknown | Unknown | | | |
| 318 | Firesteine Reservoir | New Site | 1,000 | Unknown | Unknown | | | |
| 486 | Flyfisher Reservoir | New Site | 25 | Unknown | Unknown | | | |
| 512 | Fritzler Reservoir 2 | New Site | | Unknown | Unknown | | Yes | |
| 319 | Gray Reservoir 3A | New Site | 15 | Unknown | Unknown | | | |
| 320 | Gray Reservoir 3B | New Site | 20 | Unknown | Unknown | | | |
| 321 | Gray Reservoir 3C | New Site | 20 | Unknown | Unknown | | | |
| 322 | Gray Reservoir 3D | New Site | 10 | Unknown | Unknown | | | |
| 323 | Gray Reservoir 3E | New Site | 10 | Unknown | Unknown | | | |
| 324 | Gray Reservoir 3F | New Site | 15 | Unknown | Unknown | | | |
| 325 | Gray Reservoir 3G | New Site | 10 | Unknown | Unknown | | | |
| 326 | Gray Reservoir 3H | New Site | 10 | Unknown | Unknown | | | |
| 327 | Gray Reservoir 3I | New Site | 10 | Unknown | Unknown | | | |
| 467 | Great Western Reservoir 1 | New Site | | Unknown | Unknown | | | |
| 468 | Great Western Reservoir 2 | New Site | | Unknown | Unknown | | | |
| 469 | Great Western Reservoir 3 | New Site | | Unknown | Unknown | | | |
| 287 | Grover Reservoir | New Site | 2,506 | Unknown | Unknown | | | |
| 372 | Guy Gulch Reservoir | New Site | 35,000 | Unknown | Unknown | | | |
| 316 | Hansen Stenzel Reservoir | New Site | | Unknown | Unknown | | | |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 448 | Happy Canyon Reservoir & Recharge Area | New Site | | Unknown | Unknown | | | |
| 413 | Harden Reservoir 2 | New Site | 3 | Unknown | Unknown | | | |
| 310 | Harris Reservoir A | New Site | 350 | Unknown | Unknown | | | |
| 426 | High Chaparral Pond | New Site | | Unknown | Unknown | | | |
| 416 | Hiwan Reservoir 10 | New Site | 206 | Unknown | Unknown | | | |
| 415 | Hiwan Reservoir 9 | New Site | 230 | Unknown | Unknown | | | |
| 305 | Home Place Pond No 14 | New Site | | Unknown | Unknown | | | |
| 306 | Home Place Pond No 15 | New Site | | Unknown | Unknown | | | |
| 282 | Jackpot Reservoir | New Site | | Unknown | Unknown | | Yes | |
| 398 | Jackson Cr Prop Pond 1 | New Site | | Unknown | Unknown | | | |
| 407 | Jackson Cr Prop Pond 11 | New Site | | Unknown | Unknown | | | |
| 408 | Jackson Cr Prop Pond 12 | New Site | | Unknown | Unknown | | | |
| 396 | Jackson Cr Prop Pond 13 | New Site | | Unknown | Unknown | | | |
| 399 | Jackson Cr Prop Pond 2A | New Site | | Unknown | Unknown | | | |
| 395 | Jackson Cr Prop Pond 2B | New Site | | Unknown | Unknown | | | |
| 400 | Jackson Cr Prop Pond 3 | New Site | | Unknown | Unknown | | | |
| 401 | Jackson Cr Prop Pond 4 | New Site | | Unknown | Unknown | | | |
| 402 | Jackson Cr Prop Pond 5 | New Site | | Unknown | Unknown | | | |
| 403 | Jackson Cr Prop Pond 6 | New Site | | Unknown | Unknown | | | |
| 404 | Jackson Cr Prop Pond 7 | New Site | | Unknown | Unknown | | | |
| 405 | Jackson Cr Prop Pond 8 | New Site | | Unknown | Unknown | | | |

## Table 3. Potential Surface Storage Sites in the South Platte Basin

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 406 | Jackson Cr Prop Pond 9 | New Site | | Unknown | Unknown | | | |
| 329 | Kammerzell Lake | New Site | 14 | Unknown | Unknown | | | |
| 409 | Keats Pond 1 | New Site | 25 | Unknown | Unknown | | | |
| 410 | Keats Pond 2 | New Site | 20 | Unknown | Unknown | | | |
| 284 | Klug Reservoir 3 | New Site | 715 | Unknown | Unknown | | Yes | |
| 417 | Krain Pond 1 | New Site | 33 | Unknown | Unknown | | | |
| 418 | Krain Pond 2 | New Site | 36 | Unknown | Unknown | | | |
| 452 | Kurtz Reservoir | New Site | 10,500 | Unknown | Unknown | | | |
| 350 | Lafayette Reservoirs 1&2 | New Site | 180 | Unknown | Unknown | | | |
| 385 | Lake Roxborough | New Site | | Unknown | Unknown | | | |
| 481 | Lasalle Reservoir | New Site | 36 | Unknown | Unknown | | | |
| 365 | Leavenworth Reservoir 1 | New Site | 155 | Unknown | Unknown | | | |
| 366 | Leavenworth Reservoir 2 | New Site | 160 | Unknown | Unknown | | | |
| 450 | Lone Tree Reservoir & Recharge No 2 | New Site | | Unknown | Unknown | | | |
| 449 | Lone Tree Reservoir No 1 | New Site | | Unknown | Unknown | | | |
| 433 | Lost Park Reservoir | New Site | | Unknown | Unknown | | | |
| 482 | Lower Equalizer Reservoir 1 | New Site | 900 | Unknown | Unknown | | | |
| 483 | Lower Equalizer Reservoir 2 | New Site | 760 | Unknown | Unknown | | | |
| 501 | Lower Sandstone Reservoir | New Site | 60 | Unknown | Unknown | | | |
| 330 | Maitland/Loveland Reservoir | New Site | | Unknown | Unknown | | | |
| 351 | Mary E Miller Reservoir | New Site | | Unknown | Unknown | | | |

### Table 3. Potential Surface Storage Sites in the South Platte Basin

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 375 | Mcdonald Reservoir 1 | New Site | 8 | Unknown | Unknown | | | |
| 376 | Mcdonald Reservoir 2 | New Site | 12 | Unknown | Unknown | | | |
| 377 | Mcdonald Reservoir 3 | New Site | 10 | Unknown | Unknown | | | |
| 378 | Mcdonald Reservoir 4 | New Site | 5 | Unknown | Unknown | | | |
| 379 | Meadow Ranch Reservoir 1 | New Site | 145 | Unknown | Unknown | | | |
| 380 | Meadow Ranch Reservoir 2 | New Site | 145 | Unknown | Unknown | | | |
| 381 | Meadow Ranch Reservoir 3 | New Site | 145 | Unknown | Unknown | | | |
| 382 | Meadow Ranch Reservoir 4 | New Site | 145 | Unknown | Unknown | | | |
| 383 | Meadow Ranch Reservoir 5 | New Site | 145 | Unknown | Unknown | | | |
| 384 | Meadow Ranch Reservoir 6 | New Site | 145 | Unknown | Unknown | | | |
| 386 | Meadow Ranch Reservoir 7 | New Site | 145 | Unknown | Unknown | | | |
| 297 | Miracle Lake | New Site | 95 | Unknown | Unknown | | | |
| 283 | Moonshine Reservoir | New Site | | Unknown | Unknown | | Yes | |
| 492 | Morey Pond Reservoir | New Site | | Unknown | Unknown | | | |
| 438 | N Sterling Harmony W Reservoir | New Site | | Unknown | Unknown | | Yes | |
| 335 | Neighbors Pond 1 | New Site | 123 | Unknown | Unknown | | | |
| 333 | Neighbors Pond 2 | New Site | 105 | Unknown | Unknown | | | |
| 508 | New Cache Agricultural Pond 1 | New Site | | Unknown | Unknown | | Yes | |
| 278 | Noonen Seep Reservoir | New Site | 176 | Unknown | Unknown | | | |
| 313 | North Lone Pine Reservoir | New Site | | Unknown | Unknown | | | |
| 295 | Northglenn Reservoir | New Site | | Unknown | Unknown | | | |

## Table 3. Potential Surface Storage Sites in the South Platte Basin

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 292 | Oar Reservoir A | New Site | 6,200 | Unknown | Unknown | | | |
| 294 | Oar Reservoir B | New Site | 10,200 | Unknown | Unknown | | | |
| 463 | Oar Reservoir C | New Site | 4,500 | Unknown | Unknown | | | |
| 293 | Oar Reservoir D | New Site | 4,000 | Unknown | Unknown | | | |
| 343 | Oleson No 1 Reservoir | New Site | | Unknown | Unknown | | | |
| 344 | Oleson No 2 Reservoir | New Site | | Unknown | Unknown | | | |
| 345 | Oleson No 3 Reservoir | New Site | | Unknown | Unknown | | | |
| 355 | Opalair Reservoir | New Site | 30 | Unknown | Unknown | | | |
| 363 | Paradise Valley Reservoir No 2 | New Site | 50 | Unknown | Unknown | | | |
| 362 | Paradise Valley Reservoir No 3 | New Site | 50 | Unknown | Unknown | | | |
| 412 | Petersburg Reservoir | New Site | 5 | Unknown | Unknown | | | |
| 437 | Phillips-Sedgwick Reservoir # 2 | New Site | | Unknown | Unknown | | | |
| 435 | Pioneer Reservoir | New Site | 200 | Unknown | Unknown | | Yes | |
| 456 | Pisano Illegal Pond | New Site | | Unknown | Unknown | | | |
| 307 | Platte Valley Pit | New Site | | Unknown | Unknown | | | |
| 309 | Platte Valley Reservoir 1 | New Site | 300 | Unknown | Unknown | | | |
| 459 | Platte Valley Trust Reservoir | New Site | | Unknown | Unknown | | | |
| 491 | Pond North Of Service Center Reservoir | New Site | | Unknown | Unknown | | | |
| 488 | Probasco Pit Reservoir | New Site | | Unknown | Unknown | | | |
| 502 | Quartz Valley Reservoir | New Site | 1,660 | Unknown | Unknown | | | |
| 388 | Ramsour Bros Pond No 1 | New Site | | Unknown | Unknown | | | |

## Table 3. Potential Surface Storage Sites in the South Platte Basin

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 389 | Ramsour Bros Pond No 2 | New Site | | Unknown | Unknown | | | |
| 390 | Ramsour Bros Pond No 3 | New Site | | Unknown | Unknown | | | |
| 420 | Red Hill Reservoir | New Site | | Unknown | Unknown | | | |
| 455 | Richardson Illegal Pond | New Site | | Unknown | Unknown | | | |
| 334 | Rock N Wp Ranch Lake 5 | New Site | 1,820 | Unknown | Unknown | | | |
| 397 | Roxborough Village Reservoir 2 | New Site | 61 | Unknown | Unknown | | | |
| 510 | Rumsey Reservoir 1 | New Site | 1,250 | Unknown | Unknown | | | |
| 511 | Rumsey Reservoir 2 | New Site | 1,250 | Unknown | Unknown | | | |
| 411 | Sandifer Pond 1 | New Site | 2 | Unknown | Unknown | | | |
| 439 | Scalva Replacement Reservoir C | New Site | 9 | Unknown | Unknown | | Yes | |
| 440 | Scalva Replacement Reservoir D | New Site | 8 | Unknown | Unknown | | Yes | |
| 352 | Section No 9 Reservoir | New Site | | Unknown | Unknown | | | |
| 392 | Sellers Gulch Reservoir 1 | New Site | | Unknown | Unknown | | | |
| 391 | Sellers Gulch Reservoir 2 | New Site | | Unknown | Unknown | | | |
| 314 | Sleeping Ute Reservoir | New Site | | Unknown | Unknown | | | |
| 317 | South Eighty Reservoir | New Site | | Unknown | Unknown | | | |
| 346 | South Flat Reservoir | New Site | 656 | Unknown | Unknown | | | |
| 500 | South Shaw Lake No 1 | New Site | 372 | Unknown | Unknown | | | |
| 342 | Southdown Reservoir Field | New Site | 5,900 | Unknown | Unknown | | | |
| 428 | Spruce Grove Reservoir | New Site | 110,000 | Unknown | Unknown | | | |
| 339 | St Vrain Portland 1 Reservoir | New Site | 13,292 | Unknown | Unknown | | | |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 387 | Stevens Jackson Reservoir 4 | New Site | 1 | Unknown | Unknown | | | |
| 311 | Taft Hill Reservoir | New Site | 1,080 | Unknown | Unknown | | | |
| 347 | Tahosa Park Reservoir | New Site | | Unknown | Unknown | | | |
| 301 | Tani Lake 1 | New Site | | Unknown | Unknown | | | |
| 298 | Tani Lake 2 | New Site | | Unknown | Unknown | | | |
| 299 | Tani Lake 3 | New Site | | Unknown | Unknown | | | |
| 300 | Tani Lake 5 | New Site | | Unknown | Unknown | | | |
| 429 | Tarryall Reservoir | New Site | 107,000 | Unknown | Unknown | | | |
| 285 | Tew Reservoir | New Site | | Unknown | Unknown | | Yes | |
| 514 | The Pinery Lsp East Pond | New Site | | Unknown | Unknown | | | |
| 515 | The Pinery Lsp North Pond | New Site | | Unknown | Unknown | | | |
| 513 | The Pinery Lsp West Pond | New Site | | Unknown | Unknown | | | |
| 308 | Thornton Doeringsfeld Pit | New Site | 6,000 | Unknown | Unknown | | | |
| 476 | Thornton Ncci Reservoir | New Site | | Unknown | Unknown | | | |
| 315 | Trap Lake Ii | New Site | 3,800 | Unknown | Unknown | | | |
| 419 | Trout Creek Ranch Pond | New Site | | Unknown | Unknown | | | |
| 356 | Trucksess Pond | New Site | | Unknown | Unknown | | | |
| 291 | Tucson South Reservoirs | New Site | 5,200 | Unknown | Unknown | | | |
| 373 | Tunnel No 1 Reservoir | New Site | 110,000 | Unknown | Unknown | | | |
| 371 | Tunnel No 3 Reservoir | New Site | 110,000 | Unknown | Unknown | | | |
| 425 | Venture 73 Reservoir | New Site | | Unknown | Unknown | | | |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 480 | W W Farms Lake 1 | New Site | 3,514 | Unknown | Unknown | | | |
| 441 | W6 Irr Pond | New Site | 5 | Unknown | Unknown | | Yes | |
| 443 | W6 New Reservoir | New Site | 5 | Unknown | Unknown | | Yes | |
| 442 | W6 Trout Pond | New Site | 3 | Unknown | Unknown | | Yes | |
| 504 | Walker Reservoir | New Site | 2,000 | Unknown | Unknown | | | |
| 472 | Walters Reservoir 1 | New Site | 480 | Unknown | Unknown | | | |
| 473 | Walters Reservoir 2 | New Site | 160 | Unknown | Unknown | | | |
| 471 | Warren Gulch Reservoir No 1 | New Site | 48 | Unknown | Unknown | | | |
| 303 | Water Hazard Pond No 1 | New Site | 5 | Unknown | Unknown | | | |
| 302 | Water Hazard Pond No 2 | New Site | 9 | Unknown | Unknown | | | |
| 296 | Wattenburg Lake | New Site | 2,966 | Unknown | Unknown | | | |
| 434 | Wears Ditch Reservoir | New Site | | Unknown | Unknown | | | |
| 348 | Welty Lake | New Site | | Unknown | Unknown | | | |
| 464 | West Wabash Storage & Recharge Structure | New Site | 125 | Unknown | Unknown | | | |
| 424 | Widdofield Reservoir | New Site | | Unknown | Unknown | | | |
| 286 | Willow Creek Reservoir 2 | New Site | | Unknown | Unknown | | Yes | |
| 451 | Windmill Reservoir No 1 | New Site | | Unknown | Unknown | | | |
| 447 | Woodside Reservoir | New Site | 50 | Unknown | Unknown | | | |
| 445 | Wray-2 Hatchery Ponds | New Site | 160 | Unknown | Unknown | | | |
| 446 | Wray-2 Reservoir | New Site | 150 | Unknown | Unknown | | | |

## Table 3. Potential Surface Storage Sites in the South Platte Basin

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| Primary Source: Chatfield Reservoir Reallocation Final Integrated Feasibility Report and Environmental Impact Statement | | | | | | | | |
| 208 | Penley Reservoir | New Site | 12,725 | Unknown | Unknown | | | |
| Primary Source: GIS Dam Site Inventory Shapefile from State of Colorado | | | | | | | | |
| 257 | Altona Dam & Reservoir | New Site | 26,720 | Unknown | Unknown | | | |
| 210 | Big John Reservoir | Potential New Site | 30,000 | Unknown | Unknown | | | |
| 259 | Bootleg Reservoir | New Site | 6,194 | Unknown | Unknown | | Yes | |
| 260 | Bradley Ranch Reservoir | New Site | 77,000 | Unknown | Unknown | | | |
| 211 | Buck Gulch Reservoir | Potential New Site | 67,000 | Unknown | Unknown | | | |
| 213 | Cone Mountain Reservoir | Potential New Site | 33,300 | Unknown | Unknown | | | |
| 261 | Craig Meadows Reservoir | New Site | 15,000 | Unknown | Unknown | | | |
| 214 | Crescent Reservoir | Potential New Site | 11,300 | Unknown | Unknown | | | |
| 262 | Dowe Flats Reservoir | New Site | 119,000 | Unknown | Unknown | | | |
| 215 | East Bijou Reservoir | Potential New Site | 219,600 | Unknown | Unknown | | | |
| 216 | Estabrook Res. Site No. 1 | Potential New Site | 233,000 | Unknown | Unknown | | | |
| 217 | Estabrook Res. Site No. 2 | Potential New Site | 405,000 | Unknown | Unknown | | | |
| 218 | Ferndale Reservoir | Potential New Site | 785,000 | Unknown | Unknown | | | |
| 263 | Greasewood Reservoir | New Site | 67,268 | Unknown | Unknown | | Yes | |
| 252 | Hackett Reservoir | Potential New Site | 55,200 | Unknown | Unknown | | | |
| 264 | Hall Reservoir | New Site | 49,464 | Unknown | Unknown | | | |
| 220 | Idlewilde Reservoir | Potential New Site | 200,000 | Unknown | Unknown | | | |
| 221 | Inion Reservoir | Potential New Site | 28,000 | Unknown | Unknown | | | |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 265 | Link Slater Reservoir | New Site | 58,190 | Unknown | Unknown | | | |
| 223 | Little S. St. Vrain Res. | Potential New Site | 37,000 | Unknown | Unknown | | | |
| 224 | Livermore Reservoir | Potential New Site | 394,000 | Unknown | Unknown | | | |
| 225 | Longmont Sugar Plant | Potential New Site | 44,000 | Unknown | Unknown | | | |
| 226 | Lookout Reservoir | Potential New Site | 43,000 | Unknown | Unknown | | | |
| 266 | March Reservoir | New Site | 15,863 | Unknown | Unknown | | Yes | |
| 228 | Middle Bijou Reservoir | Potential New Site | 111,700 | Unknown | Unknown | | | |
| 229 | Muddy Creek Reservoir | Potential New Site | 72,000 | Unknown | Unknown | | | |
| 230 | New Cheesman Reservoir | Potential New Site | 743,000 | Unknown | Unknown | | | |
| 231 | North Sheep Mountain Res. | Potential New Site | 150,000 | Unknown | Unknown | | | |
| 267 | Northern W-Y Reservoir | New Site | 30,000 | Unknown | Unknown | | | |
| 232 | Orodell Reservoir | Potential New Site | 55,000 | Unknown | Unknown | | | |
| 268 | Park Reservoir | New Site | 6,767 | Unknown | Unknown | | | |
| 269 | Phillips-Sedgwick Reservoir #1 | New Site | 18,200 | Unknown | Unknown | | | |
| 233 | Rowell Hill Reservoir | Potential New Site | 150,000 | Unknown | Unknown | | | |
| 253 | Shawnee Reservoir | Potential New Site | 50,000 | Unknown | Unknown | | | |
| 270 | Southern W-Y Reservoir | New Site | 50,000 | Unknown | Unknown | | | |
| 236 | Steamboat Mountain Res. | Potential New Site | 55,000 | Unknown | Unknown | | | |
| 254 | Sterling Recharge Reservoir | Potential New Site | 35,000 | Unknown | Unknown | | Yes | Need to confirm site does not exist |
| 237 | Stone Canyon Reservoir | Potential New Site | 31,800 | Unknown | Unknown | | | |
| 271 | Sunken Lake Reservoir | New Site | 5,093 | Unknown | Unknown | | Yes | |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 238 | Thorodin Reservoir | Potential New Site | 33,000 | Unknown | Unknown | | | |
| 239 | Toll Gate Reservoir | Potential New Site | 34,300 | Unknown | Unknown | | | |
| 240 | Tungsten Reservoir | Potential New Site | 74,000 | Unknown | Unknown | | | |
| 255 | Two Forks Reservoir | New Site | 1,100,000 | Unknown | Unknown | | | |
| 241 | Upper Poudre Reservoir | Potential New Site | 97,000 | Unknown | Unknown | | | |
| 243 | West Bijou Reservoir | Potential New Site | 111,700 | Unknown | Unknown | | | |
| 272 | West Nile Reservoir | New Site | 26,950 | Unknown | Unknown | | Yes | |
| 256 | West Plum Creek | Potential New Site | 730,000 | Unknown | Unknown | | | |
| Primary Source: Multi-Basin Water Supply Investigation | | | | | | | | |
| 251 | Little Owl Creek Reservoir | New Site | 75,000 | Unknown | Unknown | | Yes | |
| Primary Source: Northern Integrated Supply Project Final Technical Memorandum 5D: Existing Reservoirs with Enlargement and Rehabilitation Potential | | | | | | | | |
| 75 | Bear Creek Lake | Enlargement | 32,000 | Unknown | Unknown | | | |
| 52 | Beaver Park Reservoir | Enlargement | 7,000 | Unknown | Unknown | | | >5 residences impacted |
| 78 | Big Kammerzell Reservoir | Enlargement | 215,000 | Unknown | Unknown | | | |
| 40 | Big Windsor Reservoir | Enlargement | 29,200 | Unknown | Unknown | | | |
| 56 | Boulder Reservoir | Enlargement | 11,000 | Unknown | Unknown | | | |
| 46 | Carter Lake Reservoir | Enlargement | 108,400 | Unknown | Unknown | | | |
| 45 | Chimney Hollow Pond | Enlargement | 65,500 | Unknown | Unknown | | | |
| 25 | Cobb Lake | Enlargement | 39,500 | Unknown | Unknown | | | >5 residences impacted |
| 26 | Douglass Reservoir | Enlargement | 53,400 | Unknown | Unknown | | | >5 residences impacted |
| 8 | Empire Reservoir | Rehabilitation | 2,779 | Unknown | Unknown | | Yes | |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 59 | Foothills Reservoir | Enlargement | 4,260 | Unknown | Unknown | | | |
| 68 | Foster Reservoir | Enlargement | 3,500 | Unknown | Unknown | | | |
| 54 | Gold Lake | Enlargement | 400 | Unknown | Unknown | | | |
| 50 | Great Western Reservoir | Enlargement | 18,400 | Unknown | Unknown | | | |
| 47 | Green Ridge Glade Reservoir | Enlargement | 5,440 | Unknown | Unknown | | | Pursued by City of Loveland |
| 71 | Gross Reservoir | Enlargement | 72,000 | No | Unknown | | | |
| 27 | Halligan Reservoir | Enlargement | 15,000 | No | Unknown | Yes | | Subject of current EIS by City of Fort Collins |
| 43 | Hertha Reservoir | Enlargement | 74,300 | Unknown | Unknown | | | |
| 55 | Highland Reservoir Number 2 | Enlargement | 3,300 | Unknown | Unknown | | | |
| 87 | Hilsboro Reservoir | Enlargement | 5,000 | Unknown | Unknown | | | |
| 22 | Horsetooth Reservoir | Enlargement | | Unknown | Unknown | | | |
| 79 | Howlet Reservoir | New Site | 4,000 | Unknown | Unknown | | | |
| 73 | Idaho Springs Reservoir | Enlargement | 950 | Unknown | Unknown | | | |
| 2 | Julesburg Reservoir | Enlargement | 21,900 | Unknown | Unknown | | Yes | |
| 80 | Julesburg Reservoir | Rehabilitation | 5,700 | Unknown | Unknown | | Yes | |
| 81 | Klug Reservoir | Enlargement | | Unknown | Unknown | | Yes | |
| 53 | Left Hand Valley Reservoir | Enlargement | 3,000 | Unknown | Unknown | | | >5 residences impacted |
| 82 | Little Kammerzell Reservoir | Enlargement | 6,964 | Unknown | Unknown | | | |
| 83 | Lower Latham Reservoir | Enlargement | | Unknown | Unknown | | | |
| 70 | Marshall Lake | Enlargement | 15,200 | Unknown | Unknown | | | |
| 60 | McIntosh Lake | Enlargement | 1,500 | Unknown | Unknown | | | Significant impact on existing residences |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 51 | Milton Reservoir | Enlargement | 72,000 | Unknown | Unknown | | | |
| 84 | Mose Davis Reservoir | Enlargement | 3,600 | Unknown | Unknown | | | |
| 24 | North Poudre Reservoir Number 5 and 6 | Enlargement | 48,470 | Unknown | Unknown | | | >5 residences impacted |
| 44 | Pinewood Springs Reservoir | Enlargement | 2,740 | Unknown | Unknown | | | |
| 1 | Prewitt Reservoir | Rehabilitation | 4,634 | Yes | Unknown | | Yes | Info updated on 2/9/17 based on email conversation with Jim Yahn (jim@northsterling.org) |
| 58 | Ralph Price/Button Rock Reservoir | Enlargement | 12,500 | Unknown | Unknown | | | |
| 74 | Ralston Reservoir | Enlargement | 4,800 | Unknown | Unknown | | | |
| 10 | Riverside Reservoir | Rehabilitation | 2,500 | Unknown | Unknown | | Yes | |
| 28 | Seaman Reservoir | Enlargement | 38,000 | Unknown | Unknown | Yes | | Subject of current EIS by City of Greeley. Possibility for enlargement of 120,000 ac-ft, but would require new dam at that size |
| 69 | Silver Lake | Enlargement | 5,000 | Unknown | Unknown | | | |
| 85 | Spomer Reservoir | Enlargement | 5,000 | Unknown | Unknown | | | |
| 57 | Terry Lake (Pleasant Valley) | Enlargement | 4,000 | Unknown | Unknown | | | >5 residences impacted |
| 86 | Thomas Reservoir | Enlargement | 10,200 | Unknown | Unknown | | | |
| 21 | Trap Lake | Enlargement | 5,600 | Unknown | Unknown | | | |
| 5 | Wildcat Reservoir | New Site | 60,000 | Unknown | Unknown | | Yes | |
| 11 | Willow Creek Reservoir | Enlargement | 32,000 | Unknown | Unknown | | Yes | |
| Primary Source: Northern Integrated Supply Project Phase II Alternative Evaluation | | | | | | | | |
| 61 | Antelope Park | New Site | 7,000 | Unknown | Unknown | | | |

## Table 3. Potential Surface Storage Sites in the South Platte Basin

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 48 | Berts Corner | New Site | 10,000 | Unknown | Unknown | | | |
| 41 | Black Hollow Reservoir | New Site | 10,700 | Unknown | Unknown | | | |
| 31 | Box Elder | New Site | 20,300 | Unknown | Unknown | | | |
| 72 | Broomfield | New Site | 21,900 | Unknown | Unknown | | | Designed by City of Broomfield |
| 66 | Buckingham | New Site | 35,000 | Unknown | Unknown | | | |
| 42 | Cactus Hill | New Site | 104,071 | Unknown | Unknown | | | |
| 32 | Calloway Hill | New Site | 63,000 | Unknown | Unknown | | | |
| 49 | Chimney Hollow | New Site | 110,000 | No | Unknown | | | |
| 18 | Galeton Reservoir | New Site | 80,000 | No | No | | Yes | Subject of current EIS by Northern Water |
| 34 | Glade East | New Site | 303,000 | No | Unknown | | | Subject of current EIS by Northern Water |
| 33 | Glade West | New Site | 303,000 | No | Unknown | | | Subject of current EIS by Northern Water |
| 36 | Grey Mountain | New Site | 204,000 | Unknown | Unknown | | | |
| 9 | Hardin Reservoir | New Site | 400,000 | Unknown | Unknown | | Yes | |
| 12 | Horse Creek Reservoir | Enlargement | 60,000 | Unknown | Unknown | | Yes | |
| 63 | Little Narrows | New Site | 23,000 | Unknown | Unknown | | | |
| 13 | Lone Tree Creek | New Site | 14,000 | Unknown | Unknown | | | |
| 64 | Lykins Gulch | New Site | 20,000 | Unknown | Unknown | | | |
| 17 | Point of Rocks Reservoir | New Site | 224,000 | Unknown | Unknown | | Yes | |
| 35 | Portal | New Site | 310,000 | Unknown | Unknown | | | |
| 37 | Poudre | New Site | 143,000 | Unknown | Unknown | | | |
| 30 | Rawhide Creek | New Site | 30,300 | Unknown | Unknown | | | |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| 29 | Rawhide North | New Site | 140,000 | Unknown | Unknown | | | |
| 39 | Rockwell | New Site | 39,000 | Unknown | Unknown | | | |
| 16 | Sandborn Reservoir | New Site | 224,000 | Unknown | Unknown | | Yes | |
| 62 | Smithy Mountain | Enlargement | 73,800 | Unknown | Unknown | | | |
| 6 | South Platte (Narrows) Reservoir | New Site | 1,960,000 | Unknown | Unknown | | Yes | |
| 14 | Spring Creek | New Site | 27,500 | Unknown | Unknown | | | |
| 65 | Table Mountain | New Site | 5,000 | Unknown | Unknown | | | |
| 38 | Trailhead | New Site | 24,200 | Unknown | Unknown | | | |
| 15 | Weld | New Site | 1,962,000 | Unknown | Unknown | | Yes | |
| Primary Source: Northern Integrated Supply Project Technical Memorandum 5E Upper Saint Vrain Yield Analysis | | | | | | | | |
| 244 | Coffintop Reservoir | New Site | 115,900 | Unknown | Unknown | | | |
| Primary Source: Ovid Reservoir and Dam Preliminary Design Report | | | | | | | | |
| 186 | Ovid Reservoir | New Site | 7,700 | Unknown | Unknown | | Yes | Can be built at 11,100 ac-ft capacity with a ring dike and excavation |
| Primary Source: Pawnee Creek Flood Control Project - Phase 1 Project Scoping Report | | | | | | | | |
| 202 | P3 | New Site | 50,700 | Unknown | Unknown | | Yes | |
| 204 | P6 | New Site | 10,900 | Unknown | Unknown | | Yes | |
| 205 | P7 | New Site | 15,400 | Unknown | Unknown | | Yes | |
| 203 | W-NP2 | New Site | 24,400 | Unknown | Unknown | | Yes | |
| Primary Source: Preliminary Conceptual Plan for Proposed Pawnee Pass Dam and Reservoir in Logan County Colorado | | | | | | | | |
| 200 | Pawnee Pass Dam | New Site | | Unknown | Unknown | | Yes | |

**Table 3. Potential Surface Storage Sites in the South Platte Basin**

| Site ID | Site Name | Category | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|---|
| Primary Source: South Wiggins Recharge Project | | | | | | | | |
| 111 | McCarthy Reservoir | Enlargement | 10,000 | Unknown | Unknown | | Yes | |

## Table 4. Potential Aquifer Storage Sites in the South Platte Basin

| Site ID | Site Name | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|
| Primary Source: 2015 South Platte Basin Surface Water Availability Analysis - Appendix G | | | | | | | |
| 131 | ASR Future Storage | | Unknown | Unknown | Yes | | |
| 132 | ASR Pilot Phase Storage | | Unknown | Unknown | Yes | | |
| Primary Source: Colorado Water Conservation Board SB-193 Underground Water Storage Study | | | | | | | |
| 176 | Arapahoe Confined - East | 690,000 | Unknown | Unknown | | Yes | |
| 150 | Arapahoe Confined - Northwest | 511,000 | Unknown | Unknown | | | |
| 152 | Arapahoe Confined - Southwest | 204,000 | Unknown | Unknown | | | |
| 177 | Arapahoe Unconfined - East | 324,000 | Unknown | Unknown | | Yes | |
| 153 | Arapahoe Unconfined - West | 324,000 | Unknown | Unknown | | | |
| 163 | Badger/Beaver Creek | 311,000 | Unknown | Unknown | | Yes | |
| 157 | Cache la Poudre River Basin | 291,000 | Unknown | Unknown | | | |
| 171 | Dawson Unconfined - East | 520,000 | Unknown | Unknown | | Yes | |
| 149 | Dawson Unconfined - West | 1,169,000 | Unknown | Unknown | | | |
| 173 | Denver Confined - East | 60,000 | Unknown | Unknown | | | |
| 172 | Denver Confined - West | 87,000 | Unknown | Unknown | | Yes | |
| 175 | Denver Unconfined - East | 770,000 | Unknown | Unknown | | Yes | |
| 174 | Denver Unconfined - West | 387,000 | Unknown | Unknown | | | |
| 179 | Laramie-Fox Hills Confined - East | 1,059,000 | Unknown | Unknown | | Yes | |
| 178 | Laramie-Fox Hills Confined - West | 900,000 | Unknown | Unknown | | Yes | |
| 181 | Laramie-Fox Hills Unconfined - East | 85,000 | Unknown | Unknown | | Yes | |
| 180 | Laramie-Fox Hills Unconfined - West | 122,000 | Unknown | Unknown | | | |

## Table 4. Potential Aquifer Storage Sites in the South Platte Basin

| Site ID | Site Name | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|
| 143 | Lower Beebe Draw/ Box Elder Creek | 61,000 | Unknown | Unknown | | | |
| 162 | Lower Bijou Creek | 1,067,000 | Unknown | Unknown | | Yes | |
| 141 | Lower Kiowa Creek | 806,000 | Unknown | Unknown | | Yes | |
| 139 | Lower Lost Creek | 157,000 | Unknown | Unknown | | Yes | |
| 151 | Ogallala - North | 89,412,000 | Unknown | Unknown | | | |
| 165 | South Platte River - Balzac to State Line | 890,000 | Unknown | Unknown | | Yes | |
| 155 | South Platte River - Denver Metro | 353,000 | Unknown | Unknown | | | |
| 142 | South Platte River - Fort Morgan Area | 968,000 | Unknown | Unknown | | Yes | |
| 164 | South Platte River - Fort Morgan to Balzac | 890,000 | Unknown | Unknown | | Yes | |
| 159 | South Platte River - Greeley to Fort Morgan | 94,000 | Unknown | Unknown | | Yes | |
| 156 | South Platte River - Metro to Greeley | 169,000 | Unknown | Unknown | | | |
| 166 | South Platte River - South Park | 899,000 | Unknown | Unknown | | | |
| 158 | Upper Beebe Draw/ Box Elder Creek | 268,000 | Unknown | Unknown | | Yes | |
| 161 | Upper Bijou Creek | 466,000 | Unknown | Unknown | | | |
| 160 | Upper Kiowa Creek | 234,000 | Unknown | Unknown | | Yes | |
| 140 | Upper Lost Creek | 1,260,000 | Unknown | Unknown | | Yes | |
| Primary Source: SPSS Project - CCWCD Interview Notes | | | | | | | |
| 207 | New Aquifer Storage Near Orchard Recharge Project | | Yes | Unknown | | Yes | Recharge project described with 100 cfs diversion form the South Platte River, with potential for aquifer storage partnerships |

**Table 4. Potential Aquifer Storage Sites in the South Platte Basin**

| Site ID | Site Name | Additional Storage (ac-ft) | Potential for Consumptive Partnerships | Potential for Non-Consumptive Partnerships | IPP | In Study Area | Notes |
|---|---|---|---|---|---|---|---|
| Primary Source: 2015 South Platte Basin Implementation Plan | | | | | | | |
| 245 | Bijou/Empire System ASR | | Unknown | Unknown | | Yes | |
| Primary Source: CDSS Reservoirs GIS Shapefile, Division 1 | | | | | | | |
| 290 | Aurora Underground Reservoir B | 920 | Unknown | Unknown | | | |
| 465 | West Wabash Underground Storage Structure | 110 | Unknown | Unknown | | | |
| Primary Source: South Wiggins Recharge Project | | | | | | | |
| 516 | South Wiggins Recharge Project | 24,000 | Unknown | Unknown | | Yes | |

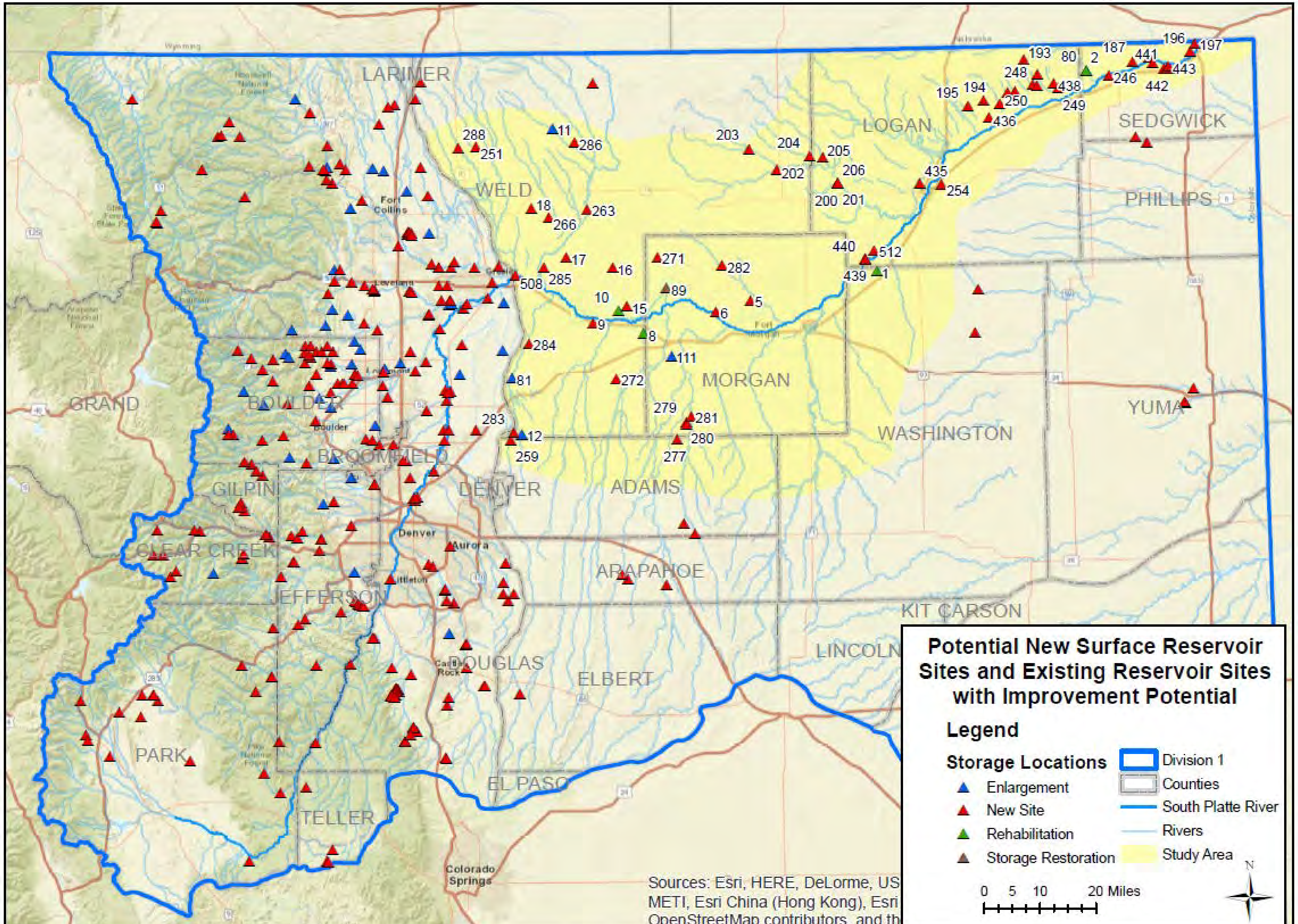


**Figure 1. Cataloged Sites Where New Surface Storage Could Be Developed in Division 1**

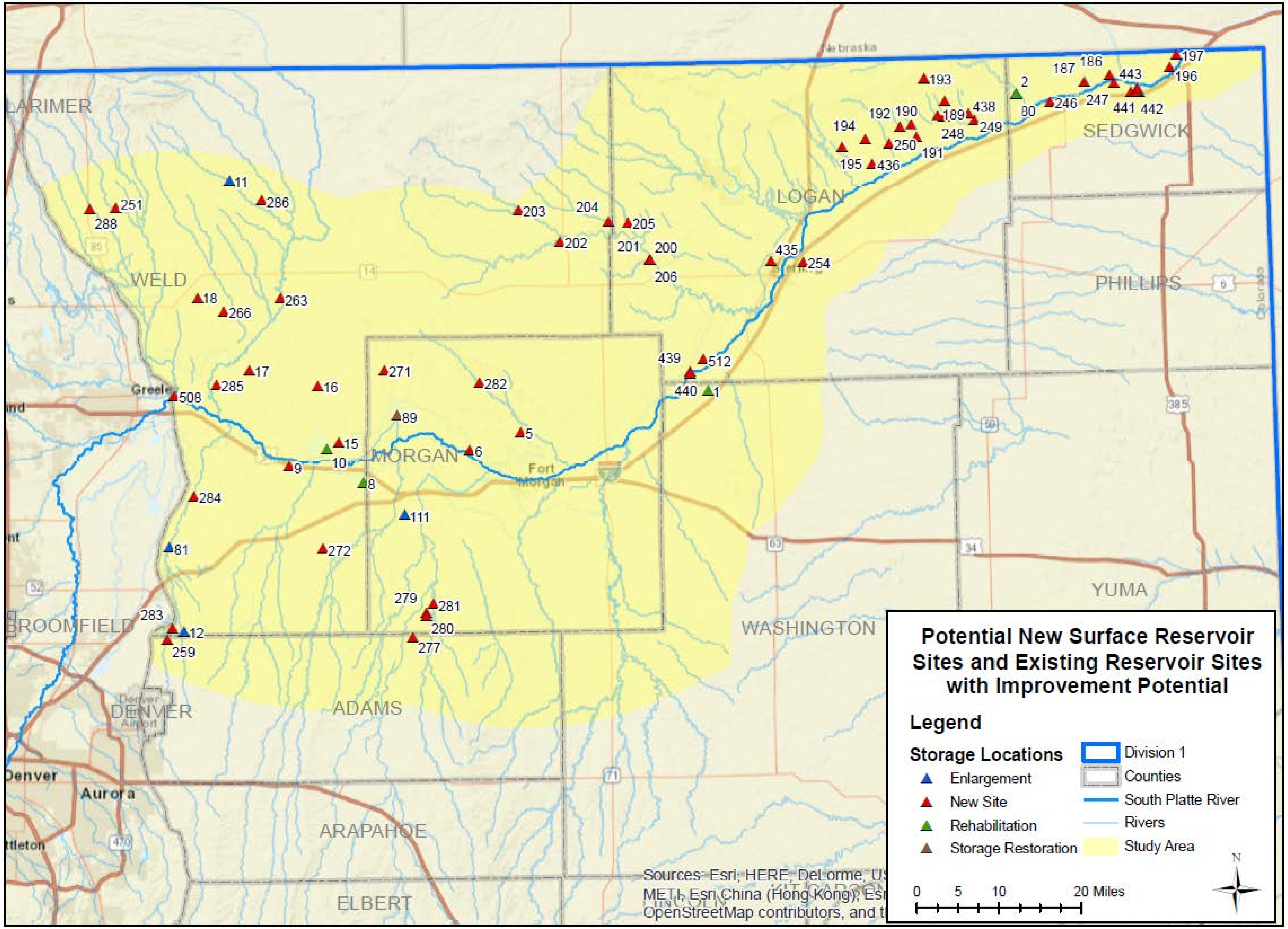


**Figure 2. Cataloged Sites Where New Surface Storage Could be Developed in the Study Area**

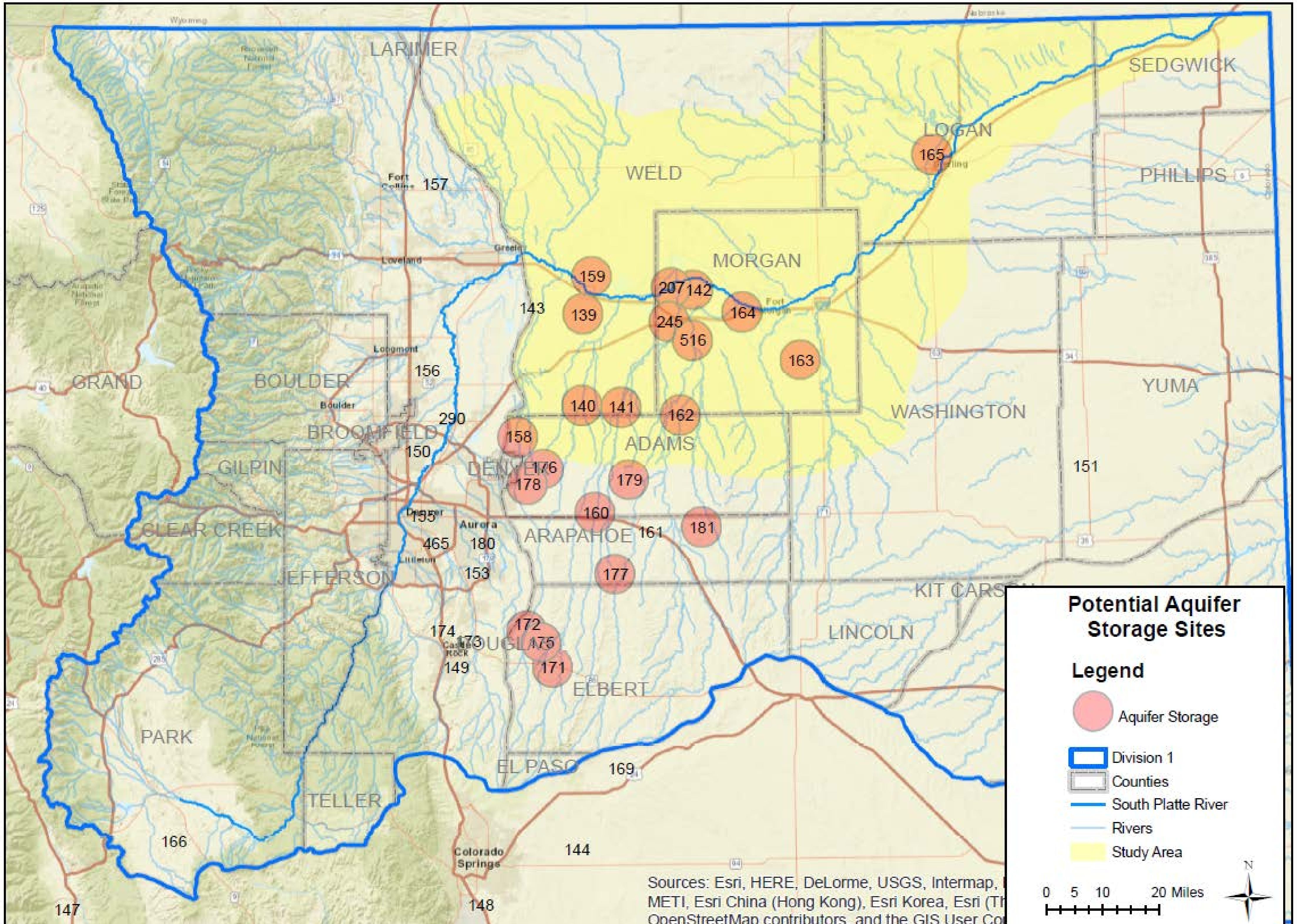


**Figure 3. Cataloged Aquifer Storage Sites in Division 1**

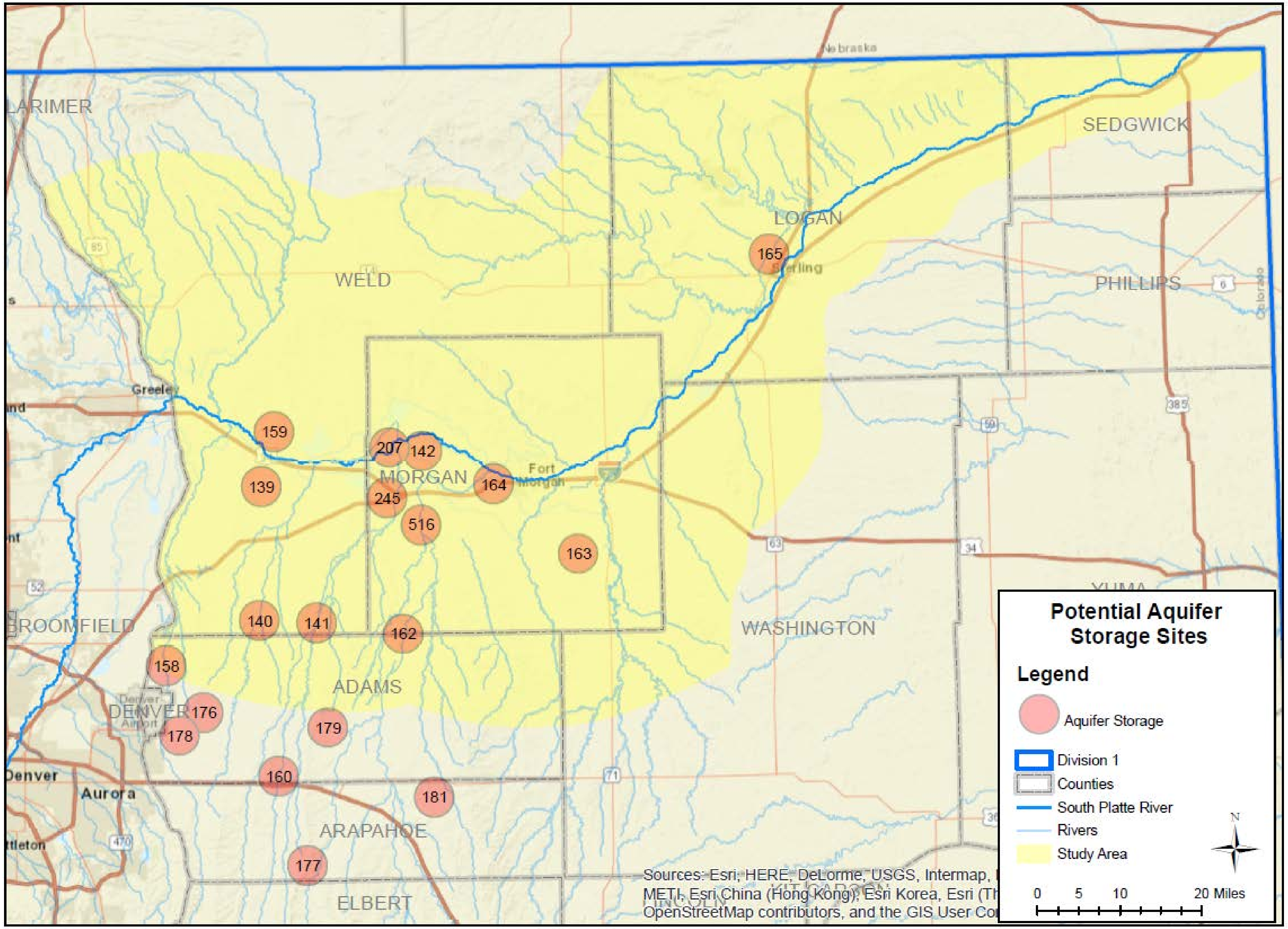


**Figure 4. Cataloged Aquifer Storage Sites in or Near the Study Area**

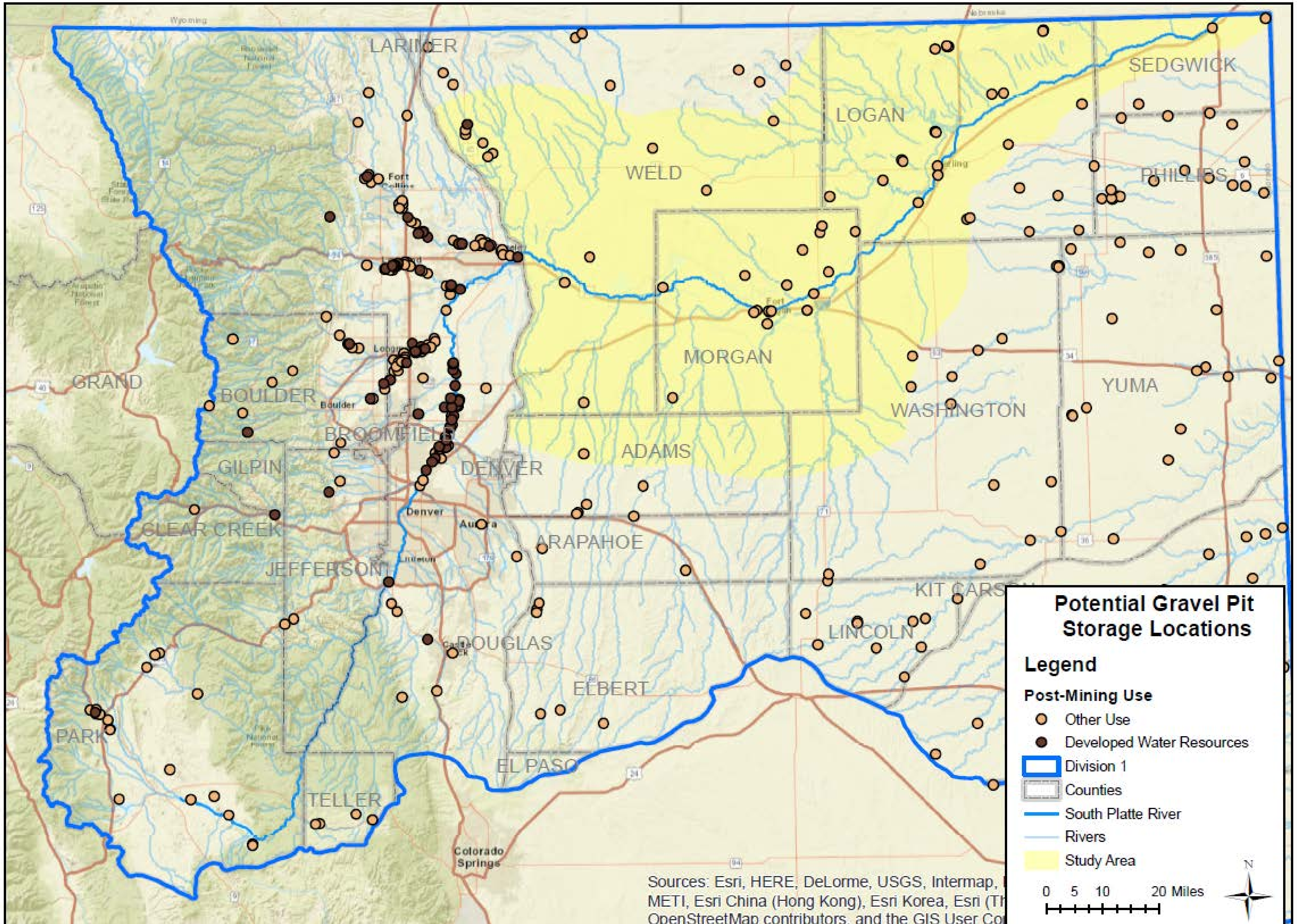


**Figure 5. Potential Gravel Pit Storage Sites in Division 1**

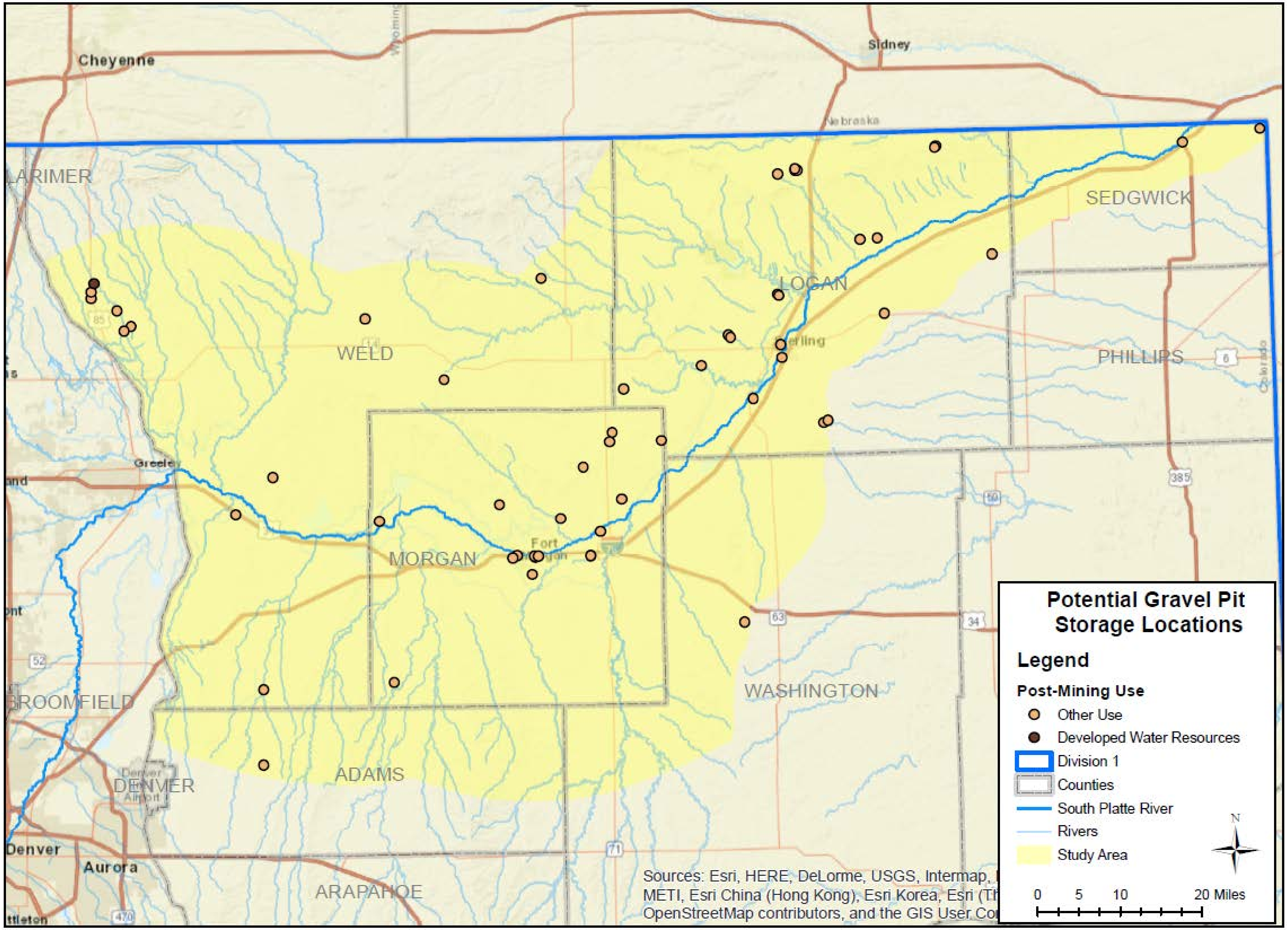


Figure 6. Potential Gravel Pit Storage Sites in the Study Area

# APPENDIX C – LEGAL AND REGULATORY REVIEW TM

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**SPSS Final Memorandum**

**To:** Chip Paulson, Enrique Triana, and Joshua Cowden - Stantec

**From:** Leonard Rice Engineers

**Date:** November 30, 2017

**Subject:** Literature Review for South Platte Storage Study

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Leonard Rice Engineers, Inc. ("LRE"), has performed a high level review of the legal framework that may impact the South Platte Storage Study ("SPSS") being performed in connection with HB-1256 2016. According to HB-1256-2016, the legislature is interested in computing the amount of water that could have been stored in the South Platte Basin in Colorado but rather went down stream to Nebraska. This interest appears to be focused on storm flows, excess runoff, and other water events wherein current water rights are being fulfilled and excess water is available that can then be stored for future use (hereinafter the "Excess Water"). Under LRE's final Scope of Work we were tasked to review and provide a written description of applicable laws and agreements that will affect the estimation of storable water in the South Platte, including the 1928 South Platte River Compact required flows, constraints associated with Platte River Recovery Implementation Program (PRRIP), Tamarack recharge credits, augmentation plans, groundwater pumping administration, and the Rules and Regulations for the Management and Control of Designated Ground Water.

The following memorandum summarizes the major federal, state, and local legal and administrative factors that impact the ability to divert and store excess water and therefore, should be considered in the planning and permitting of any future water storage project within the South Platte drainage. In addition to the factors summarized below, there are additional federal, state, and local legal and administrative factors that may apply to the environmental, land use, construction, and operation components of a future water storage project. These additional legal and administrative factors will be considered in the later phases of the project.

## Federal

Depending on the type of storage project identified, the following Federal factors may influence the ability to divert and store excess water.

1. South Platte River Compact (C.R.S. § 37-65-101)
2. Endangered Species Act – Section 7 Consultation (ESA Section 7))
3. Platte River Recovery Implementation Program (PRRIP)

### ***South Platte River Compact (C.R.S. § 37-65-101)***

- **a.** Between Nebraska and Colorado
- **b.** Signed April 23, 1923
- **c.** Within Colorado there are two sections of the South Platte River
    - **i.** Upper Section west of the intersection of the river and the Washington County Line

   - **ii.** Lower Section which is east of the intersection of the river and the Washington County Line downstream to the intersection of the river and the State line.
- **d.** Interstate Station is a gauging station near Julesburg Colorado above the Western Irrigation District of Nebraska canal diversion.
   - **i.** Interstate Station is the gauging station to determine compliance with the compact (daily mean flow of 120 cfs between April 1 and October 15)[1]
- **e.** Colorado shall not permit diversions in the Lower Section between April 1 and October 15 to supply Colorado appropriators with priority subsequent to June 14, 1897 if said diversions will diminish flow at the Interstate Station below the daily mean of 120 cfs.
- **f.** Colorado may use all the waters of the river flowing within Colorado during October 15 and April 1 of the next year[2]
- **g.** Colorado shall have the right to all diversions in the Upper Section.

Between April 1 and October 15 the water right owners in Water District 64 collectively strive to keep the daily mean flow at the Interstate Station at or above 120 cfs thereby preventing the June 14, 1897 Compact call. If the Compact call is in effect, water rights junior to June 14, 1897 are not diverting in the Lower Section, and augmentation plans are being operated in accordance with decrees, Colorado is considered acting in compliance with the terms and condition of the South Platte Compact[3]. When Colorado is active in compliance with the South Platte Compact, and flow at the Interstate Station is still less than 120 cfs, Colorado is not obligated to deliver water to the South Platte River.

Under the South Platte River Compact there is the opportunity to capture and use of the 35,000 acre-feet of water that may be available during October 15 and April 1 of the next year under the South Platte River Compact. Under the South Platte River Compact Article VI, Paragraph 2(a), Colorado has reserved the right to store, use and to have in storage in readiness for use on and after April 1 each year an aggregate of 35,000 acre-feet of water to be diverted from the river in the Lower Section between October 15 and April 1. Further discussion needs to occur as to whether (i) the state of Colorado has ever diverted South Platte River water under this provision of the compact, (ii) the PRRIP is affected by this diversion, and (iii) if able to be diverted where would/could the water be stored and how would/could this water be used in the future.

***Endangered Species Act – Section 7 Consultation (ESA Section 7) and Platte River Recovery Implementation Program ("PRRIP")***

If an action or project, that has a federal nexus, is likely to adversely affect any listed endangered or threatened species, a Section 7 consultation under the Endangered Species Act (ESA) will be required. Since 1978, the U.S. Fish and Wildlife Service (the "Service") has consistently found,

[1] This flow is subject to variable climatic conditions and other conditions that may affect the daily flow in a minor way.
[2] The use of this water is subject to Article VI which allows Nebraska to divert 500 cfs through the Perkins County Canal during this time so long as water is available after Colorado meets all diversions in the Upper Section, meets all diversions in the Lower Section with a priority date before December 17, 1921, and satisfies the removal of 35, 000 acre-feet of water to storage.
[3] Per conversation with Water Division 1 Engineer Dave Nettles.

through formal ESA Section 7 consultations with Federal agencies, that federal actions resulting in depletions to flows in the Platte River system are likely to jeopardize the continued existence of one or more federally-listed threatened or endangered species and adversely modify critical habitat.[4]

In 2006, a landmark agreement was signed between the governors of Colorado, Nebraska, and Wyoming and the U.S. Secretary of the Interior (the "Interior") to implement a basin-wide Platte River Recovery Implementation Program (the "PRRIP Program"). The purpose of the PRRIP Program is to provide streamlined ESA compliance for water users in the Platte River basin. The PRRIP Program went into effect on January 1, 2007.

Colorado's plan under the agreement and the PRRIP Program is to account for depletions within the South Platte drainage for water-related activities implemented prior to July 1, 1997 (Existing water related activities) and to identify mechanisms to allow the implementation of water-related activities after July 1, 1997 (New water-related projects). Colorado is meeting its obligations under the plan through re-regulating flows of water within the South Platte River west of the state line with Nebraska. This is done on the Tamarack Ranch and Pony Express State Wildlife Areas.[5] The operator of the State Wildlife Areas is the Colorado Department of Wildlife, but through an MOU, the South Platte Water Related Activities Program, Inc. ("SPWRAP") is responsible for the operational costs.

While compliance with the Program is the burden of the State of Colorado, the SPWRAP is the non-profit entity that assists the state in compliance with the Program. Under the Colorado plan, all existing water-related activities are covered including irrigation wells that were augmented prior to June 30, 1997. Moreover, new water-related activities will be covered by the plan so long as the new project is (i) operated on behalf of Colorado water users; (ii) does not involve a major on-stream reservoir (greater than 2,000 acre-feet[6]) located on the mainstem of the South Platte anywhere downstream of Denver; (iii) not a hydropower diversion/return project anywhere downstream of Denver; and (iv) within the average annual water supply of 98,010 acre-feet to serve Colorado's population increase during February through July. Per the PRRIP Program definition of Major On-Stream Reservoirs, reservoirs, including gravel pit reservoirs, adjacent to the main stem of the South Platte River and reservoirs on tributaries to the South Platte River are not considered to be located on the "mainstem[7]."

To be covered by the plan, the participant must comply with the SPWRAP's member criteria, which includes applying for and paying for corresponding assessments. Standardized reporting forms are available to help prospective members calculate corresponding assessments. These assessments reflect the costs of operating this non-profit corporation. SPWRAP's first year of

[4] Information review at www.platteriver.org.
[5] See Colorado's Initial Water Project (Tamarack I), December 7, 2005, Colorado's Plan for Future Depletions (Tamarack II), October 24, 2006, Updated December 1, 2015, Memorandum of Understanding (MOU) for the Planning, Development and Operation of the Managed Groundwater Recharge Facilities on the State Wildlife Areas in the Lower South Platte River (March 19, 2009).
[6] PRRIP Attachment 5, Section 9, Colorado's Plan for Future Depletions. October 24, 2006, Updated December 1, 2015.
[7] Id.

operation was 2007. Project proponents can become members immediately, or at a future date. However, entities that become members in later years will be assessed at a rate that addresses SPWRAP costs from Year 1.[8]

Once an entity becomes a member of SPWRAP, Colorado's plan will cover a project that involves a Federal nexus. The entity (the member of SPWRAP) will work with the federal agency(s) involved and file a request for formal Section 7 consultation. This process will be streamlined and the FWS will issue a Tiered Biological Opinion authorizing the project if the aforementioned criteria are met. If an entity is not covered by SPWRAP (the aforementioned criteria are not met) then the entity must still comply with Section 7 of the ESA and develop a stand-alone biological opinion addressing the incremental effects associated with the individual project. This can be laborious, time consuming, and very expensive.

Item for Further Consideration: It is unclear whether or not projects within the designated basins of the South Platte River drainage that have a federal nexus are included under the PRRIP. If designated basins are excluded from the South Platte River drainage and therefore excluded under the PRRIP, compliance with Section 7 of the Endangered Species Act may not be possible under the SPWRAP framework.

## State

In addition to meeting the federal issues outlined above, the following state laws and guidelines will need to be complied with for new projects within the South Platte River basin.

1. Water Right Determination and Administration Act (C.R.S. § 37-92)
2. Reservoirs (C.R.S. § 37-87)
3. Colorado Groundwater Management Act (C.R.S. § 37-90)
4. Rules and Regulations for the Management and Control of Designated Ground Water (2 C.C.R. 410-1.)
5. Proposed changes to Designated Basin Rules 5.6 and 5.8. (12/23/2016 Draft)
6. Denver Basin Artificial Recharge Extraction Rules (2 C.C.R. 402-11)
    a. Denver Basin Rules (2 C.C.R. 402-6)
    b. Statewide Nontributary Ground Water Rules (2 C.C.R. 402-7)
7. Supreme Court Rulings – *Bd. Of County Comm'rs v. Park County Sportsman's Ranch , LLP*, 45 P.3d 693 (Colo. 2002)[Listing the conditions that the owner of an underground storage project would have to prove to establish a right in water court]
8. Operation and Accounting for Porosity Storage Reservoirs – State Engineer Guideline found at http://water.state.co.us/SurfaceWater/SWRights/Pages/default.aspx
9. Administrative Statement Regarding the Management of Storm Water Detention Facilities and Post-Wildland Fire Facilities in Colorado February 11, 2016. Found at http://water.state.co.us/DWRIPub/Documents/DWR%20Storm%20Water%20Statement.pdf

[8] The basis for annual assessments, and corresponding reporting forms are available via the SPWRAP Website (www.spwrap.org).

The following section highlights key elements of the above mentioned State laws and guidelines.

***Water Right Determination and Administration Act (C.R.S. § 37-92)***

Under the State of Colorado Constitution of 1876, Article XVI outlines that water within the borders of the state is the property of the state to be used by the citizens of the state. Moreover, the Constitution provides the backbone of the prior appropriation system (first in time, first in right). Presently, the provisions of the Constitution are codified in the Water Right Determination and Administration Act (C.R.S. § 37-92), which was passed by the Colorado Legislature in 1969. Under this legislation water courts and water referees were established and their functions defined. It is the water courts that adjudicate new water rights (including storage rights) and approve permanent changes to water rights.[9] Furthermore, duties of the State Engineer as administrator of water within the state was clarified. This legislation also set forth augmentation plans to replace out of priority depletions (protecting senior rights from junior diversions), the relationship between groundwater and surface water in the state, key definitions regarding water administration, and the establishment of water divisions and division engineers.[10]

With respect to "storage," the Water Right Determination and Administration Act defines "storage" as "the impoundment, possession, and control of water by means of a dam."[11] A water storage right is almost always confirmed by a court decree. The basic elements of a water storage right include:

1) Identification of a structure where the water is stored;
2) An annual amount of storage (normally expressed in acre-feet), which, in modern decrees, includes active and dead storage, exposed surface acreage and fill rate;
3) A legal description of the axis of the dam;
4) Identification of the point of diversion from the stream or tributary from which the storage water is diverted, including the means of conveyance by ditch or pipeline if this is an off-channel reservoir;
5) A priority date for purposes of administration; and
6) Often, there are limitations on type and place of use; such as a description of the lands or a location where the stored water may be used after impoundment.[12]

A water storage right, like any other water right, can be changed, but the applicant risks re-quantification of the water right based upon historical and legal usage limitations applied after the fact.[13]

Underground storage outside the boundary of a designated ground water basin is also recognized under Colorado law if such water is placed in an aquifer "by other than natural means" by an

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[9] The State Engineer has certain powers to issue Substitute Water Supply Plans (C.R.S. § 37-92-308),

[10] Section 37-92 is a complex statue that covers more than the issues listed. This literature review is intended to outline the applicable laws, rules and policy that would affect new storage in the South Platte. Additional legal and technical analysis will be required.

[11] C.R.S. § 37-92-103(10.8).

[12] *Id.*

[13] *Id.*

application with a right.[14] This definition was reviewed by the Sportsman's Ranch II Supreme Court to determine what conditions an owner of an underground storage project would have to prove to establish a storage right. As the Court noted, an owner must:

1) Capture, possess, and control the water it intends to put into the aquifer;
2) Not injure other water use rights, either surface or underground, by appropriating the water for recharge;
3) Not injure water use rights, either surface or underground, as a result of recharging the aquifer and storing water in it;
4) Show that the aquifer is capable of accommodating the stored water without injuring other water use rights;
5) Show that the storage will not tortiously interfere with overlying landowners' use and enjoyment of their property;
6) Not physically invade the property of another by activities such as directional drilling, or occupancy by recharge structures or extraction wells, without proceeding under the procedures for eminent domain;
7) Have the intent and ability to recapture and use the stored water; and
8) Have an accurate means for measuring and accounting for the water stored and extracted from storage in the aquifer.15

***C.R.S. Section 37-87, Reservoirs***
C.R.S. § 37-87 addresses the construction of reservoirs, inspections of reservoirs, and enforcement for violations. These statutory obligations generally apply after the planning phase of a reservoir project. Therefore, a study to determine the ability to divert and store excess water would not be impacted by these obligations.

Underground aquifers are not considered reservoirs within the meaning of C.R.S. § 37-87 except to the extent such aquifers are filled by other than natural means with water diverted under a conditional or decreed right. As such, aspects of C.R.S. § 37-87 could apply to the construction and operation of alternative storage mechanisms that utilize underground aquifers.

***Colorado Groundwater Management Act (C.R.S. § 37-90), Rules and Regulations for the Management and Control of Designated Ground Water (2 C.C.R. 410-1), and Proposed Changes to Designated Basin Rules 5.6 and 5.8***
The Colorado Groundwater Management Act ("GMA") created designated ground water, the Colorado Ground Water Commission ("Commission"), ground water management districts for local control and management of designated ground water, and a statutory scheme to allocate and administer designated ground water.

Under Colorado law there are four (4) types of groundwater; tributary groundwater, nontributary groundwater, Denver Basin groundwater, and designated groundwater.

[14] C.R.S. § 37-92-103(10.8).
[15] *Bd. of County Comm'rs v. Park County Sportsman's Ranch, LLP*, 45 P.3d 693, 705, n. 19 (Colo. 2002) (*Sportsman's Ranch II*)

Designated ground water is a separate and unique resource that has been created by the General Assembly.[16] Designated ground water is not considered "nontributary" ground water, as is commonly misunderstood.[17] The GMA defines designated ground water as:

> [g]round water which in its natural course would not be available to and required for the fulfillment of decreed surface rights, or ground water in areas not adjacent to a continuously flowing natural stream wherein ground water withdrawals have constituted the principal water usage for at least fifteen years preceding the date of the first hearing on the proposed designation of the basin, and which in both cases is within the geographic boundaries of a designated ground water basin.
>
> "Designated ground water" shall not include any ground water within the Dawson-Arkose, Denver, Arapahoe, or Laramie-Fox Hills formation located outside the boundaries of any designated ground water basin that was in existence on January 1, 1983.[18]

The statutes, rules, and regulations of the commission and the local district govern the allocation and administration of designated ground water. Once the Commission designates a basin under its statutory authority, the ground water within that basin typically all becomes designated ground water.[19] For example, within the South Platte drainage designated basins of interest in this phase of the SPSS project (i.e., Lost Creek, Kiowa-Bijou, Upper Crow Creek, and Camp Creek), numerous ground water aquifers exist below each designated basin boundary. While all of these different aquifers are different sources of ground water, they are all collectively referred to as designated ground water and are regulated under the GMA and the Commission Rules. This concept is important because within its statutory authority, the Commission can define how each specific source should be allocated and administered.[20]

Under the current Rules and Regulations for Management and Control of Designated Ground Water, Aquifer Storage and Recovery (ASR) is not expressly allowed. Rule 5.8 currently allows for the practice of artificial recharge in the designated basins, however, the rule is general in nature and makes the application unclear. The Commission is currently evaluating whether to remove Rule 5.8 and expand Rule 5.6, the Replacement Plan rule, to allow for ASR. With the proposed rule changes, the Commission is proposing that ASR within the designated basins would operate as a

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[16] *See Goss*, 993 P.2d at 1182-83.

[17] While the Denver Basin aquifers encompass both designated and non-designated ground water, Denver Basin ground water within the boundaries of a designated basin is still designated ground water and should not be confused with nontributary ground water, which, pursuant to a 2000 Colorado Supreme Court decision, is a separate category of ground water. *See Upper Black Squirrel Creek Groundwater Mgmt. Dist. v. Goss*, 993 P.2d 1177, 1182 (Colo. 2000).

[18] C.R.S. § 37-90-103(6).

[19] *See* C.R.S. § 37-90-106. The designation of a basin is premised on a designated basin geological and hydrogeological report. This report would be the basis of designating the basin, and in this author's experience, all the aquifers within each designated basin to date are considered designated ground water.

[20] For a detailed analysis of designated ground water please refer to William H. Fronczak, "Designated Groundwater: Colorado's Unique Way of Administering its Underground Resources," 7 *U. Denv. Water L. Rev*. 111 (Fall 2004) and *Colorado Water law Benchbook,* Second Ed. (Carrie l. Ciliberto and Timothy J. Flanagan eds., CLE in Colo., Inc. 2016) Chap. 8 Designated Basins.

replacement plan subject to the general replacement plan criteria and specific criteria for alluvial, bedrock, and Denver Basin aquifers.

Water that is withdrawn and exported out of a designated basin as designated ground water is considered fully consumable and can be used and reused to extinction once exported. The current Rules and Regulations for Management and Control of Designated Ground Water are not explicit as to the nature of free river water that is diverted from the South Platte River and placed in the designated basin for later withdrawal and export.

***Denver Basin Artificial Recharge Extraction Rules***

In 1995 the State Engineer, pursuant to statutory authority, promulgated the Denver Basin Artificial Recharge Extraction Rules (2 C.C.R. 402-11). These rules work together with the Denver Basin Rule and the Statewide Non-Tributary Rules regarding the placement of water into and the extraction of such placed water out of unconfined and confined aquifers within the Denver Basin aquifers outside the boundaries of a designated basin. These rules do expressly allow for the practice of ASR within the Denver Basin. The Denver Basin and Statewide Non-Tributary Rules are referenced in the Denver Basin Artificial Recharge Extraction Rules because cylinders of appropriation, existing withdrawals, and new withdrawals of naturally occurring groundwater out of the Denver Basin may occur as a part of or in addition to the artificial recharge.

***State Engineer Administrative Guidelines and Statements***

Two guidelines were reviewed that would have a potential impact on storage either above or below ground within the South Platte Drainage. The first is a State Engineer Guideline regarding the Operation and Accounting for Porosity Storage Reservoirs and the second is an Administrative Statement Regarding the Management of Storm Water Detention Facilities and Post-Wildland Fire Facilities in Colorado February 11, 2016.

Porosity Storage Reservoirs are a defined term for vessels that store water underground in shallow alluvial deposits that are intentionally isolated from the surrounding alluvial deposits. The preferred method of containment is with the use of slurry walls (i.e. City of Aurora Prairie Waters Project). The difference with porosity storage, compared to gravel pit storage, is that the material within the slurry walls is not mined and the natural alluvial deposit is used as the storage media. Benefits of porosity storage includes (i) elimination of evaporative losses associated with traditional storage reservoirs, (ii) use of the alluvial material as a filter media; (iii) minimal impact to overlying land; and (iv) isolation of the water stored from the surrounding aquifer and streams. Porosity Storage has been recognized by the State Engineer and allows complete use of the stored water without impacting the surrounding water systems or natural habitats. The State has developed guidelines for the operation and accounting required for these vessels. These guidelines for operation and accounting would have minimal impact at the planning level of this study.

The State previously administered storm water detention facilities pursuant to the 2011 "Administrative Approach for Storm Water Management." However, in 2015 the Colorado Legislature passed Senate Bill 15-212, which directs administrative requirements for storm water management.[21] Essentially this statute, as referenced and explained in the Administrative Statement Regarding the Management of Storm Water Detention Facilities and Post-Wildland Fire Facilities in Colorado, February 11, 2016 outlines the criteria that storm water detention facilities must meet to be exempt from administration under the Colorado water law. Since it is anticipated that the storage vessels contemplated under the SPSS would have to be administered under Colorado water law, these criteria most likely would not apply to a SPSS project.

## Local

The local regulations and laws (besides land use which is beyond the scope of this literature review) that would impact the SPSS would be (i) the Designated Basin Ground Water District Rules for the Lost Creek Designated Basin and the Kiowa-Bijou Designated Basin; and (ii) 1041 regulations.

### *Lost Creek Designated Basin Rules*

In addition to being controlled by the Rules and Regulations for Management and Control of Designated Ground Water, the use and management of designated groundwater within Lost Creek designated basin and Kiowa-Bijou designated basin is regulated by local regulations and laws specific to the basins.

The Regulations for the Use, Control and Conservation of Ground Water within the Lost Creek Ground Water Management District ("Lost Creek District)" were amended on March 28, 2013. These Regulations outline the Lost Creek Ground Water District Rules regarding issuance of new wells by the Commission, changes to existing wells, restrictions on replacement wells and exporting water outside the Lost Creek District, injection of water into the groundwater within the basin for recharge, and small capacity wells (less than 15 gallons per minute).

Of interest is Regulation 10 wherein the Lost Creek District outlines criteria for the "injection of water, gases, effluent, liquids or solid into any fresh water aquifer." The Lost Creek District prohibits such activity "except for fresh water recharge purposes approved by the Board of Directors of the Lost Creek District." The Lost Creek District requires that all such projects comply with the standards and procedures applicable to "Domestic Use-Quality" and "Agricultural Use-Quality" groundwater set forth in the then current Colorado Department of Public Health and Environment Water Quality Control Commission Regulation No. 41, "Basic Standards for Groundwater" (5 CCR 1002-41). The Lost Creek District also defines point or points of compliance for each recharge site or project as a monitoring well(s) in close proximity to the recharge site or project, as established by the district.

### *North Kiowa-Bijou Designated Basin Rules*

The Regulations for the Use, Control and Conservation of Ground Water within the North Kiowa Bijou Management District ("Kiowa-Bijou District") has similar regulations as to the Lost Creek District rules regarding issuance of new wells by the Commission, changes to existing wells,

[21] C.R.S. § 37-92-602(8).

restrictions on replacement wells and exporting water outside the Kiowa-Bijou District. However, these regulations do not address injection for recharge or small capacity wells.

***1041 Regulations***

The Colorado General Assembly enacted measures to further define the authority of state and local governments in making planning decisions for matters of statewide interest in 1974. The creation of 1041 regulations by state and local governments was approved in HB 74-1041 and is found in C.R.S. § 24-65.1-101. The purpose of the Act is to describe and designate areas and activities which may be of state interest and to encourage local governments to establish criteria for the administration of these areas and activities. Activities of state interest, as defined by Colorado Statute, may include, and are not limited to:

- Site selection and construction of major new domestic water and sewage treatment systems and major extension of existing domestic water and sewage treatment systems;
- Site selection and construction of major facilities of a public utility;
- Efficient utilization of municipal and industrial water projects;

The 1041 permit application process is extensive and includes the submission of detailed specifications concerning the affected environments and impacts of the proposed development.

As of the date of this memo, the local governments located within the SPSS study area known to have 1041 regulations in place include Adams County, Larimer County, Morgan County, and Weld County. A state or local government may choose to adopt 1041 regulations and guidelines for administration of matters of state interest at any time.

# APPENDIX D – HISTORICAL FLOW TM

NOTE: SOME OF THE INFORMATION IN THIS TM WAS CHANGED DURING PREPARATION OF THE FINAL REPORT

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# HB 1256 - South Platte Storage Study (SPSS)

MWH now part of Stantec

TECHNICAL MEMORANDUM

| | | | |
|---|---|---|---|
| To: | Joe Frank, Andy Moore<br>Lower South Platte Water Conservancy District, Colorado Water Conservation Board | From: | Chip Paulson, Samantha Mauzy<br>MWH Now Part of Stantec |
| Subject: | **Summary of South Platte River Historical Flow Leaving the State and Storable Water** | Date: | July 21, 2017 |

## INTRODUCTION

HB 16-1256, which authorized the South Platte Storage Study (SPSS), included a requirement to determine historical flow that could have been captured and stored in the South Platte River at the state line. Specifically, the Bill states:

> "The Board, in collaboration with the State Engineer, shall conduct or commission a hydrology study of the South Platte River Basin to estimate, for each of the previous twenty years, the volume of water that:
>
> i. Has been delivered to Nebraska in excess of the amount required to be delivered by the South Platte River Compact, Article 65 of this title; and
>
> ii. Could have otherwise been stored in the Lower South Platte River Basin."

The South Platte Point Flow Model was used to complete those two tasks. The Point Flow Model was updated for this study to include a 20-year period of daily flow records from 1996 to 2015. Details of the SPSS hydrologic analysis are provided in the "South Platte River Hydrologic Analysis TM".

## FINDINGS

Flow records and Point Flow Model results were analyzed at the South Platte River at Julesburg stream gage near the Nebraska state line to estimate: (1) physical flow in the river; and (2) water that could have been legally stored subject to South Platte River Compact requirements (referred to herein as "storable flow"). Storable flow is the maximum potential water that could have been stored by a reservoir on the mainstem of the South Platte River. Storable flow in an off-channel reservoir that would depend on diversions and conveyance facilities similar to the current lower basin reservoirs and irrigation canals would be significantly less.

Figure 1 displays annual historical flow for the 20 years from 1996 to 2015 that was delivered to Nebraska. It shows the physical flow in the river ("Water Leaving Colorado"), and the water leaving the state that could have been stored or put to beneficial use in Colorado ("Water Delivered to Nebraska in Excess of the Compact"). Figure 1 shows that physical and storable flow vary significantly from year to year. Table 1 gives selected statistics for physical flow leaving the state and storable flow at the Julesburg gage for the 20-year period from 1996 to 2015.

**Table 1. Historical Annual Flow for 1996-2015 at Nebraska State Line**

| Statistic | Physical Water Leaving Colorado (Julesburg gage) | Water Delivered to Nebraska in Excess of the Compact (Julesburg gage) |
|---|---|---|
| Annual Average (ac-ft/yr) | 436,000 | 397,000 |
| Annual Median (ac-ft/yr) | 331,000 | 293,000 |
| Minimum Year (ac-ft/yr) | 29,000 | 10,000 |
| Maximum Year (ac-ft/yr) | 1,957,000 | 1,904,000 |
| Total for 20-yr Period 1996-2015 (ac-ft) | 8,728,000 | 7,939,000 |

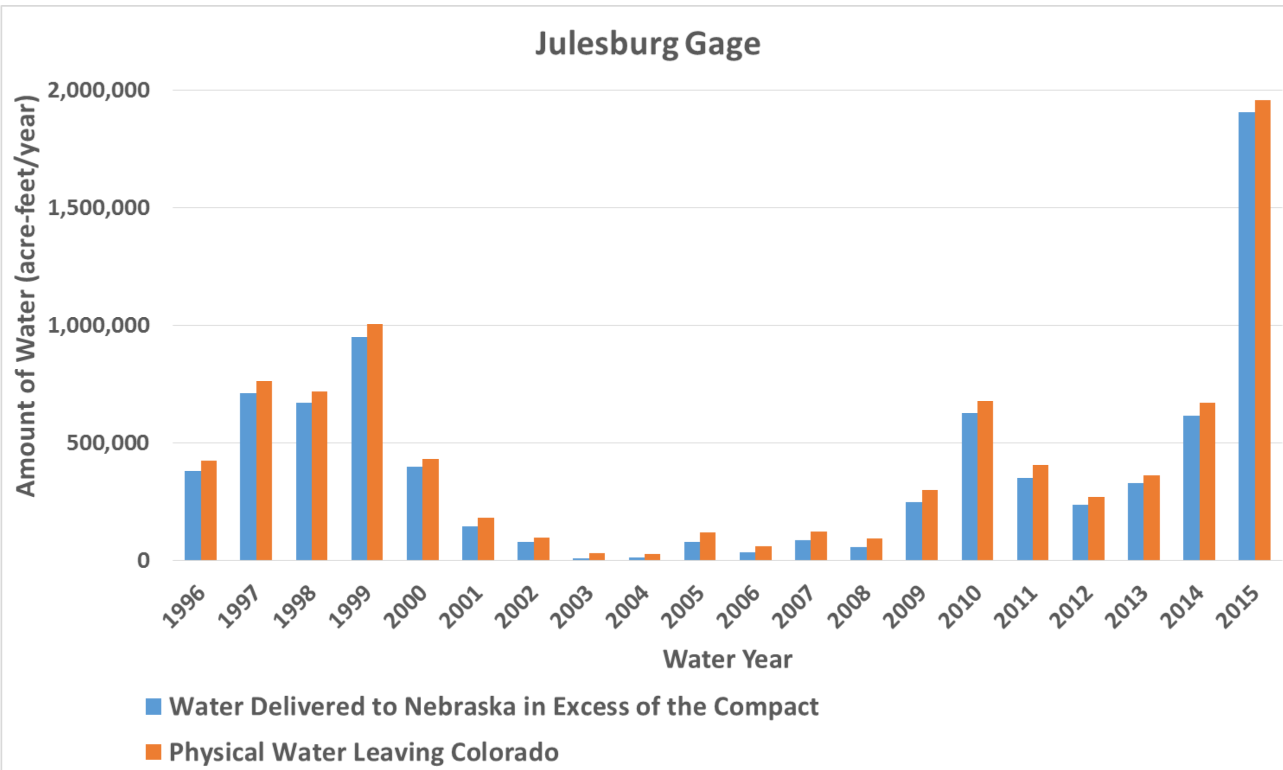


**Figure 1. South Platte River Water Delivered to Nebraska (Julesburg Gage), 1996-2015**

Figure 2 displays the annual physical flow and storable flow at the South Platte River at Kersey stream gage from 1996 to 2015. This location is below the confluence of the South Platte River and the Cache la Poudre River in Greeley, and is the upstream end of the Lower South Platte River Basin as defined in the South Platte Storage Study. As with the analysis at the Julesburg gage, storable flow is the maximum potential storable flow assuming a mainstem reservoir that can capture all available water. Although physical flow in the river at Kersey is larger than at the State line, storable flow is a smaller percentage of total flow at the Kersey gage compared to storable flow at the Julesburg gage because of the need to satisfy downstream water rights within Colorado.

Selected statistics for physical flow and storable flow at the Kersey gage are presented in Table 2. Physical flow decreases but storable flow increases in the Lower South Platte River between the Kersey gage and the State line. Physical flow decreases due to the lack of major tributaries and the significant diversions for Lower South Platte Basin water users. Storable flow increases because less water must be reserved in the stream for downstream water rights.

**Table 2. Historical Annual Flow for 1996-2015 at Greeley**

| Statistic | Physical Water at Greeley (Kersey gage) (ac-ft/yr) | Storable Water at Greeley (Kersey gage) (ac-ft/yr) |
|---|---|---|
| Annual Average | 773,000 | 262,000 |
| Annual Median | 732,000 | 165,000 |
| Minimum Year | 285,000 | 0 |
| Maximum Year | 2,001,000 | 1,447,000 |

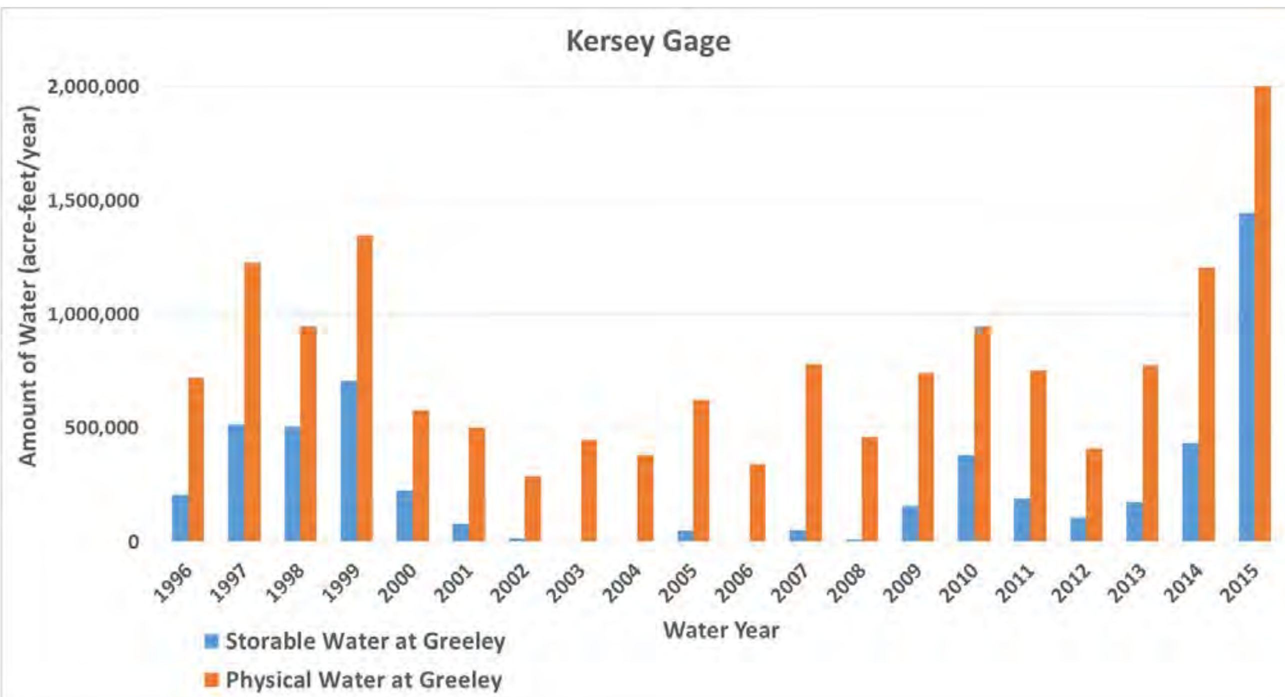


**Figure 2. Physical and Storable Flow at Greeley (Kersey Gage), 1996-2015**

# APPENDIX E – WATER AVAILABILITY TM

NOTE: SOME OF THE INFORMATION IN THIS TM WAS CHANGED DURING PREPARATION OF THE FINAL REPORT

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| | | | |
|---|---|---|---|
| To: | Joe Frank, Andy Moore | From: | Samantha Mauzy, Lisa Fardal and Chip Paulson |
| | Lower South Platte Water Conservancy District, Colorado Water Conservation Board | | MWH Now Part of Stantec |
| Subject: | **South Platte River Hydrologic Analysis** | Date: | June 26, 2017 |

## INTRODUCTION AND BACKGROUND

The South Platte Storage Study (SPSS) was initiated as a result of House Bill 16-1256 titled "South Platte Storage Study." HB16-1256, signed into law by the Governor on June 9th, 2016, authorizes the Colorado Water Conservation Board (CWCB), in collaboration with the State Engineer (SEO), and the South Platte Basin and Metro Roundtables, to identify multi-purpose water storage options along the lower South Platte River to capture flows leaving the state in excess of the legally required amounts. These water storage possibilities will include new reservoirs, the enlargement/rehabilitation of existing reservoirs, and alternative storage mechanisms (e.g., underground storage).

The third task of the SPSS project is a hydrologic flow analysis of the South Platte River basin, which includes an analysis of historical and future flows. The objective of the historical flow analysis is to estimate the amount of water that was physically and legally available for storage in the lower South Platte River based on historical hydrologic records. For the analysis of future flows, rough adjustments were made to estimate storable flows under possible future hydrologic conditions based on discounting factors such as conditional diversion or storage rights or the implementation of Identified Projects and Processes (IPPs) identified in Colorado's Water Plan.

This technical memorandum presents the results of the historical and future available flow analyses. It contains a brief overview of the updates performed on the point flow model and a description of how the available flows were estimated from the point flow model results.

## POINT FLOW MODEL

The Point Flow Model was initially developed by Ken Fritzler for Brown and Caldwell for the Lower South Platte Water Conservancy District under a Water Supply Reserve Account (WSRA) grant with the State of Colorado. The model evaluates the daily flow passing structures on the mainstem of the South Platte River between the Burlington Ditch diversion (Henderson area) and the Nebraska state line based on hydrologic data, diversion records and reconstructed call records using a detailed point flow modeling approach. The point flow analysis calculates ungaged gains and losses between measured points by simple mass balance and estimates physical flow at 62 points along the river by redistributing the gains and losses according to their spatial distribution. The model does not account for existing conditional water rights that could be used more fully in the future as they are perfected nor does it consider unused reusable return flows that might be utilized in the future.

The Point Flow Model version dated February 23, 2017 was updated to meet the needs of the SPSS project. The model was previously updated for the South Platte Basin Implementation Plan. Details of the historical flow dataset update can be found in the memorandum dated March 10, 2017 from Leonard Rice Engineers, Inc. to Stantec entitled "Task 3: Historical Point Flow Dataset Update (WY1996-WY2015)." This memorandum is provided in Appendix B. Using this data, the Point Flow Model was updated by the original developer, Ken Fritzler. The following updates were implemented:

- Daily time series in the original Point Flow Model was water years 2000 to 2013. This was extended to include water years 1996 to 2015.
- Daily call chronology was updated for the new time period.
- The Metro Effluent dataset was updated. The original Metro Effluent time series used in the Point Flow Model was obtained. This dataset (WY1994 – WY2014) provided the template for recreating the time series using publicly available data from HydroBase and Colorado Division of Water Resources (CDWR) website. Russel Stroud (Division 1 Lead Hydrographer) was also consulted to help understand the available public data for gage METSEWCO discharges operated by CDWR. The original Metro time series used in the Point Flow Model included releases back to the Burlington Canal. The final Metro time series was reconstructed using both Metro Sewer (0200700) historical diversion classes and gaged discharges from METSEWCO (discharge 1 and discharge 3) to match the proprietary dataset from Metro Wastewater without Burlington Canal releases. The resulting dataset differs from the original, but should be considered more accurate.
- Water District 2 diversion totals were updated by using administrative records (S:X F: U:Q T:0 G:) from November 1, 2010 forward instead of diversion totals as these data were not compiled correctly due to a change in both the Water Commissioner and diversion class coding requirements.
- Daily streamflow records directly from the Colorado Division of Water Resources website were used to fill missing streamflow records in HydroBase in September 2013 for several stations.
- Due to new release class protocols implemented in 2012, several new release classes (S: F: U:Q T:7 G:) not in the original dataset were identified in HydroBase for the more recent period for the Jackson Reservoir outlet, Weldon Valley Ditch return, and the Prewitt outlet.

Table 1 gives the names and types of structures used in the Point Flow Model in order from most upstream to most downstream. Figure 1 shows the location of each point in the Point Flow Model along the South Platte River. Figure 2 shows the average annual flow in the South Platte River after the updates described were made for water years 1996 to 2015. (All figures are presented at the end of this document.)

**Table 1. Points Analyzed in Point Flow Model**

| ID | Location Name | Type |
|---|---|---|
| 1 | South Platte River at Denver | Stream Gage |
| 2 | Burlington Ditch River Headgate | Diversion Structure |
| 3 | Gardeners Ditch | Diversion Structure |
| 4 | South Platte River at Commerce City | Stream Gage |
| 5 | Metro Effluent | Tributary |
| 6 | Sand Creek at Mouth Near Commerce City | Tributary |
| 7 | Clear Creek at Mouth Near Derby | Tributary |
| 8 | Fulton Ditch | Diversion Structure |
| 9 | Brantner Ditch | Diversion Structure |
| 10 | South Platte River at Henderson | Stream Gage |

| ID | Location Name | Type |
|---|---|---|
| 11 | Brighton Ditch | Diversion Structure |
| 12 | Lupton Bottom Ditch | Diversion Structure |
| 13 | Big Dry Creek at Mouth Near Fort Lupton | Tributary |
| 14 | Platteville Ditch | Diversion Structure |
| 15 | Meadow Island 1 Ditch | Diversion Structure |
| 16 | Evans No 2 Ditch/ Platte Valley Canal (Shared Headgate) | Diversion Structure |
| 17 | Meadow Island 2 Ditch/ Beeman Ditch (Shared Headgate) | Diversion Structure |
| 18 | Farmers Independent Ditch | Diversion Structure |
| 19 | Hewes Cook Ditch | Diversion Structure |
| 20 | Jay Thomas Ditch | Diversion Structure |
| 21 | St. Vrain Creek at Mouth, Near Platteville | Tributary |
| 22 | Union Ditch | Diversion Structure |
| 23 | Section No 3 Ditch | Diversion Structure |
| 24 | Big Thompson River at Mouth, near La Salle | Tributary |
| 25 | Lower Latham Ditch | Diversion Structure |
| 26 | Patterson Ditch | Diversion Structure |
| 27 | Highland Ditch | Diversion Structure |
| 28 | Cache La Poudre River Near Greeley | Tributary |
| 29 | South Platte River Near Kersey | Stream Gage |
| 30 | Empire Ditch | Diversion Structure |
| 31 | Riverside Canal/ Illinois Ditch (Shared Headgate) | Diversion Structure |
| 32 | Bijou Canal/ Corona Ranch Ditch (Shared Headgate) | Diversion Structure |
| 33 | Riverside Reservoir Outlet | Tributary |
| 34 | Jackson Lake Inlet Ditch | Diversion Structure |
| 35 | Weldon Valley Ditch | Diversion Structure |
| 36 | Jackson Reservoir Outlet | Tributary |
| 37 | Ft Morgan Canal | Diversion Structure |
| 38 | South Platte River Near Weldona | Stream Gage |
| 39 | Weldon Valley Ditch Return | Tributary |
| 40 | Deuel Snyder Canal | Diversion Structure |
| 41 | Upper Platte Beaver Canal | Diversion Structure |
| 42 | Lower Platte Beaver Ditch/Tremont Ditch (Same Point From Diversion On South Platte River) | Diversion Structure |
| 43 | North Sterling Canal/ Union Ditch (Assumes Shared Headgate) | Diversion Structure |
| 44 | South Platte River at Cooper Bridge, Near Balzac | Stream Gage |
| 45 | Prewitt Inlet Canal/ Tetsel Ditch/ Johnson Edwards Ditch (Shared Headgate) | Diversion Structure |
| 46 | South Platte Ditch | Diversion Structure |
| 47 | Prewitt Outlet | Tributary |

| ID | Location Name | Type |
|---|---|---|
| 48 | Pawnee Ditch | Diversion Structure |
| 49 | Schneider Ditch | Diversion Structure |
| 50 | Springdale Ditch | Diversion Structure |
| 51 | Sterling Irrigation Company Ditch 1 | Diversion Structure |
| 52 | Lowline Ditch/ Henderson Smith Ditch | Diversion Structure |
| 53 | Bravo Ditch | Diversion Structure |
| 54 | Iliff Platte Valley Ditch | Diversion Structure |
| 55 | Lone Tree Ditch | Diversion Structure |
| 56 | Powell Blair Ditch | Diversion Structure |
| 57 | Ramsey Ditch | Diversion Structure |
| 58 | Harmony Ditch 1 | Diversion Structure |
| 59 | Peterson Ditch | Diversion Structure |
| 60 | South Reservation Ditch | Diversion Structure |
| 61 | Liddle Ditch | Diversion Structure |
| 62 | South Platte River at Julesburg | Stream Gage |

## HISTORICAL HYDROLOGIC ANALYSIS RESULTS

Available water for the historical period 1995 to 2015 was calculated for all locations in the Point Flow Model by the following steps.

1. Daily historical flow that did not have a calling water right (available flow greater than 0), was reduced by the bypass flow required to satisfy downstream uses. With input from Division 1 staff, bypass flows in Table 2 were adopted as reasonable estimates of the requirements.

**Table 2. Bypass Flows Applied to Available Water Analysis**

| Month | Burlington to upstream of St Vrain Creek (cfs) | Downstream of St Vrain Creek to Riverside Canal (cfs) | Bijou Canal to state line (cfs) |
|---|---|---|---|
| Apr - Oct | 15 | 20 | 10 |
| Nov - Mar | 15 | 10 | 5 |

2. The South Platte River Compact requires flow at the state line to be 120 cubic feet per second (cfs) [238 ac-ft/day) or greater between April 1 and October 15. The available flow at the state line was reduced by 120 cfs during these dates. The Compact affects available flows in District 64 only.

3. Available water calculations were reduced by historically unused reusable return flows. These values were obtained from Aurora Water and Denver Water. It was assumed that both entities would reclaim all their reusable water supplies in the future.

4. Available flow at any point along the South Platte River is affected by downstream water rights that must be satisfied. Sufficient water must be left in the river at any point to meet all downstream water rights and delivery obligations. Thus, the available flow is constrained by the minimum flow that must remain in the river to assure that all downstream water rights are satisfied. If there was a call at one point in the river, it was assumed that there was no available water at that point or at any points upstream. In District 64, the 120 cfs Compact requirement could reduce the available flow to zero in the entire district. Figure 3 shows, as an example, physical flow and available water for June 20, 2005. This date was chosen arbitrarily to demonstrate how the calculation of available water was performed.

To compare available water between wet years, normal years, and dry years, water year 1999 was chosen as a representative wet year, water year 2002 was chosen as a representative dry year, and water year 2010 was chosen as a representative normal years. Figure 4 shows annual available water at all points in the Point Flow Model based on year type.

Further analysis was done seasonally for the representative wet, dry, and normal years. Average available water and physical flow in the river was plotted for February, June, and August. February was chosen to be representative of the winter season, June was chosen to be representative of the runoff season, and August was chosen to be representative of the irrigation season.

Figures 5 to 13 show available water and physical flow in the South Platte for all combinations of year type and season. See Table 3 for a summary of the conditions presented in these figures.

**Table 3. Index to Available Water and Physical Flow Figures**

| | Winter Season (February) | Runoff Season (June) | Irrigation Season (August) |
|---|---|---|---|
| **Wet Year (WY 1999)** | Figure 5 | Figure 6 | Figure 7 |
| **Dry Year (WY 2002)** | Figure 8 | Figure 9 | Figure 10 |
| **Normal Year (WY 2010)** | Figure 11 | Figure 12 | Figure 13 |

Additionally, five locations along the South Platte River were chosen for further analysis. Four locations - South Platte River at Kersey, South Platte River at Weldona, South Platte River near Balzac, and South Platte River near Julesburg – are stream gage locations. The fifth location is the Lowline Ditch/Henderson Smith Ditch diversion, which is representative of flow in the river at Sterling. Figure 14 shows these five points and their locations within the SPSS study area.

Table 4 shows the average and median annual available water for the 1995-2015 historical period for the selected locations. The average annual available water is given as an average of all years and for a representative wet, normal, and dry year, and the median of all years is given.

### Table 4. Annual Available Water for Selected Locations Based on Historical Hydrology

| Location | Average Annual Available Water [ac-ft] | | | | Median Annual Available Water [ac-ft] |
|---|---|---|---|---|---|
| | All Years | Wet Year (1999) | Normal Year (2010) | Dry Year (2002) | All Years |
| South Platte River near Kersey | 262,000 | 707,000 | 378,000 | 14,000 | 165,000 |
| South Platte River near Weldona | 281,000 | 731,000 | 411,000 | 18,000 | 179,000 |
| South Platte River near Balzac | 297,000 | 771,000 | 440,000 | 18,000 | 185,000 |
| Lowline Ditch/Henderson Smith Ditch | 314,000 | 799,000 | 476,000 | 33,000 | 200,000 |
| South Platte River at Julesburg | 397,000 | 951,000 | 627,000 | 79,000 | 289,000 |

Notes:

1. Based on 1995-2015 historical streamflows and river operations, adjusted to remove Denver Water and Aurora Water reusable return flows and account for all existing water rights and South Platte River Compact obligations.
2. “Available water” is water physically and legally available to be diverted to a new water supply project like SPSS.

Average available water calculated from the Point Flow Model was compared to CDWR historical stream gage data. According to CDWR historical stream gage data, on average, 407,000 acre-feet of water passed the Julesburg gage on an annual basis during the full period of record from 1903 to 2016. According to the Point Flow Model, on average, only 397,000 acre-feet is available for diversion. The difference is due to a combination of differences in period of record, consideration for Denver Water and Aurora Water reusable return flows, adjustments for all existing water rights, and South Platte Compact obligations. The stream gage flow average was calculated based on water years 1903 to 2016 (all years with adequate streamflow data available), whereas the Point Flow Model available water calculations are done based on water years 1996 to 2015. Available water calculations take into account the effect of Denver Water and Aurora Water reusable return flows, adjustments for all existing water rights and Compact calls, while stream gage flows do not.

Figures 15 to 20 are exceedance plots that show the percentage of time a given magnitude of available flow is equaled or exceeded in the Point Flow Model period of record for historical conditions. Daily flow exceedance plots are shown in Figures 15 to 19, an annual flow exceedance plot is shown in Figure 20, and the average monthly physical flow is shown in Figure 21.

Exchange potential between any two given points along the river can be estimated by the minimum available flow within the reach. Exchange potential is used to analyze the general exchange conditions in the South Platte River and identify points that would potentially limit or control future exchanges. The legally and physically available flow shown in Figure 22 represents the exchange potential as the minimum available flow between any two selected points of interest. Figure 23 shows a map of the location of the two points used as an example in Figure 22.

## FUTURE HYDROLOGIC CONDITIONS

HB 16-1256 specified that this storage study should be based on historical hydrology to answer the question, “how much water could we have stored in recent years if storage had been in place?” However, it is recognized that future hydrologic conditions will not be the same as historical conditions due to development of conditional water rights, implementation of proposed Identified Projects and Processes (IPPs) from the Colorado Water Plan, changed operations by water users, and a host of other factors. Per the direction of the

SPSS Review Committee, the SPSS planning will be performed using future hydrology, the effect of the unaltered historical hydrology on the performance of potential storage solutions will also be investigated.

The scope of work for the SPSS indicated that future hydrology would be developed using the same methods as were applied in the South Platte Basin Implementation Plan (BIP). In the BIP a routine was developed to reduce historical flows by diversions anticipated from IPPs in the Colorado Water Plan. This routine uses estimates of IPP annual yields obtained from the IPP proponents, and reduces available water equally in all months. The routine allows the user to select individual IPPs or all IPPs for inclusion in the analysis, since the BIP acknowledges that not all IPPs are likely to be ultimately implemented.

An alternate approach to estimate future hydrology would be to reduce the historical flows by the current conditional water right filings in the basin. Some of the conditional diversion and storage water rights are associated with IPPs, but not all of them. Both approaches involve significant speculation about future water development in the basin. The selected approach based on IPPs is assumed to give a reasonable estimate of the order of magnitude of impacts of future water development on historical hydrology.

For the SPSS the method of reducing available flows to account for implementation of IPPs was modified by assuming a monthly pattern of diversions for those proposed projects which would increase future diversions. These rough estimates were developed by the study team and were not verified with the IPP proponents. It is recognized that many factors can affect the magnitude and timing of diversions for future projects, and detailed analyses of specific IPPs was not contemplated for this project. Estimates in this study are only developed to provide a rough order of magnitude of the effect of IPPs on water available for a new South Platte storage project. IPPs which are expected to reduce future demands were not considered in the adjustment of available flows.

For IPPs with increased future diversions, it was assumed that most IPPs would divert a majority of their water during the spring runoff months when the most water is available and when junior water rights would be in priority. Assumptions were made as to the percentage of diversions that would be made during spring runoff months (May and June) and the percentage of diversions that would be made during the rest of the year (July to April). Table 5 shows the IPPs, their estimated yield from the BIP, and the assumed distribution of their diversions.

### Table 5. Seasonal Distribution of Future Diversions for IPPs

| IPP Project | Provider | Yield (ac-ft/year) | May-June Diversions | July-April Diversions |
|---|---|---|---|---|
| ACWWA Reuse Flow Project | ACWWA, SMWSA | 3,520 | n/a | n/a |
| Alternative Northern Water Supply Project | Town of Castle Rock | 2,500 | 80% | 20% |
| ASR Future Storage | Town of Castle Rock | n/a | - | - |
| ASR Pilot Phase Storage | Town of Castle Rock | n/a | - | - |
| Chatfield Pump Station | Denver Water | 3,000 | 50% | 50% |
| Chatfield Reservoir Storage Reallocation Project | Colorado Water Conservation Board, Centennial Water and Sanitation District, Central Colorado Water Conservancy District, Castle Pines North Metro District, Colorado Parks and Wildlife, Castle Rock, Center of Colorado Water Conservancy District, Castle Pines Metro District | 8,500 | 80% | 20% |
| Conservation | Centennial Water and Sanitation District | 1,764 | n/a | n/a |

| IPP Project | Provider | Yield (ac-ft/year) | May-June Diversions | July-April Diversions |
|---|---|---|---|---|
| Conservation | City of Greeley | 3,000 | n/a | n/a |
| Conservation | City of Northglenn | 600 | n/a | n/a |
| Conservation | City of Thornton | 3,500 | n/a | n/a |
| Conservation | Longmont | 3,500 | n/a | n/a |
| Conservation | Town of Castle Rock | 3,350 | n/a | n/a |
| Consolidated Mutual Water District Reservoir Construction | Consolidated Mutual Water Company | n/a | - | - |
| Denver Water Reuse | Denver Water | 1,750 | n/a | n/a |
| Downstream Reservoir Exhanges | Denver Water | 12,000 | 70% | 30% |
| Halligan Reservior Enlargement | City of Fort Collins | 7,000 | 80% | 20% |
| Highway 93 Lakes | Arvada | 500 | 80% | 20% |
| Milton Seaman Reservoir Enlargement | City of Greeley | 6,600 | 80% | 20% |
| New Storage Projects | City of Northglenn | 1,500 | 70% | 30% |
| Northern Integrated Supply Project | Town of Erie, City of Lafayette, Left Hand Water District, City of Fort Morgan, City of Dacono, Town of Eaton, Town of Windsor, City of Fort Lupton, Fort Collins - Loveland Water District, Central Weld County Water District, Town of Evans, Morgan County Water Quality District, Town of Severance, Town of Frederick, Town of Firestone | 40,000 | 70% | 30% |
| Plum Creek Diversion & WPF Upgrades | Town of Castle Rock | 4,100 | 80% | 20% |
| Prairie Waters Project | Aurora | 15,700 | 50% | 50% |
| Reclaimed Water | Erie | 5,390 | n/a | n/a |
| Reuse | City of Thornton | 2,000 | n/a | n/a |
| Reuse Plan | City of Northglenn | 700 | n/a | n/a |
| Rueter Hess Reservoir Enlargement | Parker Water and Sanitation District, Castle Rock, Castle Pines North, Stonegate | 14,810 | 80% | 20% |
| South Platte and Beebe Draw Well Project - Reuse | City of Brighton | 3,200 | n/a | n/a |
| South Platte Protection Plan | Denver Water | n/a | - | - |
| Thornton Northern Project | City of Thornton | 13,500 | 50% | 50% |
| Union Pumpback Pipeline | Longmont | 4,950 | 50% | 50% |
| Union Reservior Enlargement | Longmont | 1,770 | 80% | 20% |
| Westminster Agreement | City of Brighton | 2,000 | 50% | 50% |
| Westminster Gravel Storage | Westminster | n/a | - | - |

Notes:

1. Projects with n/a in the Diversions fields reduce future demand rather than increasing future diversions. Projects with n/a in Yield field did not have yield estimates available from the BIP.
2. Projects with blanks in the Diversions fields did not have adequate yield information. It is assumed these projects will not be built.

Table 6 shows historical average annual and median annual available water adjusted for IPP diversion estimates. These results assume all IPPs for which yield information was available in the BIP are implemented, while all IPPs without yield information in the BIP are not implemented. This is conceptually consistent with the assumption in the Colorado Water Plan that not all IPPs will ultimately be implemented. The table also shows the reduction in available water compared to the results of the historical hydrology analysis shown in Table 4. Figure 24 shows South Platte at Julesburg as an example of historical available water and how it might be affected by IPPs in the future. Plots showing the same information at the other South Platte stream gages look very similar. Figure 25 gives a comparison of the daily available water exceedance between the historical hydrology and the future hydrology adjusted for IPPs.

### Table 6. Future Available Water for Selected Locations Based on Historical Hydrology and IPP Adjustment

| Location | | Average Annual Available Water, After IPPs [ac-ft] | | | | Median Annual Available Water [ac-ft] |
|---|---|---|---|---|---|---|
| | | All Years | Wet Year (Based on 1999) | Normal Year (Based on 2010) | Dry Year (Based on 2002) | All Years |
| South Platte River near Kersey | With IPP Adjustment | 214,000 | 580,000 | 275,000 | 6,000 | 116,000 |
| | *Difference from Historical* | *-48,000* | *-127,000* | *-103,000* | *-8,000* | *-49,000* |
| South Platte River near Weldona | With IPP Adjustment | 231,000 | 601,000 | 303,000 | 9,000 | 127,000 |
| | *Difference from Historical* | *-50,000* | *-130,000* | *-108,000* | *-9,000* | *-52,000* |
| South Platte River near Balzac | With IPP Adjustment | 246,000 | 641,000 | 326,000 | 9,000 | 144,000 |
| | *Difference from Historical* | *-51,000* | *-130,000* | *-114,000* | *-9,000* | *-41,000* |
| Lowline Ditch/Henderson Smith Ditch | With IPP Adjustment | 261,000 | 666,000 | 357,000 | 15,000 | 154,000 |
| | *Difference from Historical* | *-53,000* | *-133,000* | *-119,000* | *-18,000* | *-46,000* |
| South Platte River at Julesburg | With IPP Adjustment | 332,000 | 815,000 | 494,000 | 54,000 | 232,000 |
| | *Difference from Historical* | *-65,000* | *-136,000* | *-133,000* | *-25,000* | *-57,000* |

## FINDINGS AND CONCLUSIONS

Figure 26 summarizes the results of the historical water availability analysis by showing the historical average annual available water and physical flow along with the historical median annual available water and physical flow in the SPSS study area. Figure 27 summarizes the results of the future water availability analysis by showing the future average annual available water and historical physical flow along with the future median annual available water and historical physical flow.

The results from this hydrologic analysis will be used to estimate the amount of water available to a new SPSS storage project at various locations along the South Platte River and to guide the amount of storage that could be beneficial at those locations.

It is noted that the results for estimates of available water assume water is diverted at only one point on the South Platte mainstem. If multiple diversions were to occur, the results of this analysis could be used to estimate yield from the upstream diversion but the point flow model would have to be recalculated to determine available water at a subsequent downstream diversion.

In general, available water in the South Platte mainstem increases in the downstream direction because of fewer senior water rights to constrain available water, tributary inflows, and more return flows entering the South Platte. Siting SPSS storage options further downstream will generally result in greater available water. However, the increase in available water between the Kersey gage and Sterling is relatively modest – the mean annual available water increases by 20 percent and the median annual available water increases by 30 percent between these points. Thus water availability will be an important but not a critical differentiator in siting of SPSS storage options in the majority of the study area.

Several choke points exist along the river profile that would affect exchange potential; the majority of these occur upstream of Kersey and the Poudre River confluence. While these are outside the SPSS study area for storage projects, the choke points affect the ability to exchange water from downstream storage to upstream demand centers closer to the Front Range urban corridor.

From the hydrologic analysis, it can be concluded that in general, when water is available, there is a large amount of water available for a short period of time. This confirms the expected findings based on experience in the basin. It is likely that the most feasible new storage options for capturing excess flows on the South Platte will have to be capable of "scalping" and storing high flows that occur during the annual Spring runoff period in wet years. This would require large diversion structures and/or large storage capacities with significant carry-over storage.

Future divertible flow will be less than historical divertible flow due to development of IPPs, conditional water rights and new water supply projects. For purposes of this study, IPPs for which yield estimates were available were assumed to be implemented to provide a rough order of magnitude estimate of future hydrology. Applying this adjustment to the historical point flow model reduced available annual available water by 16-18 percent throughout the study area, and reduced median available flow by 20-30 percent.

# APPENDIX A: FIGURES

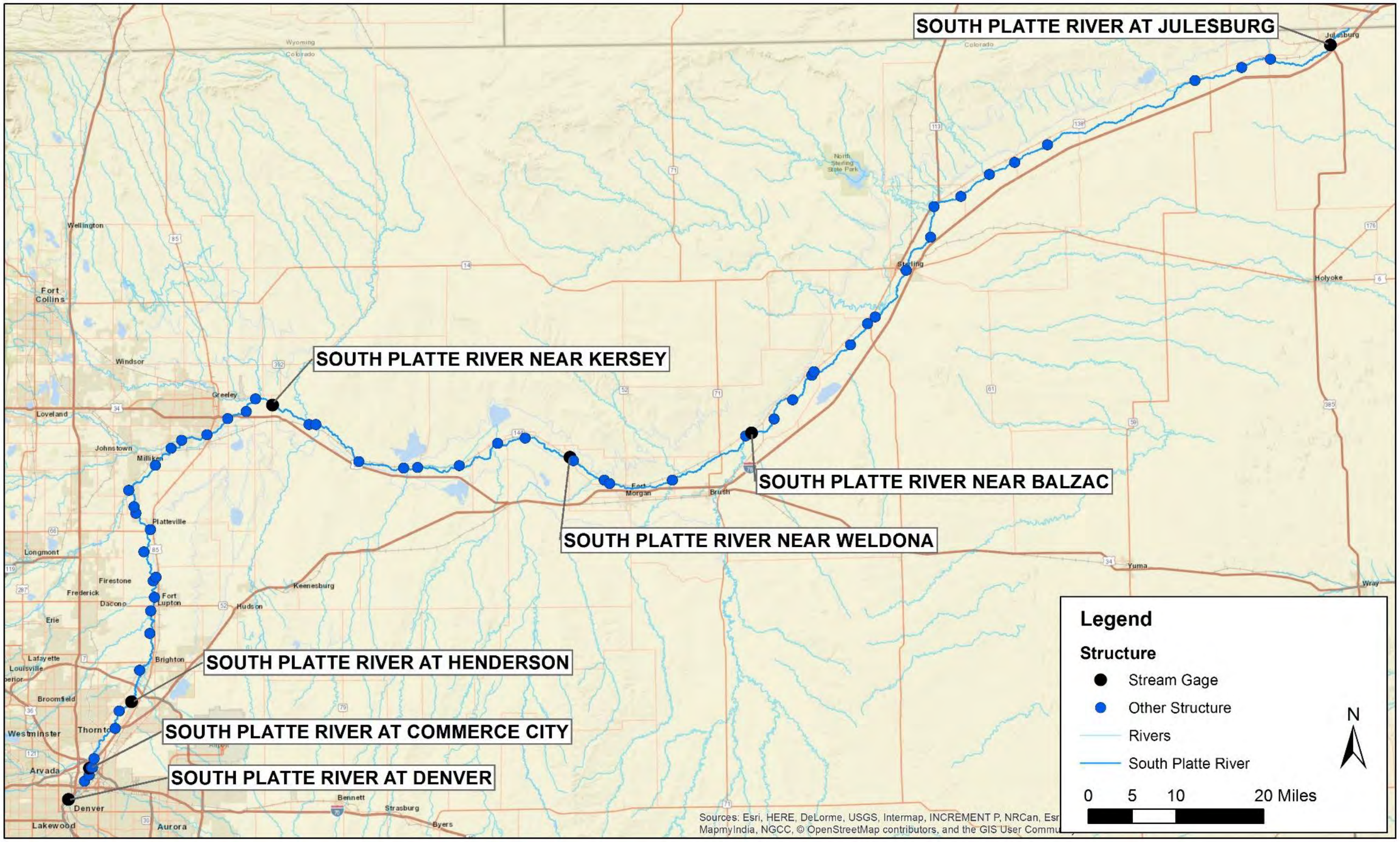


Figure 1. Point Flow Model Analysis Locations

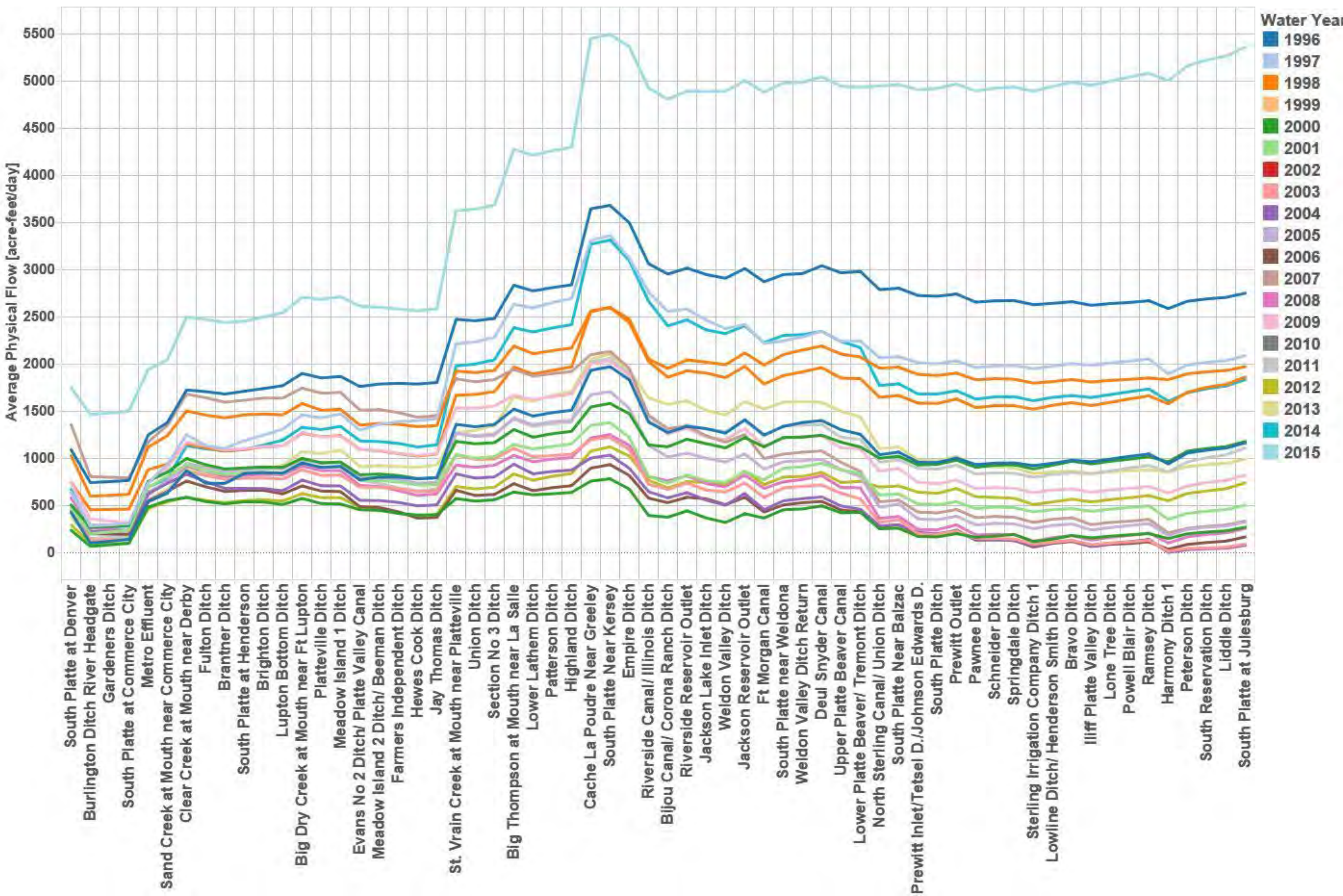


**Figure 2. Historical Average Physical Flow after Point Flow Model Updates**

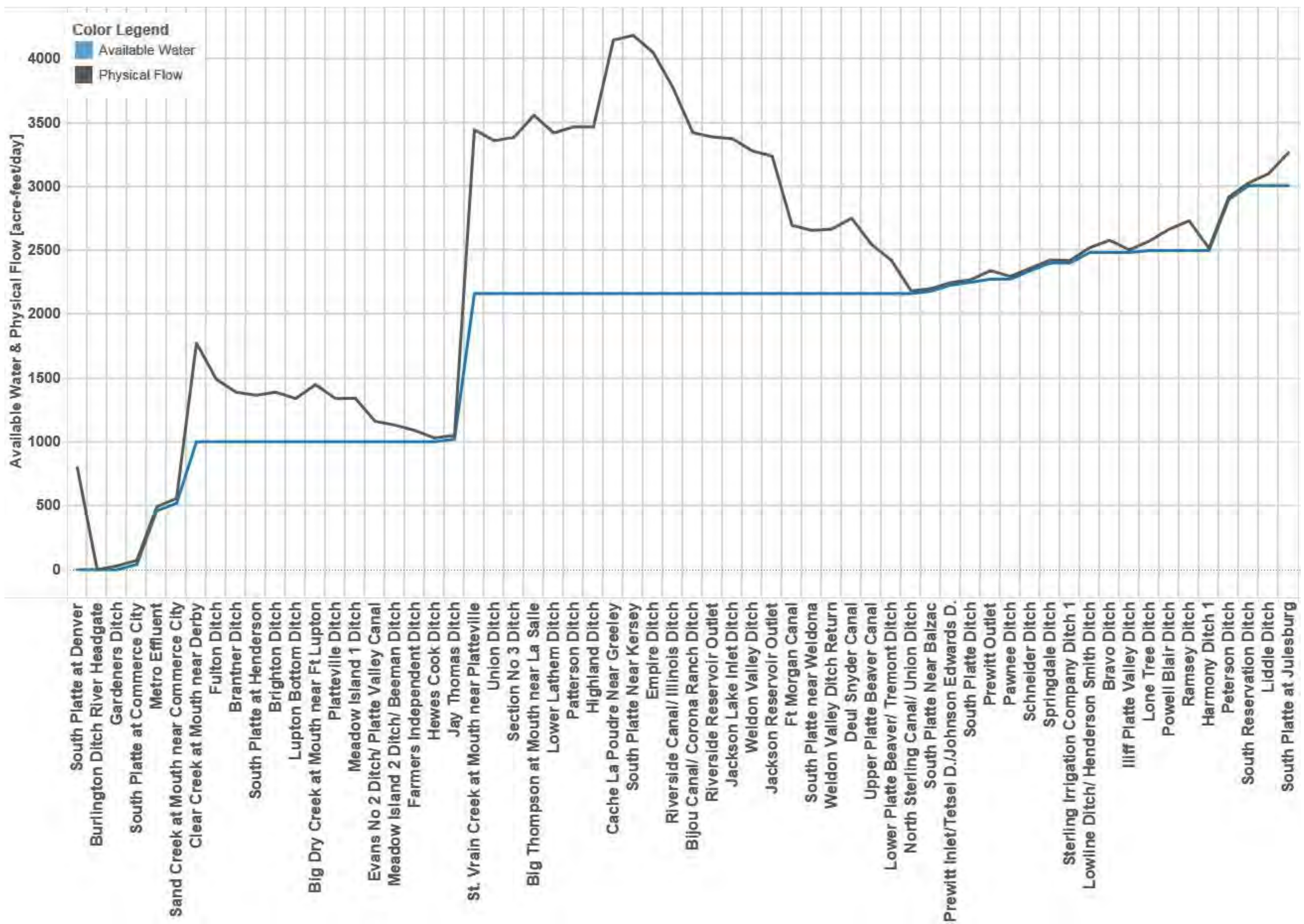


**Figure 3. Sample Daily Available Water Calculation Method – June 20, 2005**

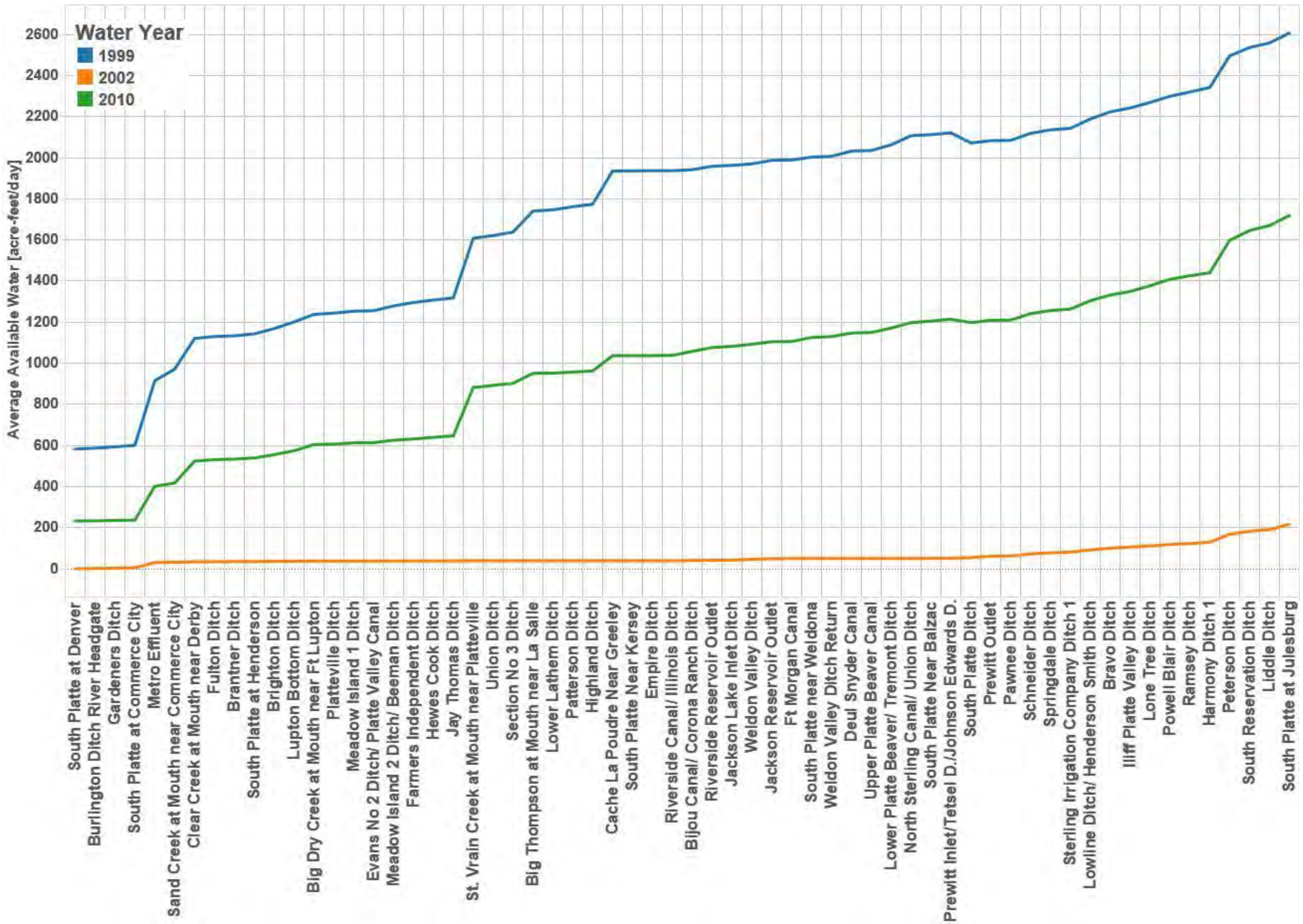


**Figure 4. Historical Daily Average Available Water for Representative Wet, Normal, and Dry Years**

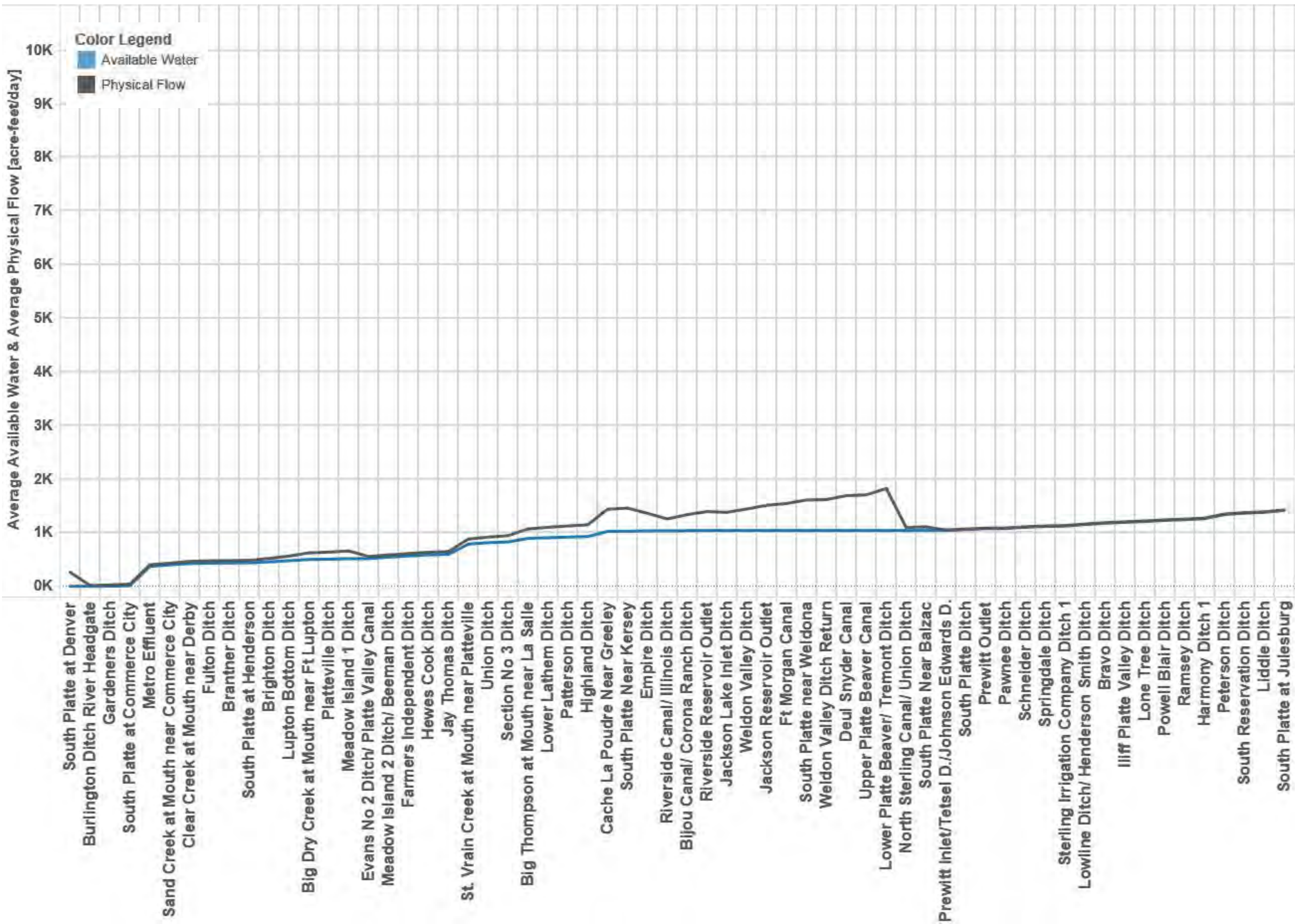


**Figure 5. Historical Available Water and Physical Flow for Wet Winter Season (February 1999)**

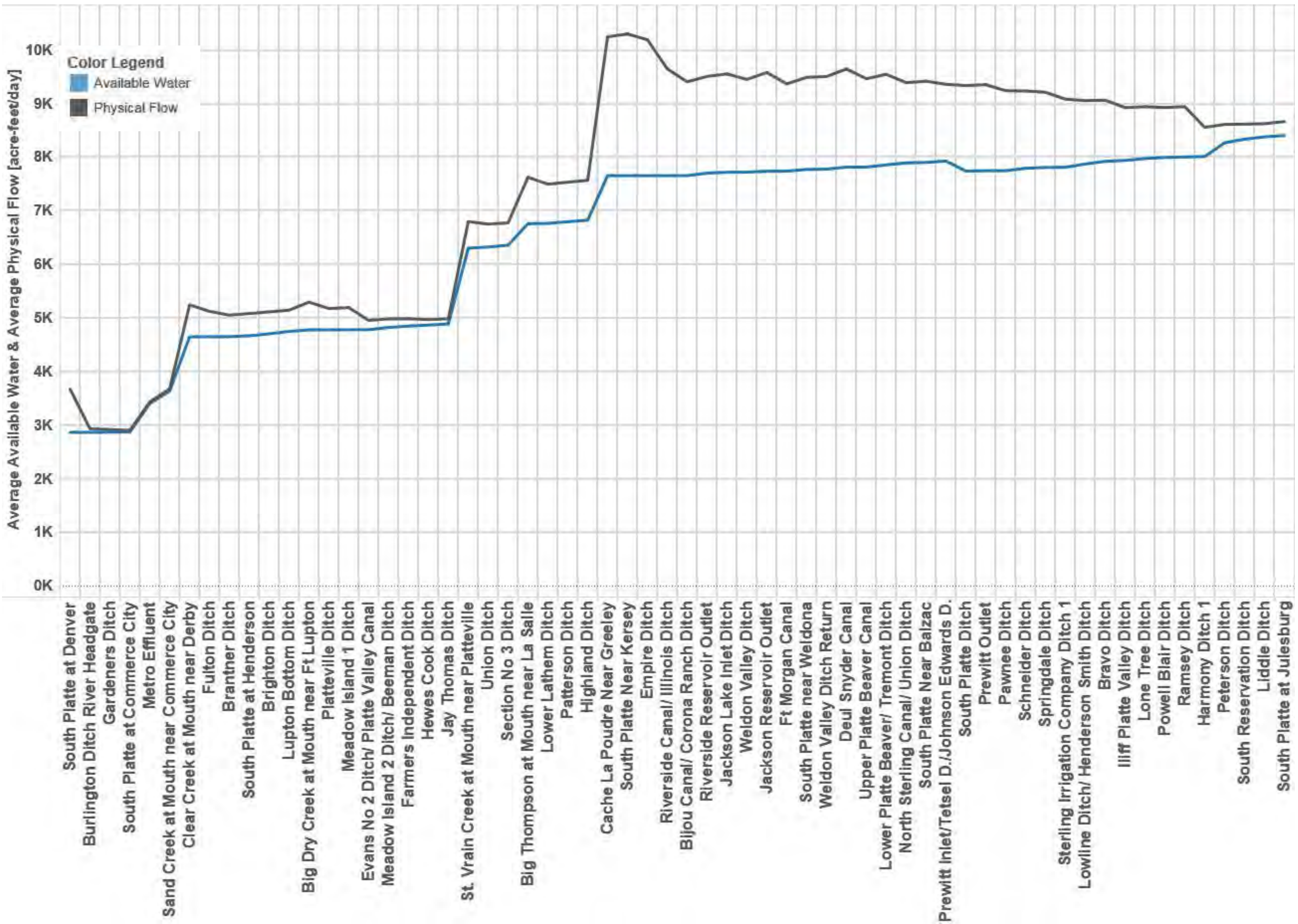


**Figure 6. Historical Available Water and Physical Flow for Wet Runoff Season (June 1999)**

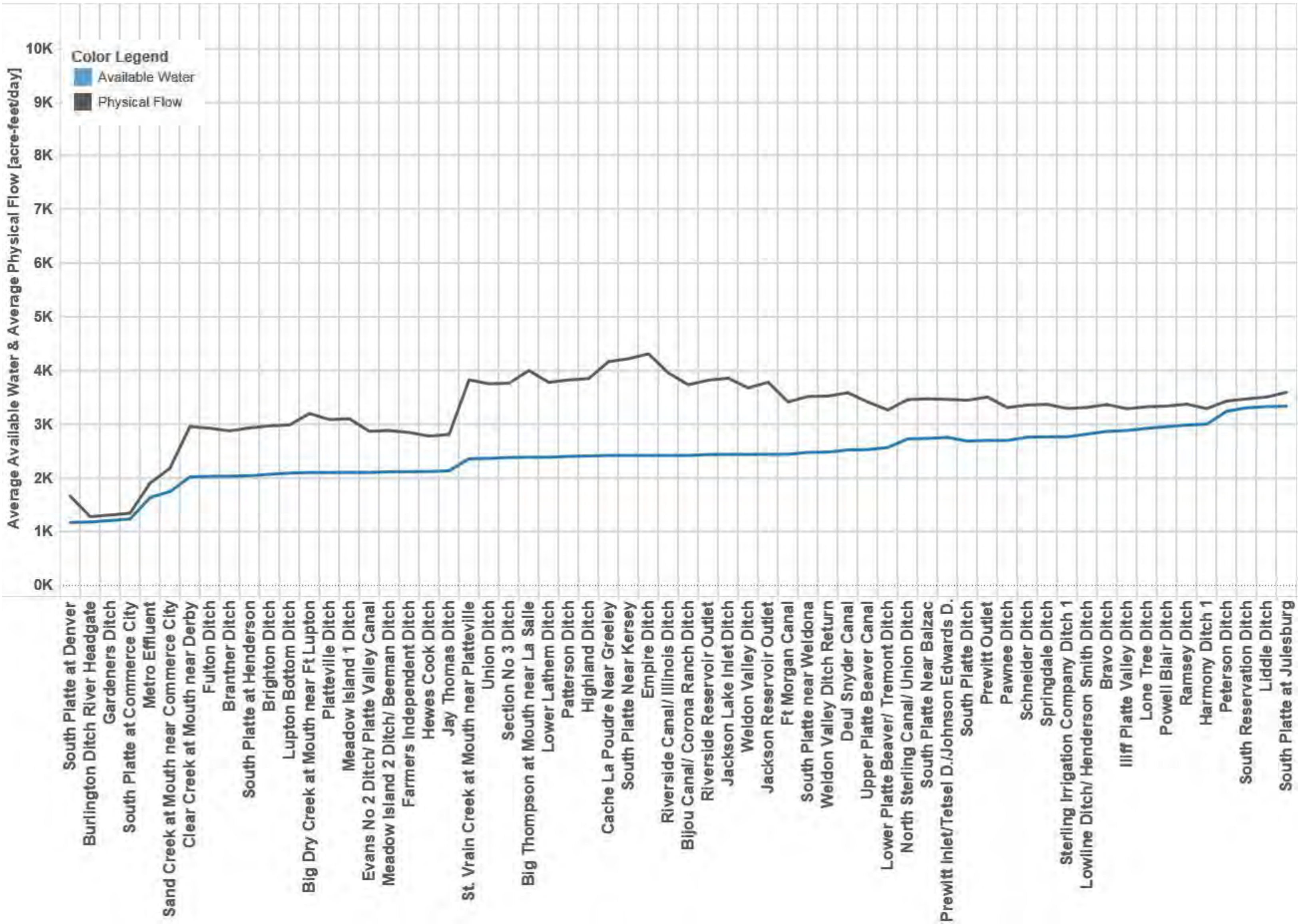


**Figure 7. Historical Available Water and Physical Flow for Wet Irrigation Season (August 1999)**

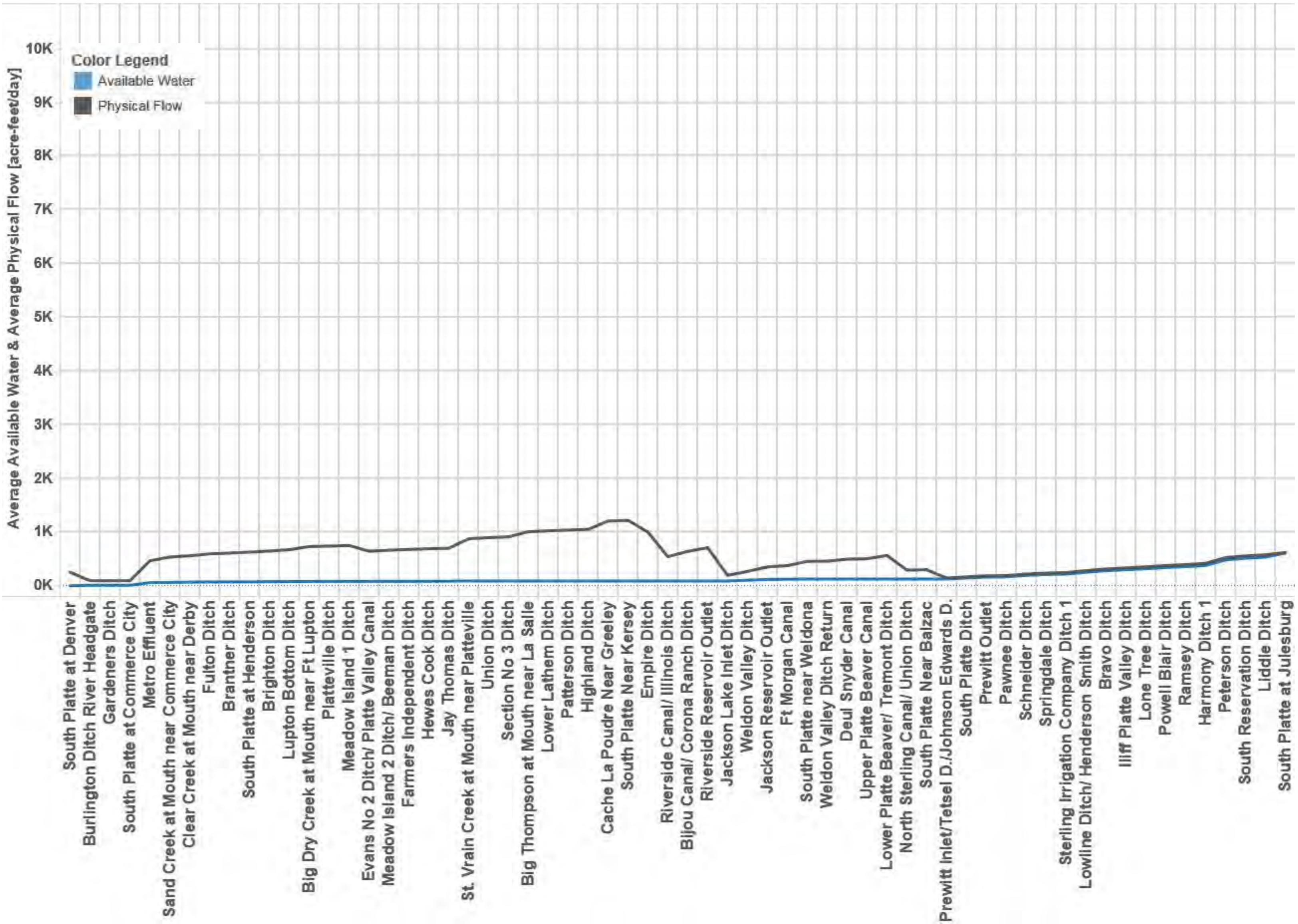


**Figure 8. Historical Available Water and Physical Flow for Dry Winter Season (February 2002)**

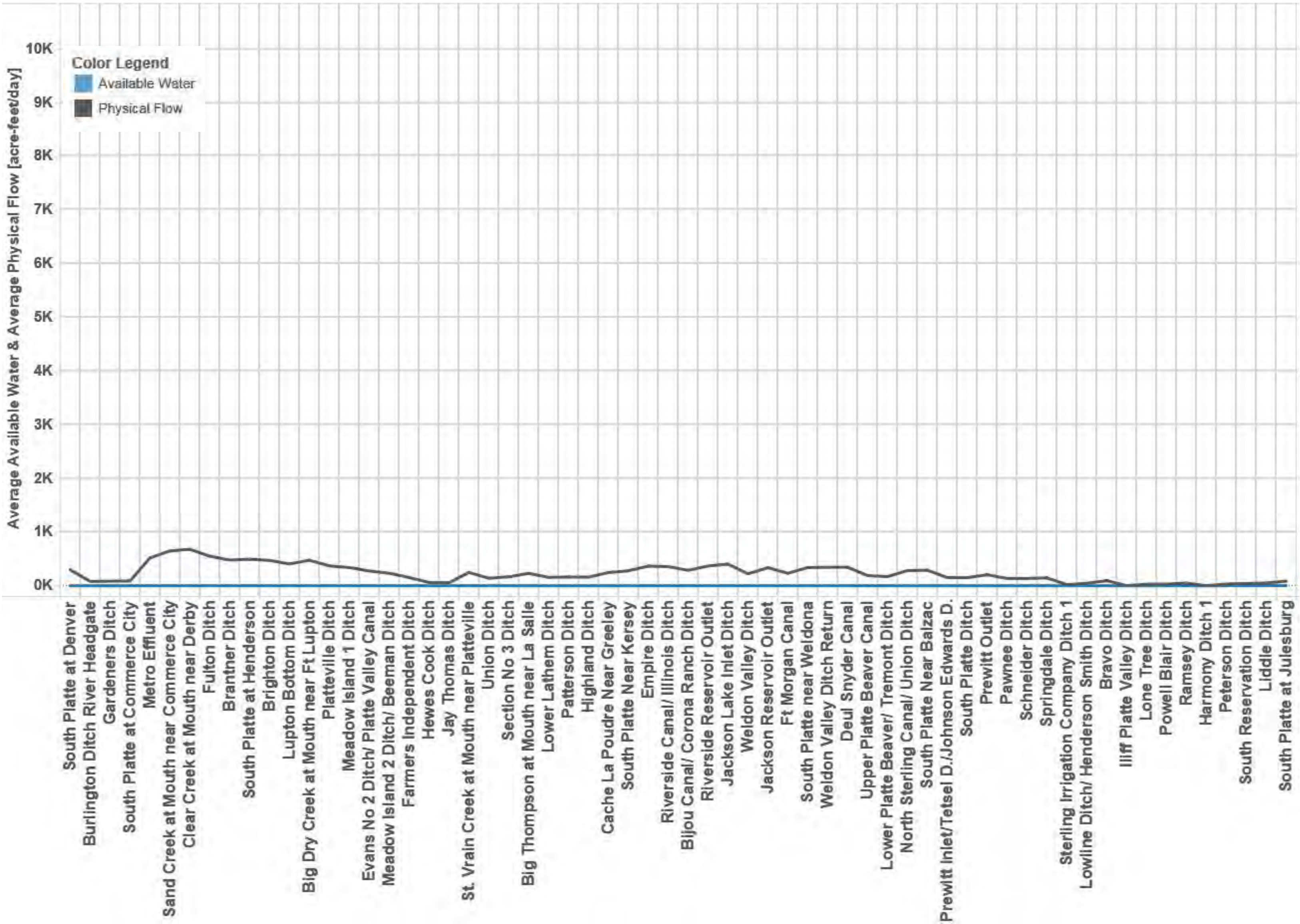


**Figure 9. Historical Available Water and Physical Flow for Dry Runoff Season (June 2002)**

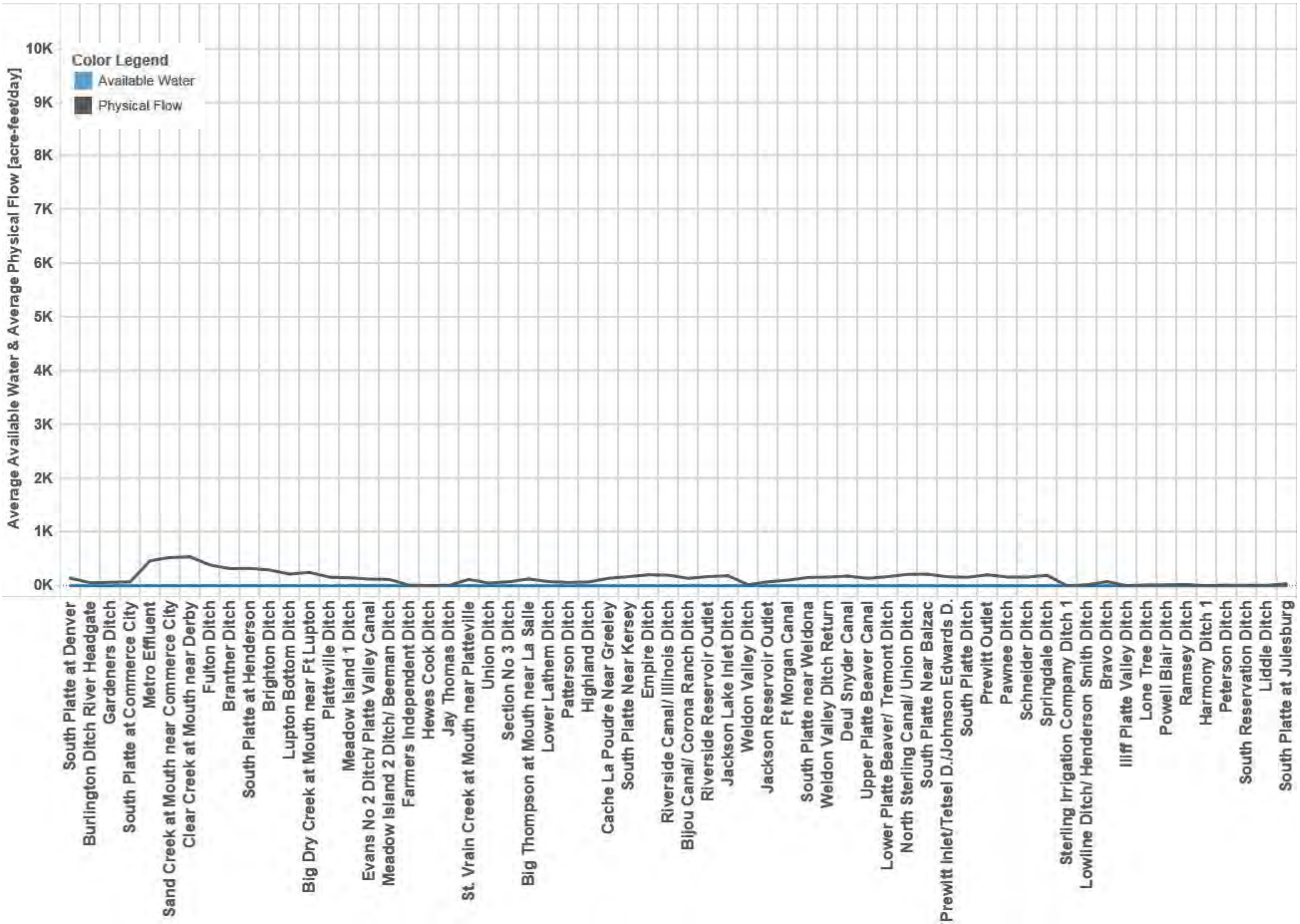


**Figure 10. Historical Available Water and Physical Flow for Dry Irrigation Season (August 2002)**

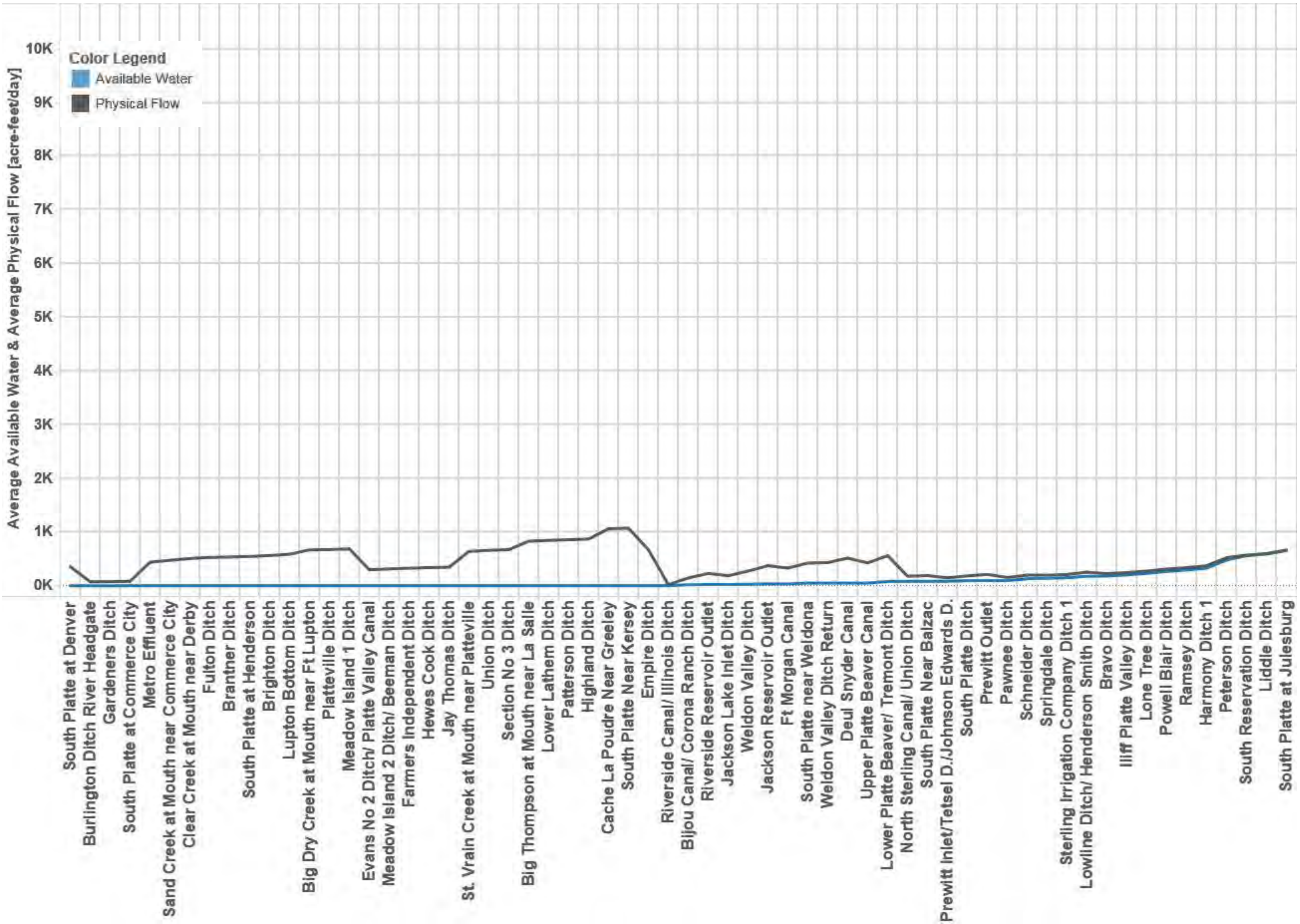


**Figure 11. Historical Available Water and Physical Flow for Normal Winter Season (February 2010)**

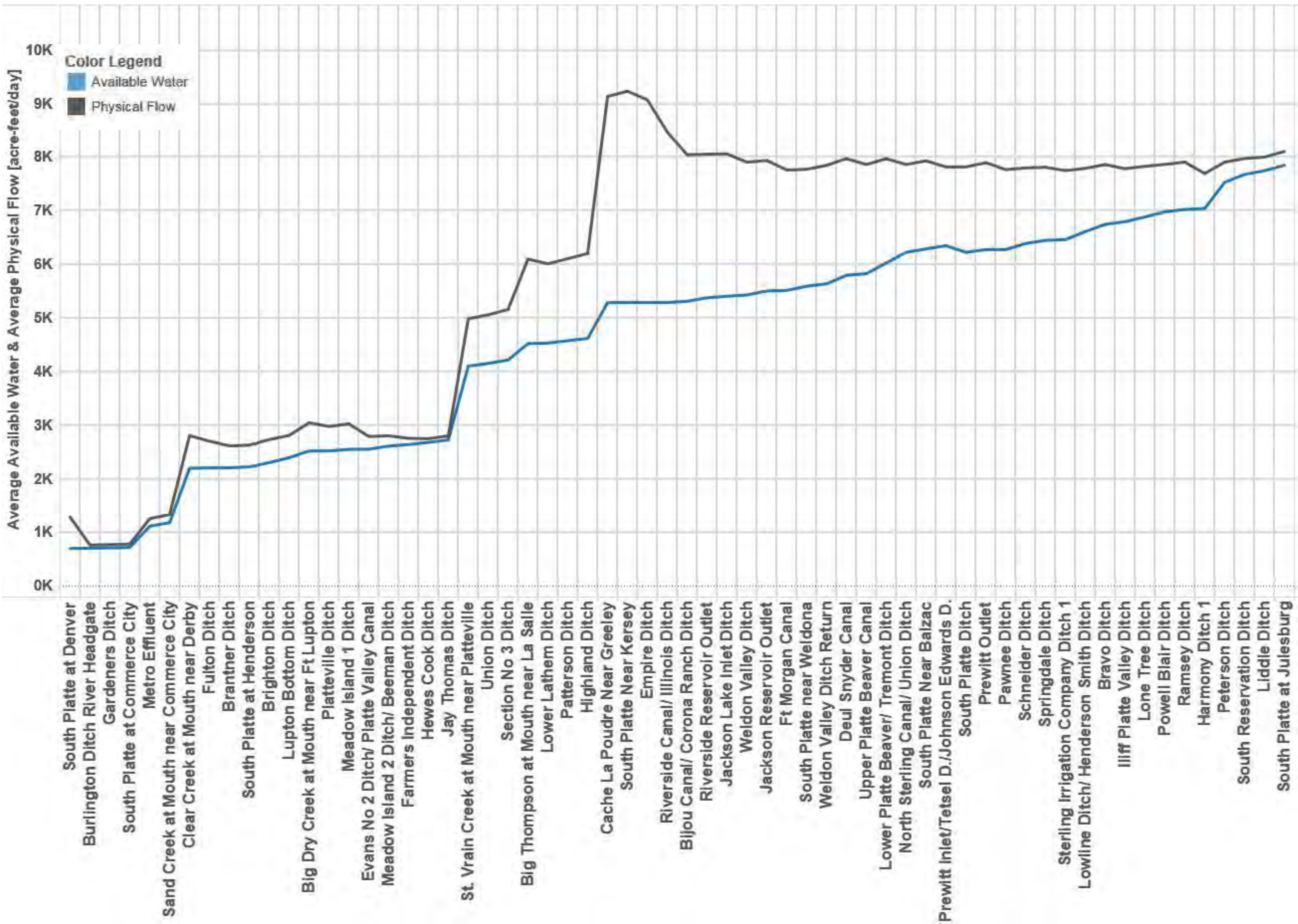


**Figure 12. Historical Available Water and Physical Flow for Normal Runoff Season (June 2010)**

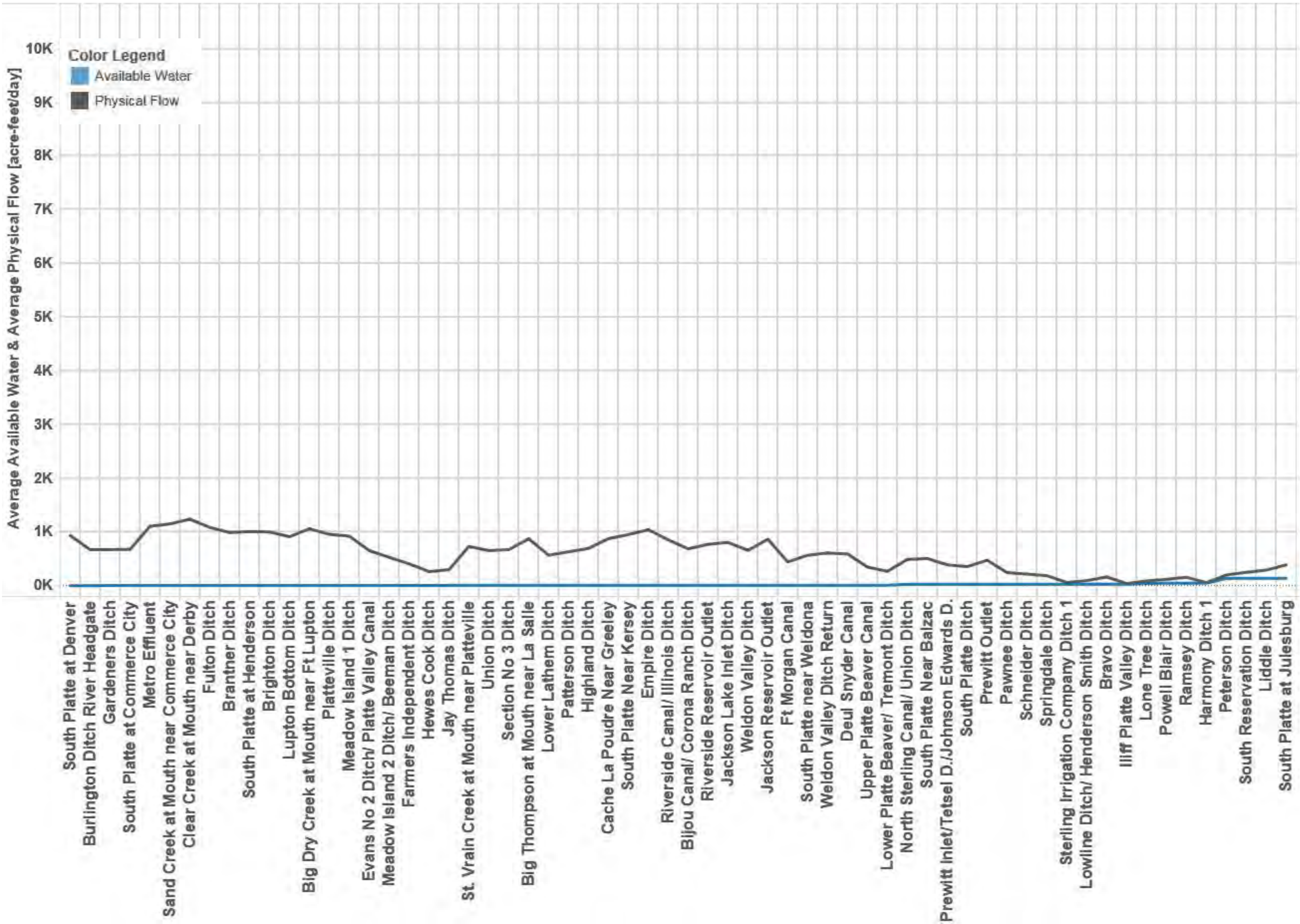


**Figure 13. Historical Available Water and Physical Flow for Normal Irrigation Season (August 2010)**

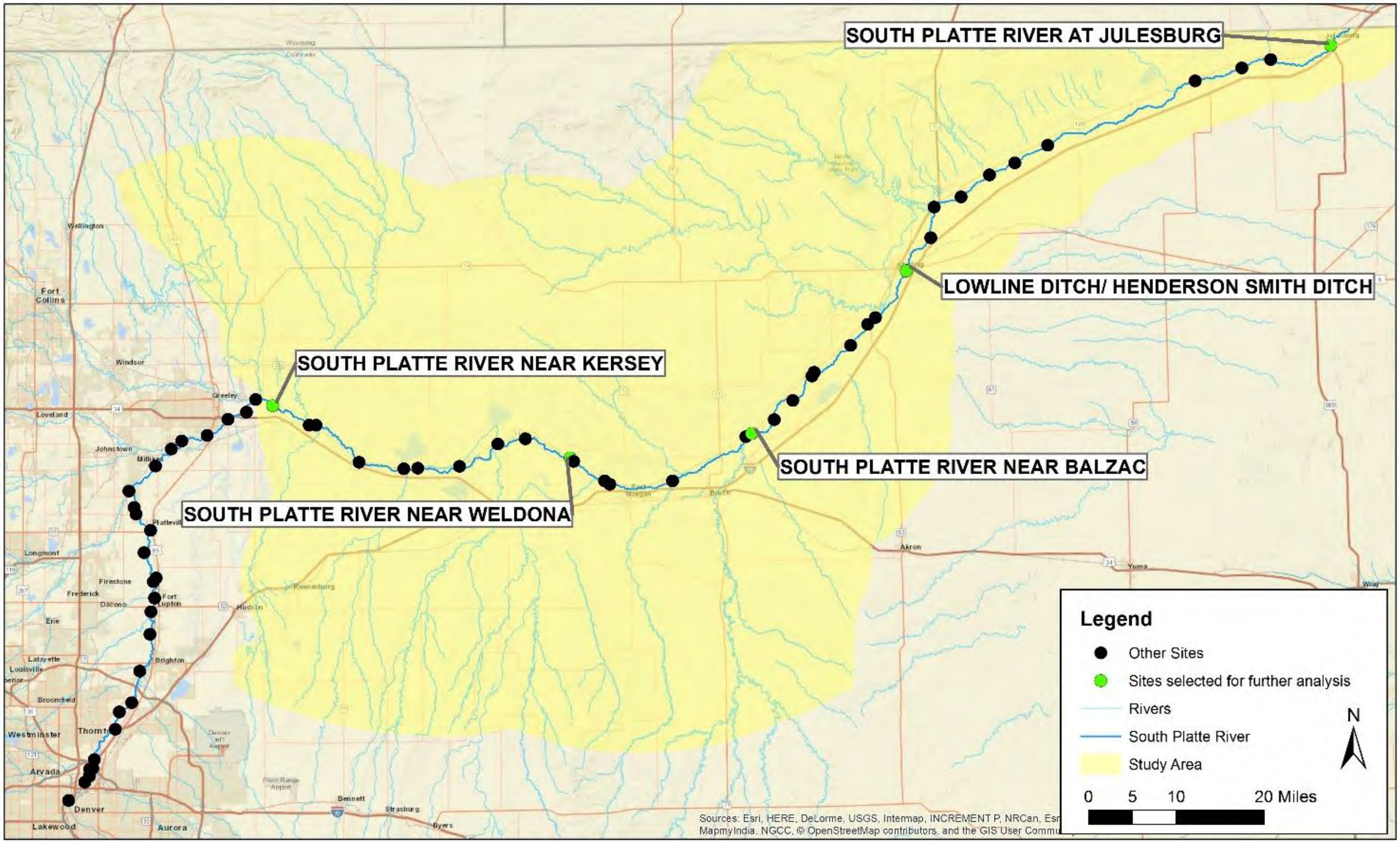


**Figure 14. Selected Locations for Additional Analysis**

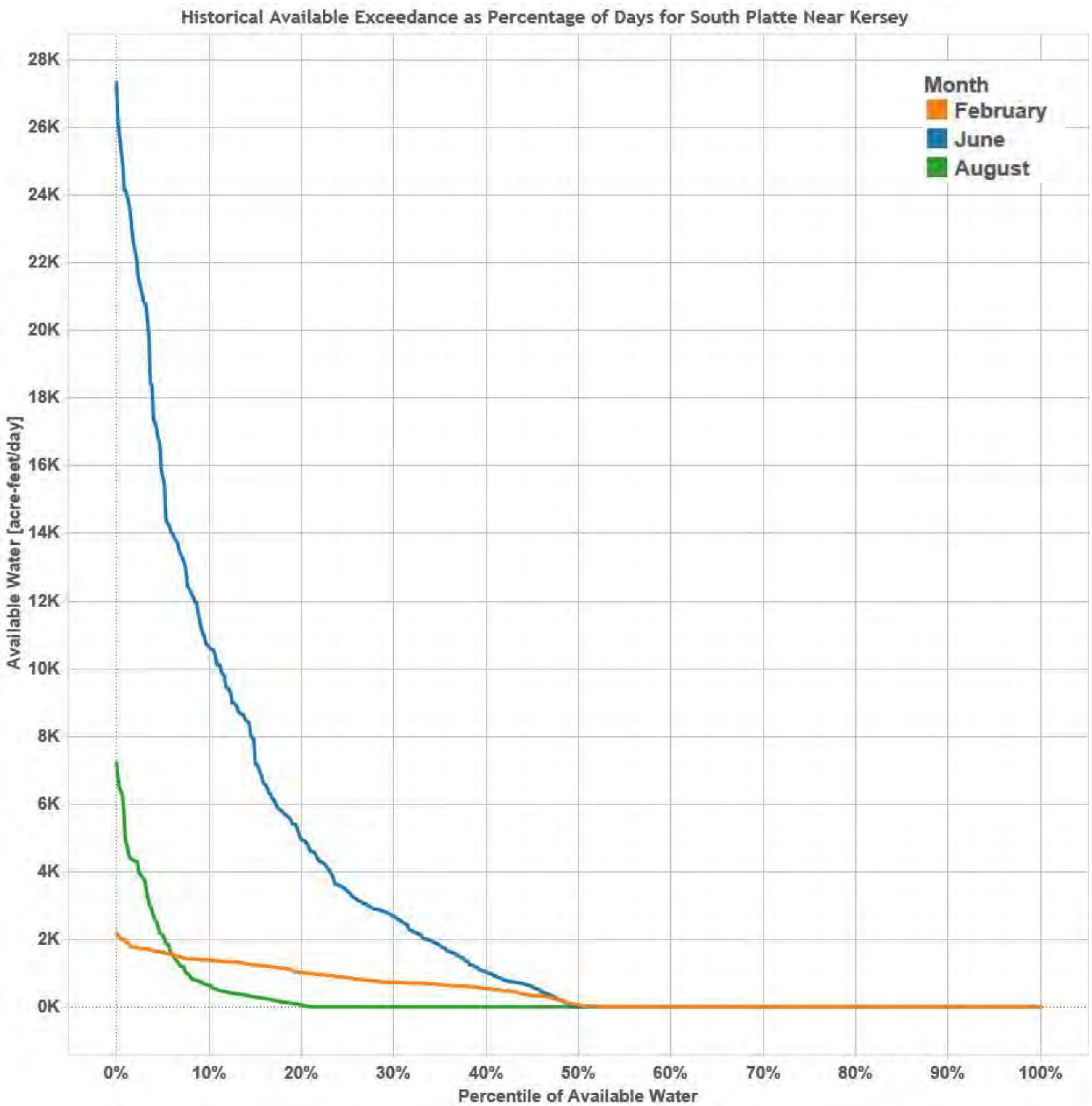


**Figure 15. Historical Daily Available Water Exceedance, South Platte near Kersey**

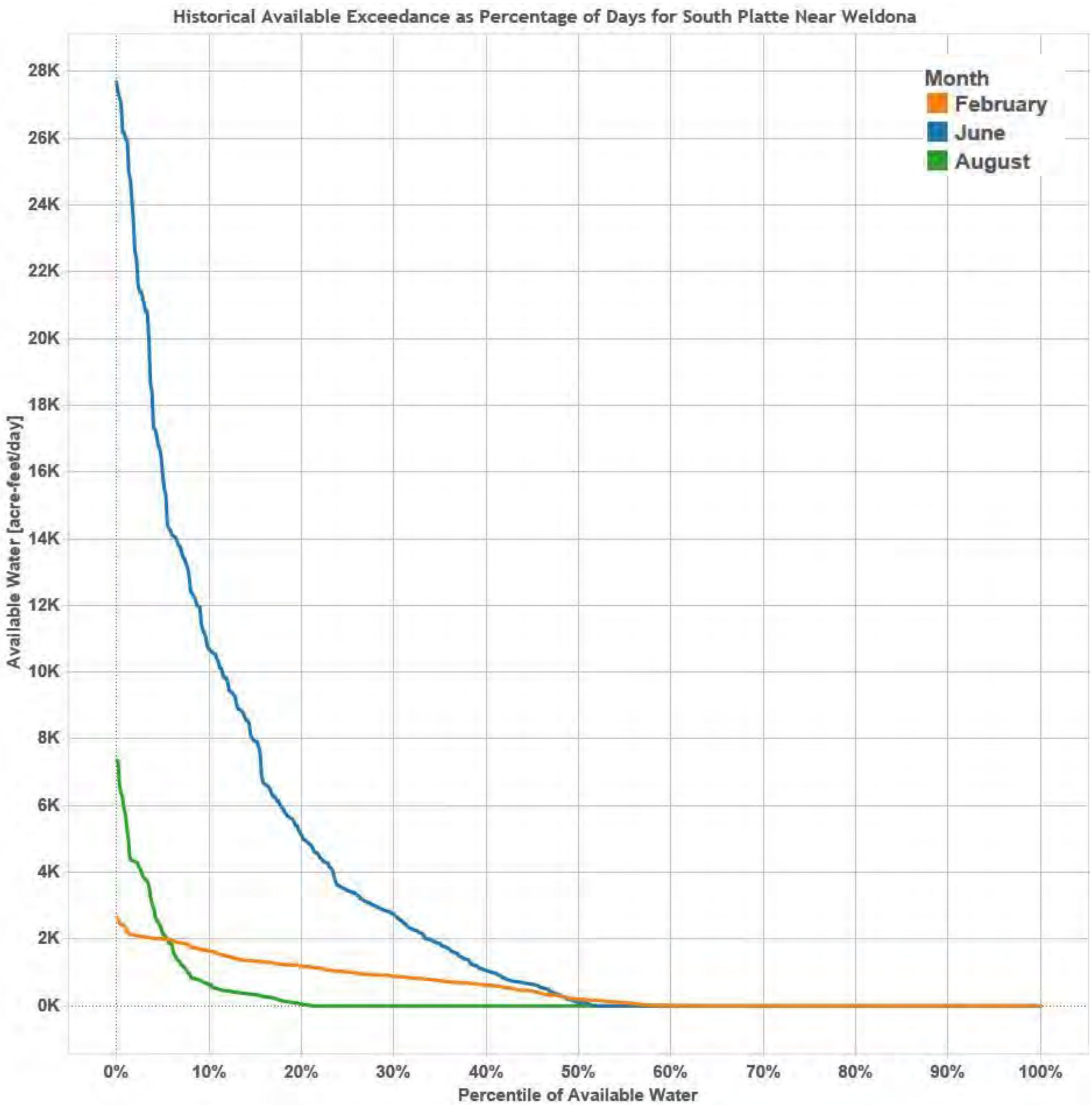


**Figure 16. Historical Daily Available Water Exceedance, South Platte near Weldona**

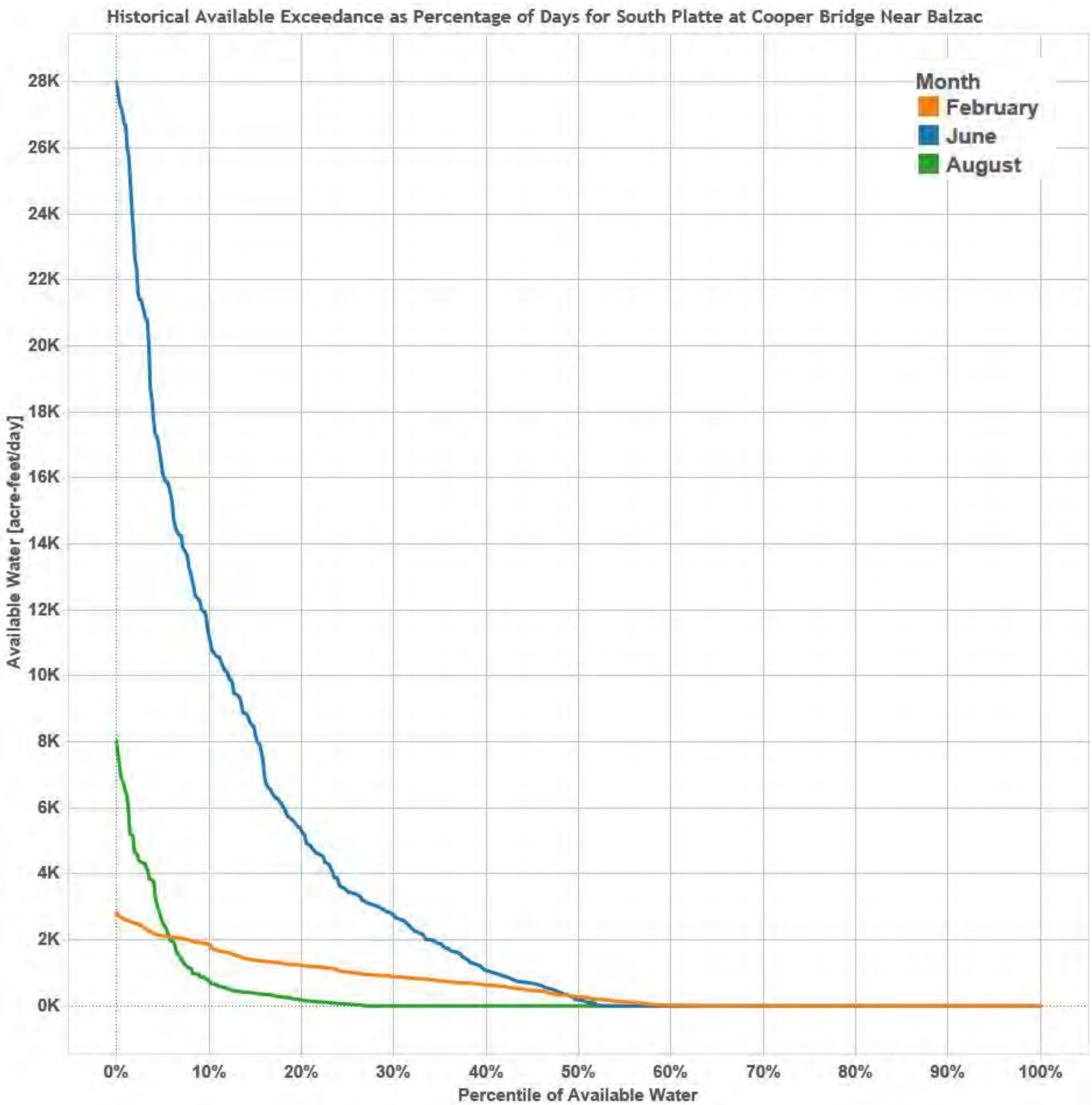


**Figure 17. Historical Daily Water Exceedance, South Platte near Balzac**

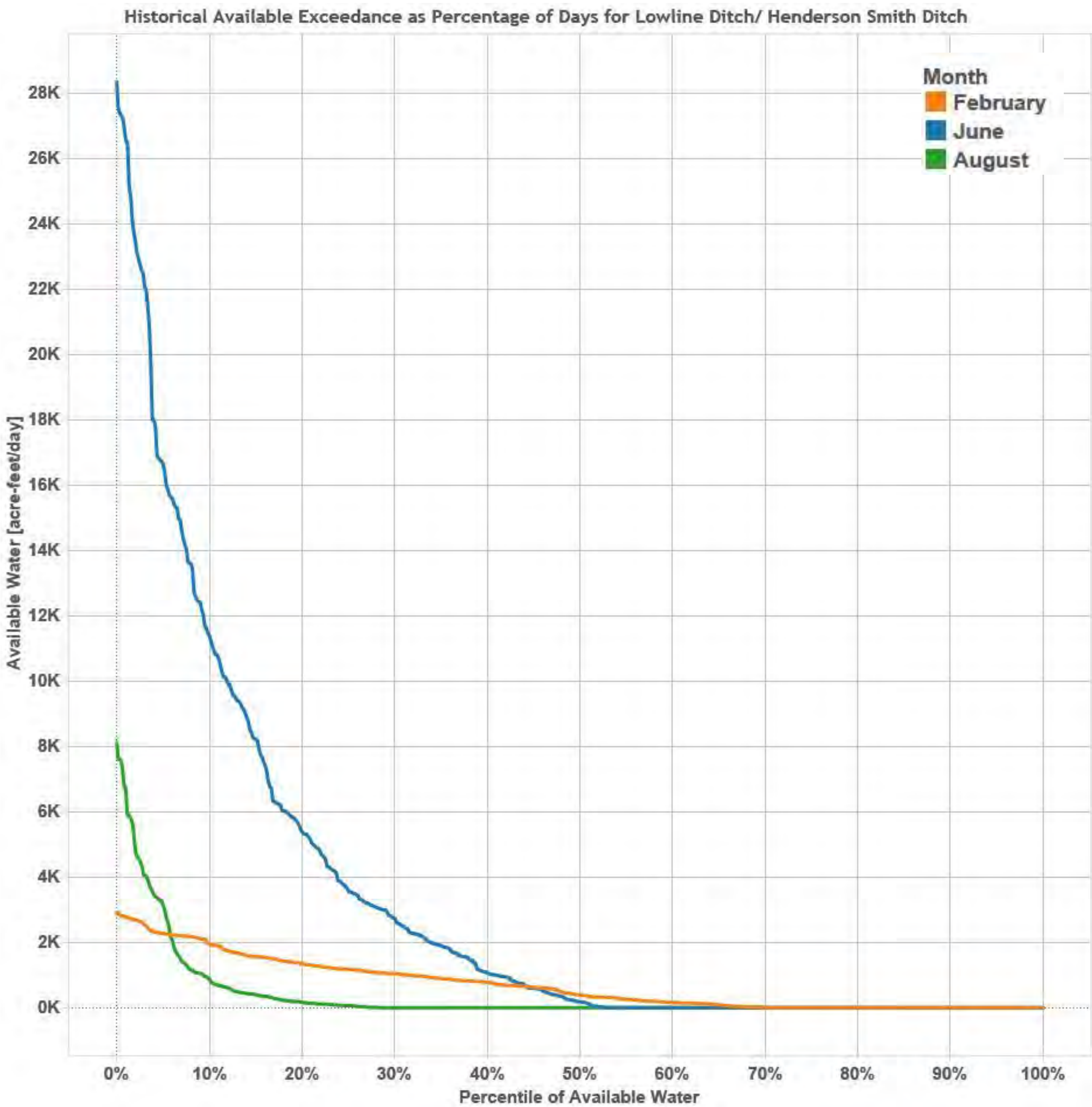


**Figure 18. Historical Daily Available Water Exceedance, Lowline Ditch/ Henderson Smith Ditch**

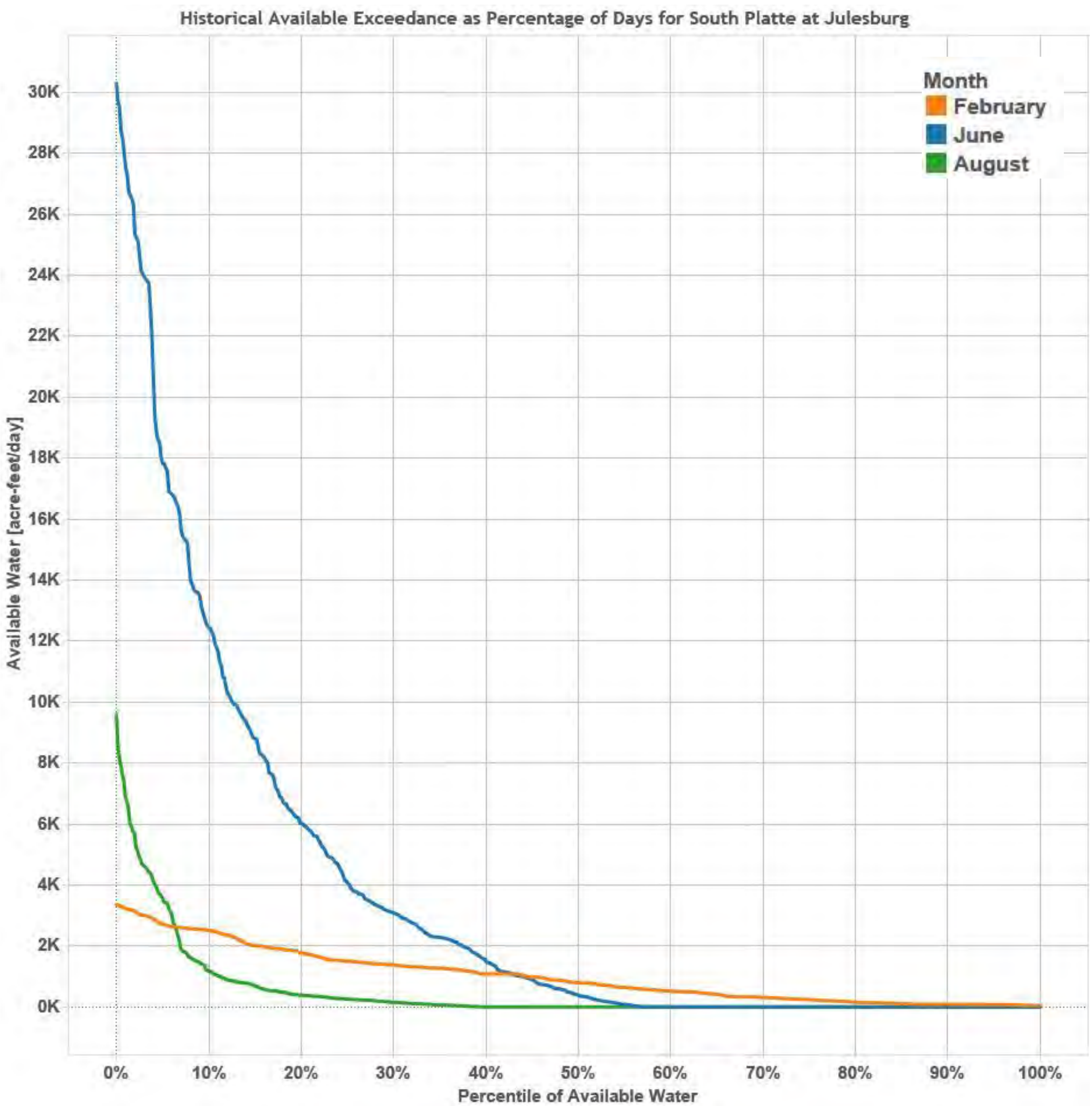


**Figure 19. Historical Daily Available Water Exceedance, South Platte at Julesburg**

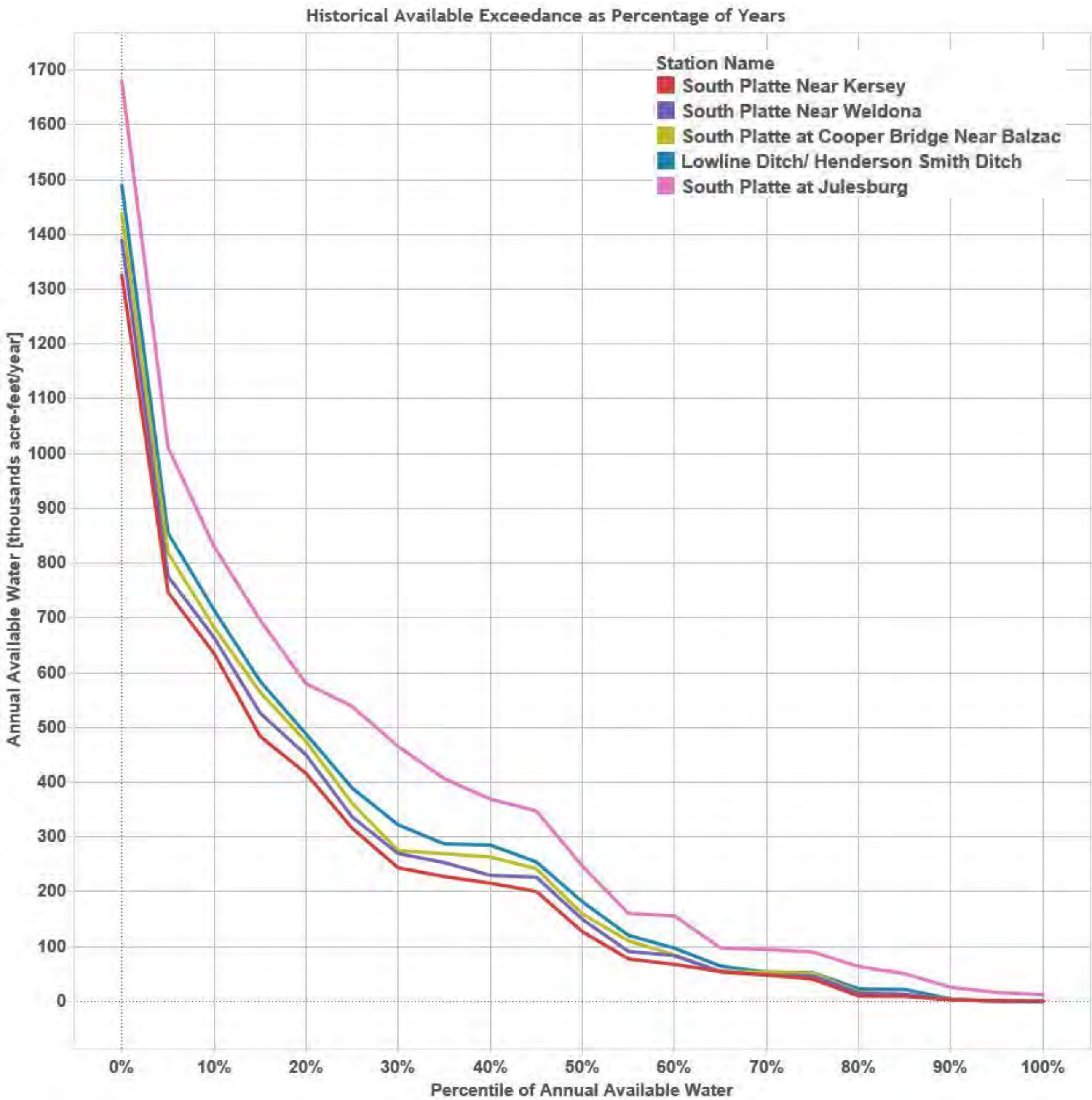


**Figure 20. Historical Annual Available Water Exceedance**

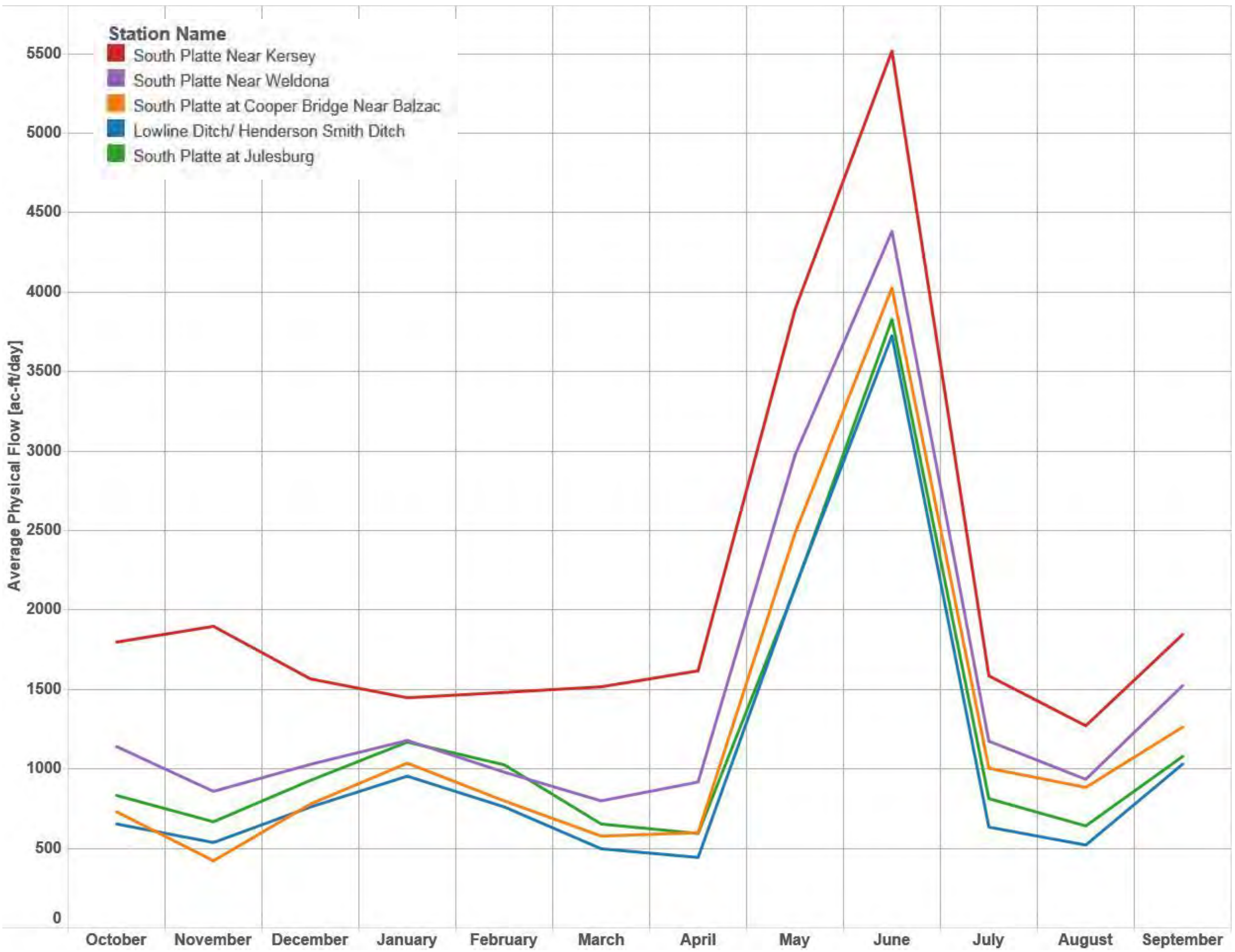


**Figure 21. Average Monthly Physical Flows**

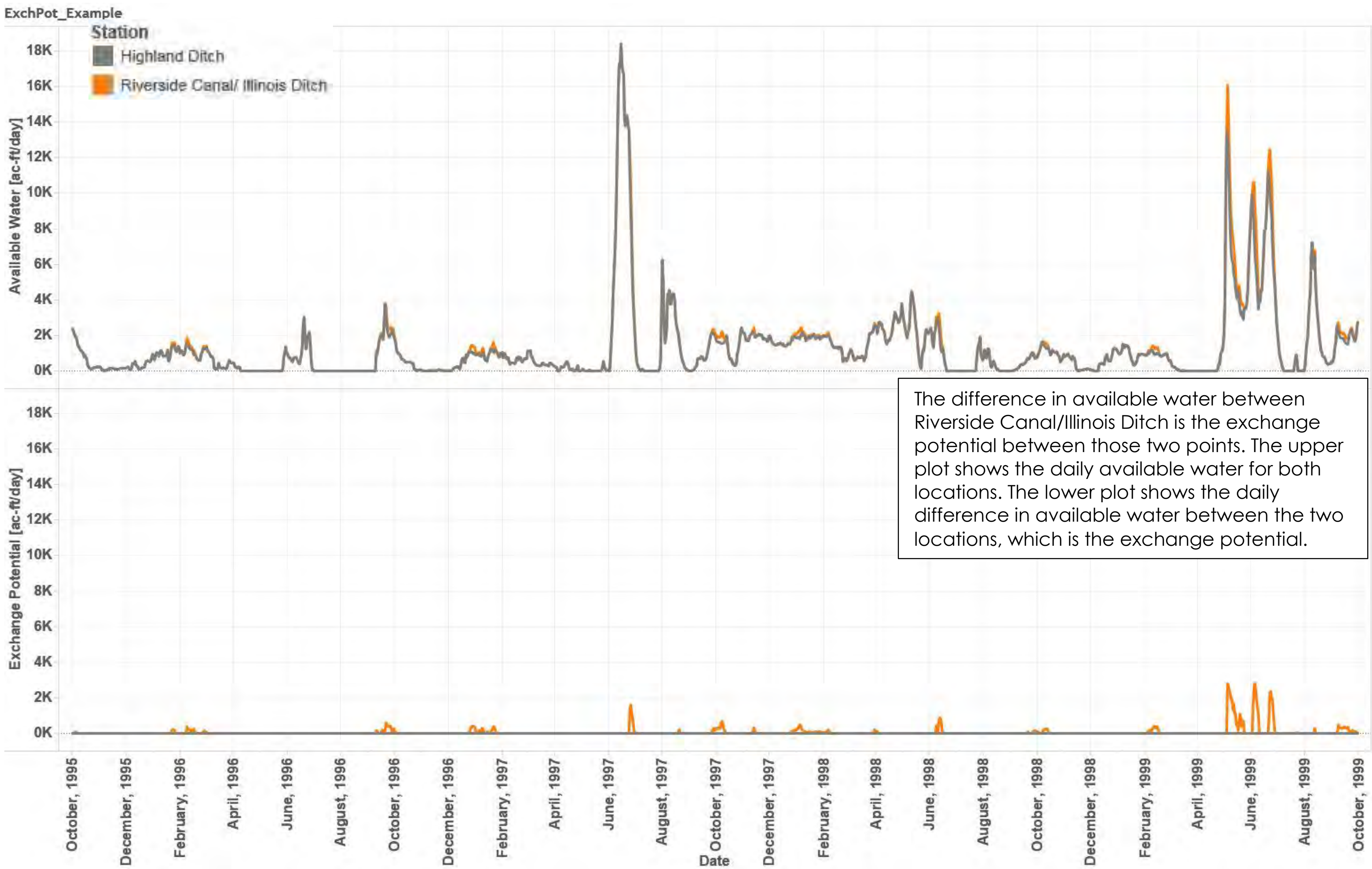


**Figure 22. Example Exchange Potential between Highland Ditch and Riverside Canal/ Illinois Ditch**

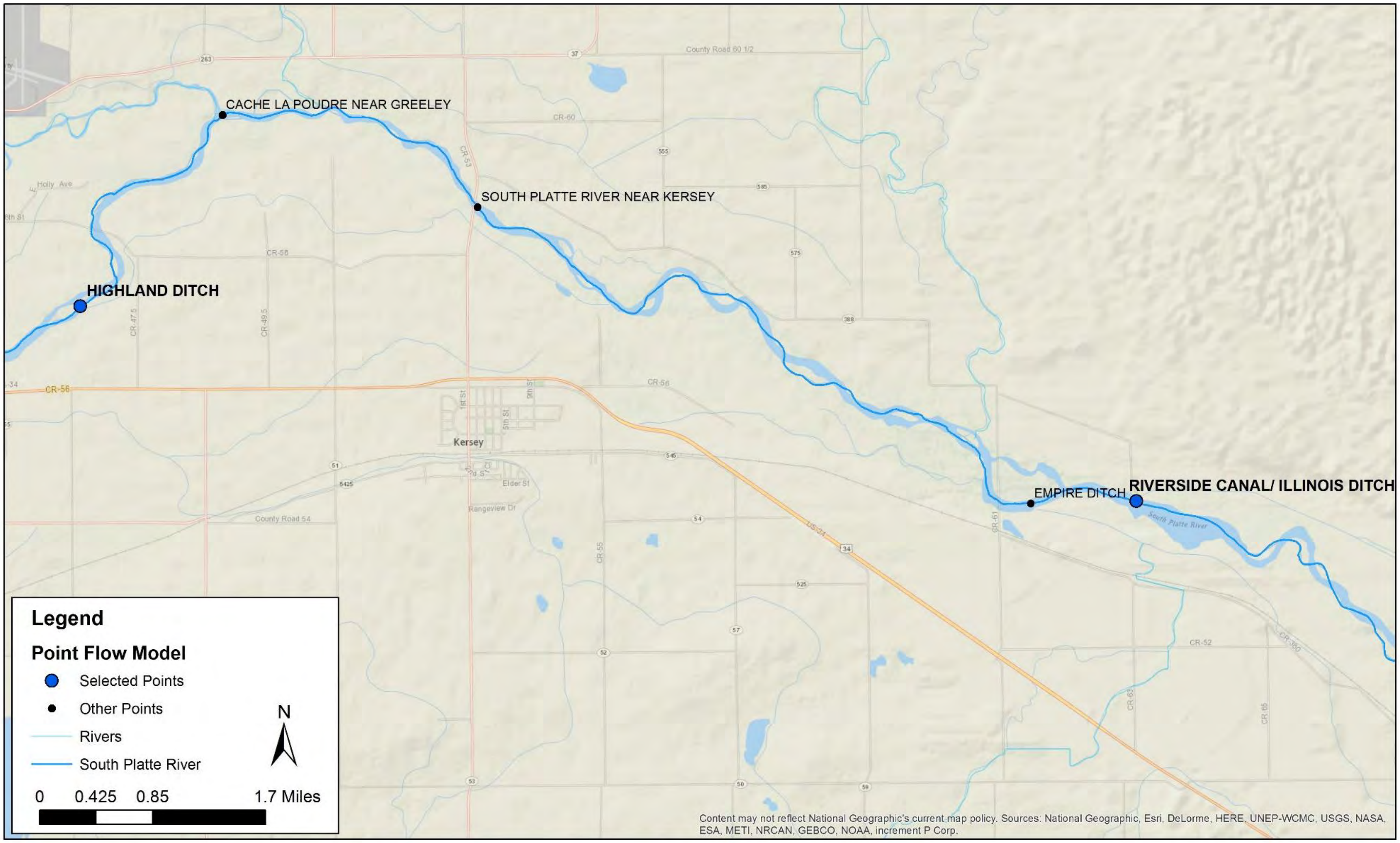


**Figure 23. Highland Ditch and Riverside Canal/ Illinois Ditch Locations**

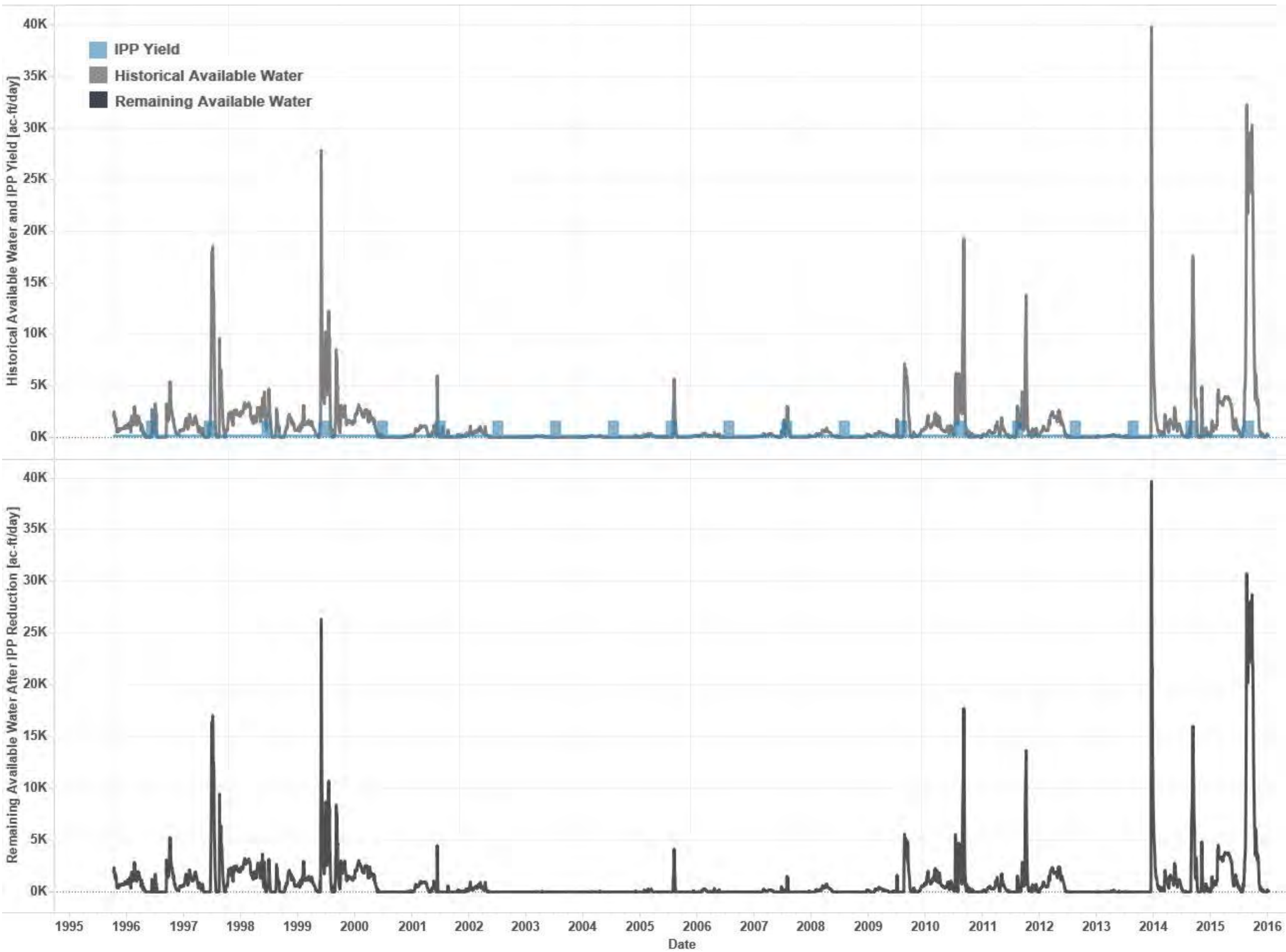


**Figure 24. Remaining Available Water after IPP Adjustment for South Platte at Julesburg**

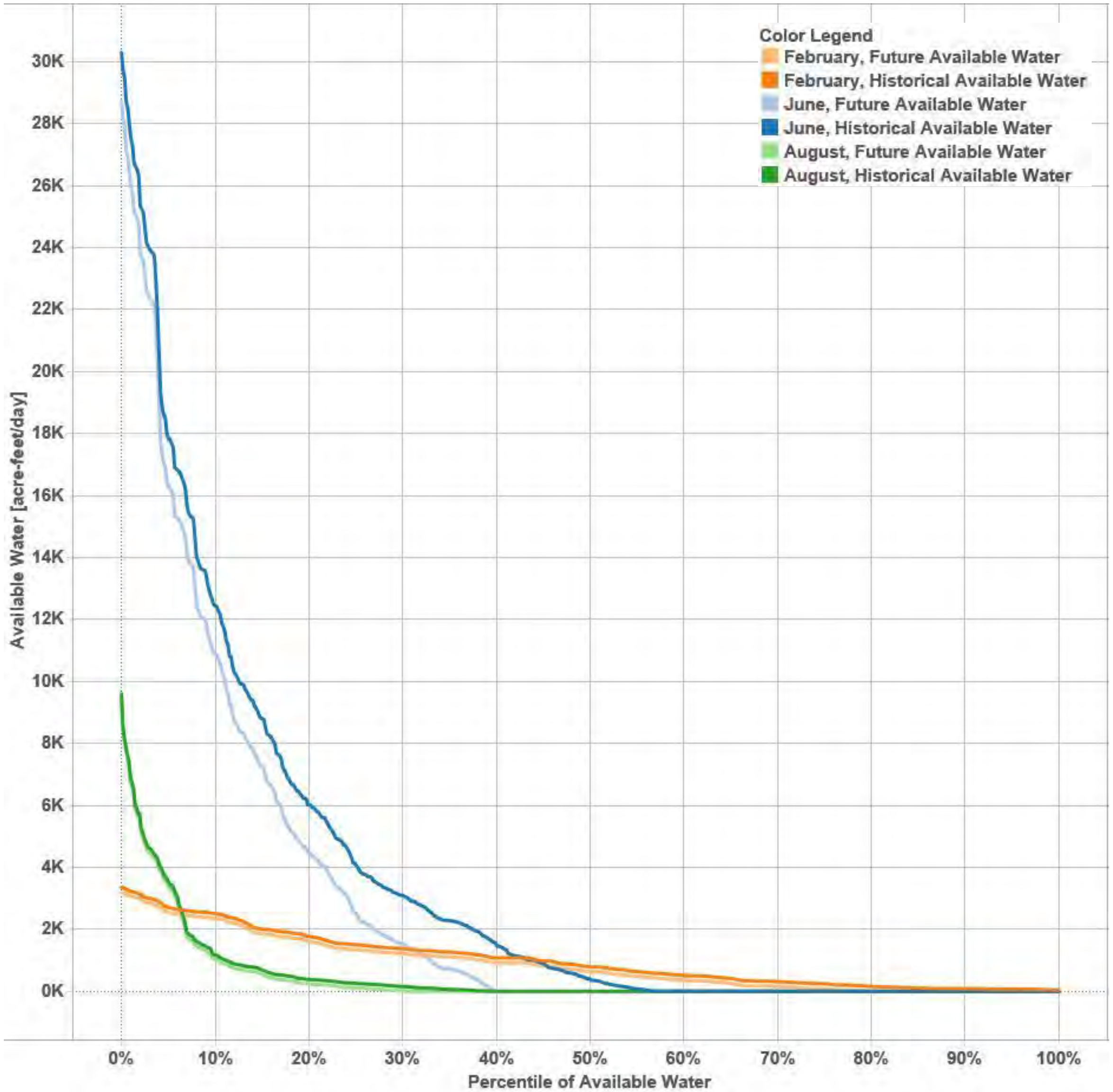


**Figure 25. Historical and Future Available Water by Month for South Platte at Julesburg Gage**

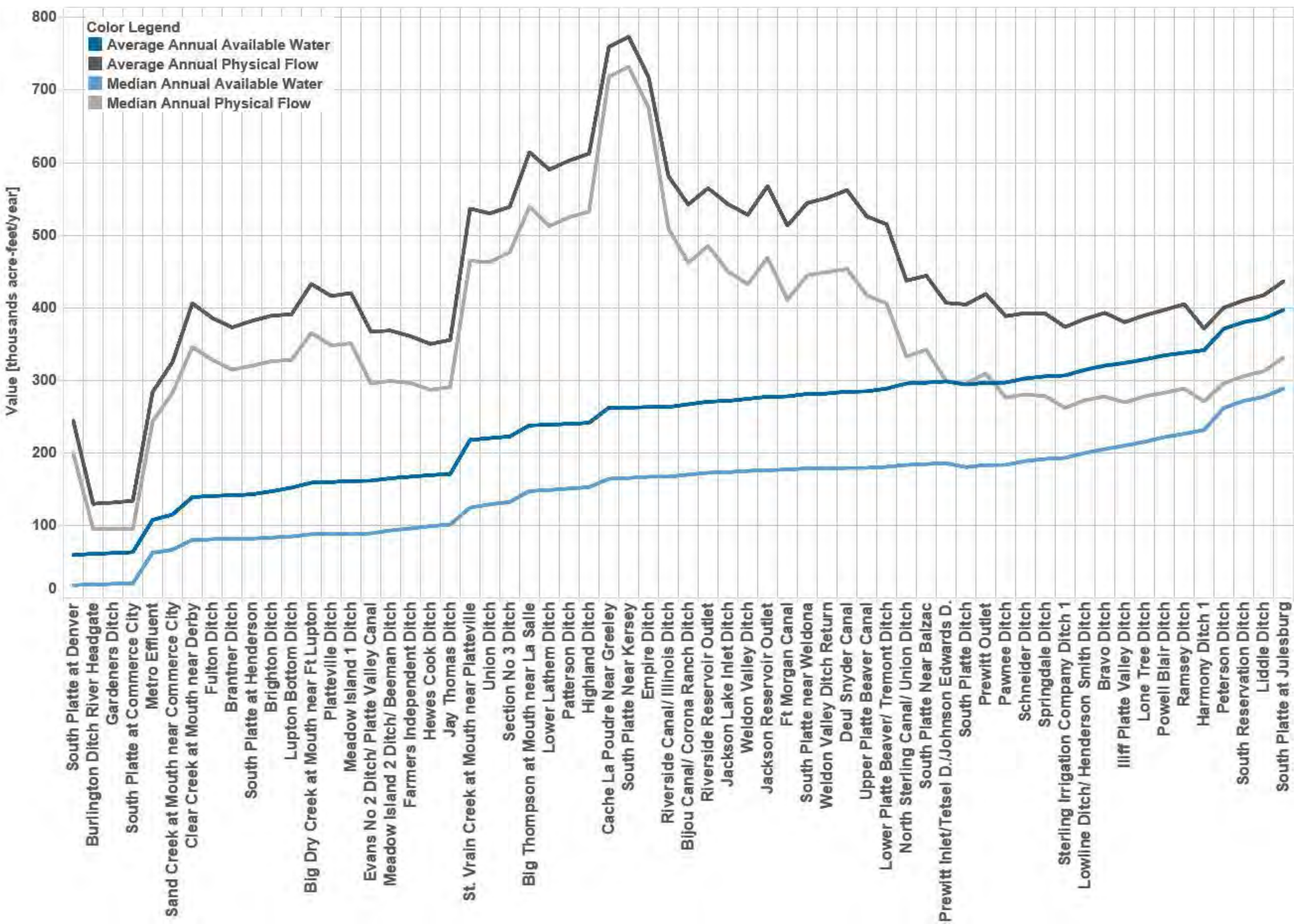


**Figure 26. Historical Average and Median Physical Flow and Available Water**

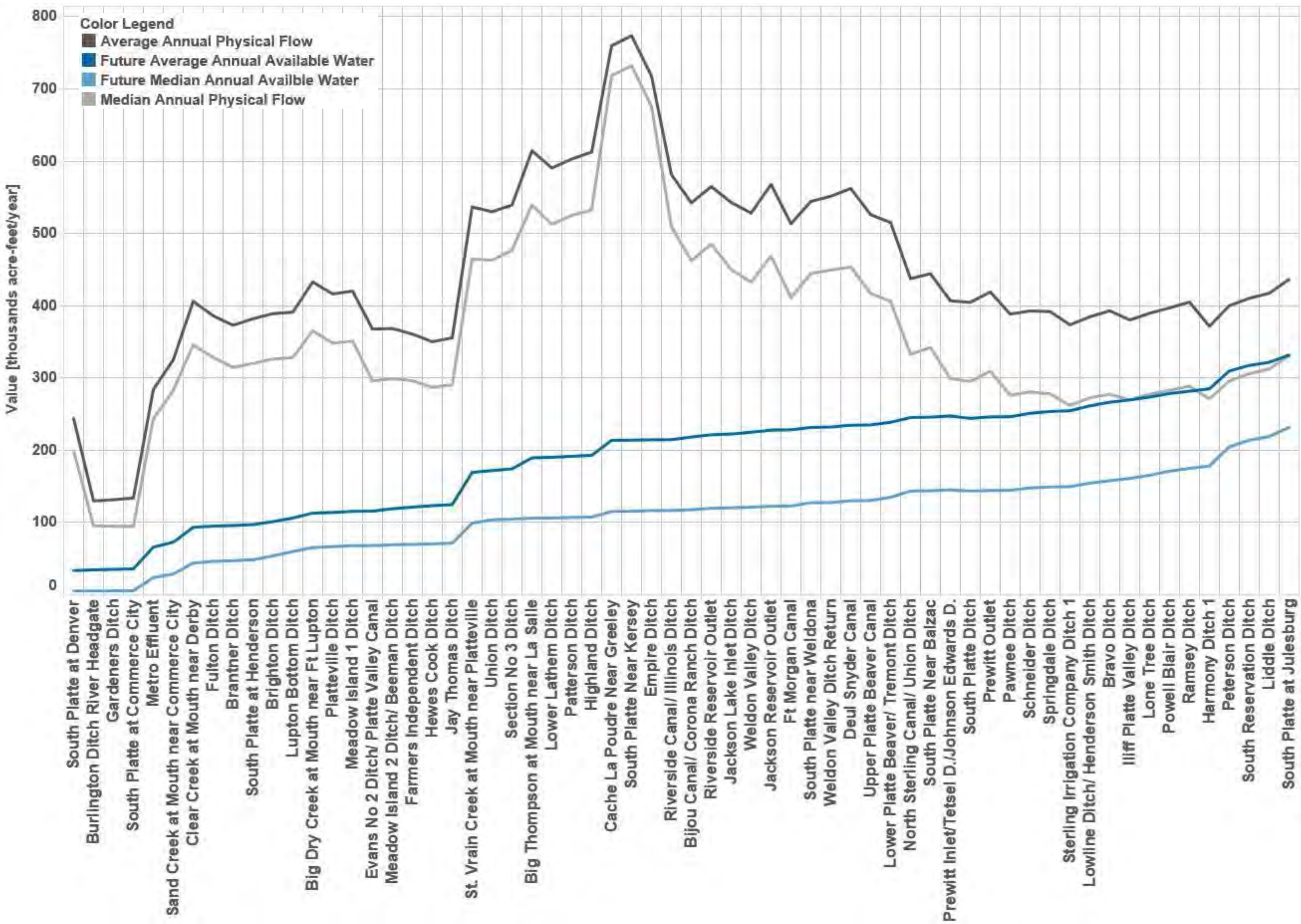


**Figure 27. Future Average and Median Physical Flow and Available Water**

# APPENDIX F – DEMANDS TM

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# SPSS Draft Memorandum

**To:** Chip Paulson, Stantec
**From:** Leonard Rice Engineers, Inc.
**Date:** July 7, 2017
**Project:** South Platte Storage Study
**Subject:** Task 2.1: Water Demands

---

The purpose of this memo is to document the methodology used to quantify agricultural and municipal & industrial (M&I) water demands for the South Platte Storage Study (SPSS). Estimates of the magnitude and location of water demand were needed for the feasibility analysis of potential storage sites.

## Approach

A simplified approach for estimating water demands was adopted for the SPSS. Because no specific users of SPSS water have been identified, and because many different storage options were investigated, a standardized approach to determining demands for storage scenarios was needed. This approach allowed for a consistent comparison of storage scenarios on the basis of their ability to meet demands in the South Platte Basin.

For the purpose of the SPSS, water demand is defined as the future agricultural or M&I gap or shortage, assuming implementation of select identified projects and processes (IPPs). Future demands were used rather than existing demands to match with the use of future condition hydrology for the SPSS supply analysis.

The State of Colorado's 2010 Statewide Water Supply Initiative (SWSI 2010) was utilized as the basis for information about the water demands within the SPSS study area. Once the potential South Platte Basin water demands were quantified, the agricultural and M&I demands were distributed along the South Platte River into demand reaches based on major stream gages.

<u>Demand Reaches</u>

To simplify the analysis of demands that could be met from SPSS storage sites, future demand estimates were aggregated by stream reach along the South Platte. From upstream to downstream, the demand reaches utilized for the SPSS include:

- Upstream of the South Platte River at Denver Gage (Upstream of Denver Gage)
- South Platte River at Denver gage to South Platte River Near Kersey gage (Denver to Kersey)
- South Platte River Near Kersey gage to South Platte River at Cooper Bridge near Balzac gage (Kersey to Balzac)
- South Platte River at Cooper Bridge near Balzac gage to South Platte River at Julesburg gage (Balzac to Julesburg)

<u>Agricultural Demand</u>

Derivation of the SPSS agricultural demands was based on the SWSI 2010 analysis of estimated 2050 agricultural demand by basin as described in SWSI 2010 Appendix I – Technical Memorandum State of Colorado Current and 2050 Agricultural Demands. According to SWSI 2010, future irrigated acres in the South Platte basin may decrease by 47,000 to 58,000 acres due to urbanization alone, under low and high population growth scenarios, respectively. The South Platte basin is one of the basins wherein the largest expected loss of irrigated acres due to urbanization is expected to occur.

2050 agricultural demands in SWSI 2010 consider a number of factors including, but not limited to, historical agricultural water use and irrigated acreage, urbanization of existing irrigated lands, agricultural to municipal water transfers, and water management decisions. The impact of these factors on future agricultural demands was quantified in SWSI 2010 based on future growth estimates, municipal water demand gaps that will be met by 2050, and interviews with water management agencies across the state. Based on the factors considered in developing the 2050 agricultural demands and shortages, we have assumed that implementation of IPPs is implicit in the 2050 shortages.

SWSI 2010 defines agricultural shortage as the difference between the water supply limited consumptive use and the irrigation water requirement of the irrigated lands. Within the South Platte Basin, SWSI 2010 found the current agricultural shortage to be 379,000 AF and the 2050 agricultural shortage to be 274,000 AF. Based on these results, SWSI 2010 concluded that the 2050 agricultural shortage in the South Platte Basin would be 72.3% (274,000/379,000 = 72.3%) of the current agricultural shortage.

To determine current agricultural demand, SWSI 2010 considered the current extent of irrigated acreage and the associated irrigation water requirement and shortage within each Water District. The Water District specific current agricultural demands were then summed to determine the agricultural demands and shortages for the South Platte Basin. The methodology used for estimating the 2050 agricultural shortage in SWSI 2010 did not look at the individual Water Districts', instead it looked at the South Platte Basin as a whole.

Therefore for the SPSS, following process was used to develop and distribute the future agricultural shortage by SPSS demand reach:

1. The 10-year average agricultural demand shortages by Water District were obtained from Appendix B to *Appendix I – Technical Memorandum State of Colorado Current and 2050 Agricultural Demands* of SWSI 2010.

2. The 10-year average current agricultural demand shortage for each Water District was then multiplied by 72.3% to calculate the future agricultural demand.

3. Each Water District was associated with a SPSS demand reach based on the location of irrigated area. The agricultural demand was further broken out as being mainstem or tributary based on the sources of water used to satisfy a majority of the irrigated area within each District.

The calculation of future agricultural demand by SPSS demand reach is presented in Table 1 below.

**TABLE 1**
**Calculation of Future Agricultural Demands**
(all values in AFY)

| | SWSI 2010 Current Ag Demand | | | Calculated Future Ag Demand | | |
|---|---|---|---|---|---|---|
| **Demand Reach** | **Water District** | **Mainstem** | **Tributary** | **Water District** | **Mainstem** | **Tributary** |
| **Upstream of Denver Gage** | WD8 | | 1,542 | WD8 | | 1,115 |
| | WD9 | | 369 | WD9 | | 267 |
| | *Reach Total* | - | *1,911* | *Reach Total* | - | *1,382* |
| **Denver to Kersey** | WD2 | 98,738 | | WD2 | 71,388 | |
| | WD3 | | 90,505 | WD3 | | 65,435 |
| | WD4 | | 39,756 | WD4 | | 28,744 |
| | WD5 | | 40,656 | WD5 | | 29,394 |
| | WD6 | | 20,928 | WD6 | | 15,131 |
| | WD7 | | 125 | WD7 | | 90 |
| | *Reach Total* | *98,738* | *191,970* | *Reach Total* | *71,388* | *138,794* |
| **Kersey to Balzac** | WD1 | 64,515 | | WD1 | 46,644 | |
| | *Reach Total* | 64,515 | - | *Reach Total* | 46,644 | - |
| **Balzac to Julesburg** | WD64 | 15,732 | | WD64 | 11,374 | |
| | *Reach Total* | *15,732* | - | *Reach Total* | *11,374* | - |
| **BASIN TOTALS** | | **178,985** | **193,881** | | **129,406** | **140,176** |

| Scaling Factor | 72.3% |
|---|---|

The demand for agricultural water is not consistent throughout the year; instead it varies based on factors such as crop demand for water, outside temperatures, and well pumping and corresponding depletions. For the purpose of SPSS we determined the monthly distribution for agricultural water in wet, dry, and average years based on the irrigation water requirement for irrigated lands in Water Division 1 and representative depletion patterns for irrigation well users.

Development of the monthly distribution for agricultural water started with an evaluation of the amount of irrigated lands satisfied by surface water supplies versus the amount of irrigated lands satisfied by both surface water and ground water supplies. Our analysis found that, of the average annual 512,081 acres irrigated in Water Districts 1, 2, and 64, 41% of irrigated lands are supplied by surface water sources alone and 59% of irrigated lands are supplied by both surface water and ground water sources.

To determine the agricultural demand pattern for irrigated lands satisfied by surface water supplies alone, we relied upon data contained in the State of Colorado's SP2008 StateCU model. This model utilizes a study period of 1950 through 2006 and provides information to calculate, among other things, the irrigation water requirement for irrigated lands throughout the South Platte basin. For the purpose of SPSS, 2002 was selected as a representative dry year and 1983 was selected as a representative wet year. Utilizing the SP2008 StateCU model we developed an average annual agricultural demand pattern for irrigated lands based on the irrigation water requirements for all irrigated area as well as the agricultural demand pattern for irrigated lands in the representative dry and wet years.

To determine the agricultural demand pattern for irrigated lands satisfied by surface water and ground water supplies, we obtained the projected well depletion patterns, prior to application of replacement supplies, from Central Colorado Water Conservancy District (CCWCD) and Lower South Platte Water Conservancy District (LSPWCD). Utilizing projected well depletion patterns for the two Districts we developed an aggregated pattern of well depletions representative of well users throughout the SPSS study area.

Finally, to develop a single agricultural demand pattern representative of all irrigated lands within the SPSS study area we assumed that 41% of the agricultural demand pattern would be represented by the wet, dry, and average irrigation water requirement demand patterns for lands satisfied by surface water supplies alone, and 59% of the agricultural demand pattern would be represented by the aggregated pattern of well depletions for lands satisfied by surface water and ground water supplies.

Table 2 provides the monthly agricultural demand pattern for the South Platte basin in wet, dry and average years, presented as a percentage of the total annual agricultural demand.

**TABLE 2**
**Agricultural Demand Pattern**
(all values are % of total demand)

| Month | Average Year | Dry Year (2002) | Wet Year (1983) |
|---|---|---|---|
| Jan | 5.8% | 6.3% | 5.3% |
| Feb | 5.5% | 6.0% | 5.1% |
| Mar | 4.8% | 5.2% | 4.4% |
| Apr | 4.7% | 5.8% | 3.7% |
| May | 7.3% | 8.2% | 3.9% |
| Jun | 12.3% | 12.8% | 7.3% |
| Jul | 16.3% | 15.7% | 20.0% |
| Aug | 15.2% | 12.7% | 20.5% |
| Sep | 10.9% | 9.8% | 14.0% |
| Oct | 6.6% | 6.2% | 6.1% |
| Nov | 4.7% | 5.1% | 4.3% |
| Dec | 5.9% | 6.4% | 5.4% |

<u>Municipal Demand</u>

Derivation of the SPSS municipal demands was based on the SWSI 2010 analysis of 2050 M&I gap analysis as described in SWSI 2010 *Appendix H – State of Colorado 2050 Municipal & Industrial Water Use Projections* and SWSI 2010 *Appendix J – Technical Memorandum 2050 Municipal and Industrial Gap*

*Analysis*. According to SWSI 2010, the 2050 M&I and self-supplied industrial (SSI) water supply gap is a function of the 2050 net new water needs minus the 2050 IPPs.

SWSI 2010 presents the South Platte Basin M&I demands in terms of regions. The SWSI South Platte regions which represent the SPSS study area include Lower South Platte Region, Northern Region, Denver Metro, and South Metro. For the purpose of SPSS, the SWSI 2010 M&I demands were disaggregated by County, then assigned to a SPSS demand reach based on the Counties within each reach. The following details the process used to develop and distribute the future M&I demands by SPSS demand reach:

1. For the SPSS study area, the SWSI regions and counties represented in each of those regions were identified.

2. The medium M&I gap at alternative IPP success rate of 60% for each SWSI region represented in the SPSS study area was obtained from *Appendix J – Technical Memorandum 2050 Municipal and Industrial Gap Analysis* of SWSI 2010

3. Based on the data available in Table 3-2 of SWSI 2010 *Appendix H – State of Colorado 2050 Municipal & Industrial Water Use Projections,* the amount of demand gap by county was calculated as the difference between the 2050 high water demand with passive conservation minus the 2008 water demand with passive conservation.

4. The SWSI 2010 medium gap at alternative IPP success rate was then distributed by county based on the percentage of demand gap by the counties within each SWSI region.

5. Based on the location of the majority of the population and future growth within each county, each county and the associated M&I demand was assigned to a specific SPSS demand reach.

The calculation of future M&I demands by county is presented in Table 3 below. Table 4 shows the association of county by SPSS demand reach.

**TABLE 3**
**Calculation of Future M&I Demands**
(all values in AFY)

| SWSI Region | Medium Gap at Alternative IPP Success Rate (60%) | Counties Represented | 2050 High Water Demand w/ Passive Conservation | 2008 Water Demand w/ Passive Conservation | 2050 Demand minus 2008 Demand | % of Demand Gap by County w/in SWSI Region | Distribute Gap Based on Difference Between 2008 and 2050 Demand |
|---|---|---|---|---|---|---|---|
| Lower Platte Region | 16,600 | Morgan | 16,000 | 8,000 | 8,000 | 57.1% | 9,486 |
| | | Logan | 14,000 | 8,000 | 6,000 | 42.9% | 7,114 |
| | | Sedgwick | 1,000 | 1,000 | - | 0.0% | - |
| | | Washington | 2,000 | 2,000 | - | 0.0% | - |
| Northern | 85,900 | Boulder | 88,000 | 59,000 | 29,000 | 17.3% | 14,828 |
| | | Larimer | 114,000 | 59,000 | 55,000 | 32.7% | 28,122 |
| | | Weld | 137,000 | 53,000 | 84,000 | 50.0% | 42,950 |
| Denver Metro | 59,300 | Adams | 125,000 | 69,000 | 56,000 | 36.8% | 21,847 |
| | | Broomfield | 20,000 | 11,000 | 9,000 | 5.9% | 3,511 |
| | | Denver | 160,000 | 112,000 | 48,000 | 31.6% | 18,726 |
| | | Jefferson | 133,000 | 94,000 | 39,000 | 25.7% | 15,215 |
| South Metro | 71,500 | Arapahoe | 173,000 | 104,000 | 69,000 | 56.6% | 40,439 |
| | | Douglas | 93,000 | 46,000 | 47,000 | 38.5% | 27,545 |
| | | Elbert | 9,000 | 3,000 | 6,000 | 4.9% | 3,516 |
| **TOTAL** | **233,300** | | | | | | **233,300** |

The typical monthly pattern for M&I demands will be calculated by others.

## Results

Table 4 below presents a summary of the agricultural and M&I future demands by SPSS reach.

**TABLE 4**
**SPSS Agricultural and M&I Demands by SPSS Demand Reach**
(all values in AFY)

| | Ag Future Demand | | | M & I Future Demand | | Total |
|---|---|---|---|---|---|---|
| **Demand Reach** | **Water District** | **Mainstem** | **Tributary** | **County** | **Total** | **Demand** |
| **Upstream of Denver Gage** | WD8 | | 1,115 | Denver | 18,726 | |
| | WD9 | | 267 | Arapahoe | 40,439 | |
| | | | | Jefferson | 15,215 | |
| | | | | Douglas | 27,545 | |
| | | | | Elbert | 3,516 | |
| | *Reach Total* | *-* | *1,382* | *Reach Total* | *105,441* | ***106,823*** |
| **Denver to Kersey** | WD2 | 71,388 | | Weld | 42,950 | |
| | WD3 | | 65,435 | Adams | 21,847 | |
| | WD4 | | 28,744 | Larimer | 28,122 | |
| | WD5 | | 29,394 | Boulder | 14,828 | |
| | WD6 | | 15,131 | Broomfield | 3,511 | |
| | WD7 | | 90 | | | |
| | *Reach Total* | *71,388* | *138,794* | *Reach Total* | *111,259* | ***321,440*** |
| **Kersey to Balzac** | WD1 | 46,644 | | Morgan | 9,486 | |
| | *Reach Total* | 46,644 | - | *Reach Total* | 9,486 | ***56,130*** |
| **Balzac to Julesburg** | WD64 | 11,374 | | Logan | 7,114 | |
| | | | | Sedgwick | 0 | |
| | | | | Washington | 0 | |
| | *Reach Total* | *11,374* | - | *Reach Total* | *7,114* | ***18,489*** |
| **BASIN TOTALS** | | **129,406** | **140,176** | | **233,300** | **502,882** |

Source of Data:

- Agricultural demand based on the following parts of SWSI 2010:
    - Appendix I – Technical Memorandum State of Colorado Current and 2050 Agricultural Demands
    - Appendix B to Appendix I - South Platte and Rio Grande Basins Agricultural Demands Methodology
        - Table 2. South Platte Basin 10-year Average Agricultural Demand

- M&I demand based on the following parts of SWSI 2010:
    - Appendix H - State of Colorado 2050 Municipal & Industrial Water Use Projections
        - Table 3-2 M&I Forecast by County with Passive Conservation
    - Appendix J - Technical Memorandum 2050 Municipal and Industrial Gap Analysis

# APPENDIX G – WATER QUALITY TM

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**SPSS Memorandum**

**To:** Chip Paulson - Stantec

**From:** Leonard Rice Engineers, Inc.

**Date:** September 18, 2017

**Subject:** Task 2.2 - Water Quality Analysis for South Platte Storage Study Water Demands

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In support of Subtask 2.2 of the South Platte Storage Study ("SPSS"), Leonard Rice Engineers, Inc. ("LRE"), has performed a high level analysis of water quality requirements for demand types within the study area. The elements included in this water quality analysis include:

- The identification of Colorado Water Quality Control Commission's ("WQCC") stream segments within the Study Area and those stream segments further analyzed as part of SPSS.
- A categorization of water demand types and associated water quality requirements consistent with the WQCC State Use Classification (e.g., domestic water supply, recreation, agriculture, aquatic life).
- A review of water quality indicators for the water use categories and review of the WQCC Regulation 93 list of impaired waters to identify segments where water quality requirements are not met.
- A summary of the WQCC List of Impaired Waters data by identified segments, and selection of key indicators to be used for screening water quality for future potential storage projects.
- And a list of treatment needs to be considered when storing and utilizing South Platte sources for multi-use benefits.

**WQCC Stream Segments within the Study Area**

The SPSS Study Area overlaps portions or the entirety of nine counties as shown on Figure 1. Throughout the State of Colorado, WQCC has adopted designated use classifications and numeric water quality standards for the State's streams, lakes, and reservoirs. Segments are divided by designated use classifications and numeric water quality standards.

Stream segment use classifications are to protect uses of the respective stream segment. In Colorado there are five use classification groups: (1) agriculture; (2) aquatic life; (3) domestic water supply; (4) recreation; and (5) wetlands. Aquatic life classifications include (1) cold water aquatic life class 1; (2) warm water aquatic life class 1; or (3) class 2 waters which can be either cold and warm water aquatic life. The classification use for recreation is further subdivided into class "E" (existing primary contact use), class "P" (potential primary contact use), class "N" (not primary contact use), and class "U" (undetermined use).

LRE identified seven stream segments: two river segments on the mainstem of the South Platte River, two segments containing associated tributaries of the South Platte River, and three segments for lakes and reservoirs in the SPSS Study Area. LRE then assessed each segment to determine if it should be included or excluded from further consideration in this phase of the SPSS. Table 1 shows the seven individual stream segments in the Study Area, descriptions, designated use classifications, and reasoning for inclusion or exclusion of the segment from further review in this memo. Figure 1 shows the location of each of these seven segments.

Of the seven identified stream segments reviewed in Table 1, three segments were found to be key stream segments for the water quality review for selecting indictors to use as a screening-level assessment of water quality for the SPSS. The three stream segments identified for further review are:

- Mainstem of South Platte River from confluence with St. Vrain to Weld/Morgan County line (COSPMS01B);
- Mainstem of South Platte River from Weld/Morgan County line to the Colorado/Nebraska border (COSPLS01); and
- Jackson and North Sterling Reservoirs (a subset of COSPLS03).

Segments COSPLS02A, COSPLS02B, COSPLS04, COSPLS05, and portions of COSPLS03 which cover tributaries and smaller lakes/reservoirs to the South Platte River, were removed from further review because of the likelihood that the majority of the water to be diverted and stored in the storage projects evaluated as part of the SPSS will use water from the mainstem of the South Platte River. Further, the potential for expansion of existing reservoirs is greatest at the existing major lakes and reservoirs included in stream segment COSPLS03.

**Table 1**
**Summary of Potential Steam Segments Considered for Review**

| WQCC Segment ID | Description of Stream Segment | Designated Uses [a] | Need for Further Review |
|---|---|---|---|
| COSPMS01B | Mainstem of the South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan County Line | • Agriculture<br>• Aquatic Life Warm 2<br>• Recreation E<br>• Water Supply | **Yes**, segment covers portion of mainstem. |
| COSPLS01 [b] | Mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border | • Agriculture<br>• Aquatic Life Warm 2<br>• Recreation E<br>• Water Supply | **Yes**, segment covers portion of mainstem. |
| COSPLS02A | All tributaries to the South Platte River, including all wetlands, from the Weld/Morgan County line to the Colorado/Nebraska border, except for the specific listings in Segment 2b | • Agriculture<br>• Aquatic Life Warm 2<br>• Recreation E<br>• Water Supply | No, tributaries were excluded from review due to lower likelihood of site selection on tributaries. |
| COSPLS02B | All tributaries to the South Platte River, including all wetlands, north of the South Platte River and below 4,500 feet in elevation in Morgan County, north of the South Platte River in Washington County, north of the South Platte River and below 4,200 feet in elevation in Logan County, north of the South Platte River and below 3,700 feet in elevation in Sedgwick County, and the mainstems of Beaver Creek, Bijou Creek and Kiowa Creek from their sources to the confluence with the South Platte River, except for the portion of Beaver Creek from its source to the Fort Morgan Canal. | • Agriculture<br>• Aquatic Life Warm 2<br>• Recreation E | No, tributaries were excluded from review due to lower likelihood of site selection on tributaries. |
| COSPLS03 | Jackson Reservoir, Prewitt Reservoir, North Sterling Reservoir, Jumbo (Julesburg), Riverside Reservoir, Empire Reservoir, and Vancil Reservoir. | • Agriculture<br>• Aquatic Life Warm 1<br>• Recreation E<br>• Water Supply | **Yes**, segment includes lakes and reservoirs within which expansion or further site development may occur. |
| COSPLS04 | All lakes and reservoirs tributary to the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border, except for specific listings in Segments 3 and 5. | • Agriculture<br>• Aquatic Life Warm 2<br>• Recreation P<br>• Water Supply | No. The storage sites in this segment would primarily be filled with water from the South Platte River mainstem. |
| COSPLS05 | All lakes and reservoirs tributary to the South Platte River north of the South Platte River and below 4,500 feet in elevaton in Morgan county, north of the South Platte river in Washington County, north of the South Platte River and below 4,200 feet in elevation in Logan County, north of the South Platte River and below 3,700 feet in elevation in Sedgwick County, and the mainstems of Beaver Creek, Bijou Creek and Kiowa Creek from their sources to the confluence with the South Platte River, except for those specific listings in Segment 3. | • Agriculture<br>• Aquatic Life Warm 2<br>• Recreation E<br>• Water Supply | No. The storage sites in this segment would primarily be filled with water from the South Platte River mainstem. |

[a] Description of Uses:

| Table 1<br>Summary of Potential Steam Segments Considered for Review | | | |
|---|---|---|---|
| WQCC Segment ID | Description of Stream Segment | Designated Uses [a] | Need for Further Review |

**Agriculture** - These surface waters are suitable or intended to become suitable for irrigation of crops usually grown in Colorado and which are not hazardous as drinking water for livestock.
**Aquatic Life Warm 1** - These are waters that (1) currently are capable of sustaining a wide variety of warm water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions. Waters shall be considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of the abundance and diversity of specifies.
**Aquatic Life Warm 2** - These are waters that are not capable of sustaining a wide variety of cold or warm water biota, including sensitive species, due to physical habitat, water flows or levels, or uncorrectable water quality conditions that result in substantial impairment of the abundance and diversity of species.
**Recreation E** - These surface waters are used for primary contact recreation or have been used for such activities since November 28, 1975.
**Recreation P** - These surface waters have the potential to be used for primary contact recreation. This classification shall be assigned to water segments for which no use attainability analysis has been performed demonstrating that a recreation class N classification is appropriate, if a reasonable level of inquiry has failed to identify any existing primary contact uses of the water segment, or where the conclusion of a use attainability analysis is that primary contact uses may potentially occur in the segment, but there are no existing primary contact uses.
**Water Supply** - These surface waters are suitable or intended to become suitable for potable water supplies. After receiving standard treatment (defined as coagulation, flocculation, sedimentation, filtration, and disinfection with chlorine or its equivalent) these waters will meet Colorado drinking water regulations and any revisions, amendments, or supplements thereto.
[b] Qualifiers for segment are Water + Fish Standards.
Source: Regulation #38 Stream Classifications and Water Quality Standards Appendix 38-1, pp. 88, 124-126 and Regulation 31, Section 31.13 State Use Classifications.

## Data Sources

*Water Quality Standards*

Statewide numeric water quality criteria have been adopted by the WQCC as recommended levels that are protective of the different designated uses. Different uses may require different levels of protection; for example, aquatic life is more sensitive to zinc (e.g., 400 μ/L) than domestic water supply (e.g., 5,000 μ/L) or agriculture (2,000 μ/L). A copy of Regulation 31 *Basic Standards and Methodologies for Surface Water* is presented in Appendix A. Table I in Regulation 31 includes criteria for physical and biological parameters, Table II covers inorganics, and Tables III and IV cover metals. These statewide criteria are usually applied as water quality standards for individual segments. These criteria only become enforceable if they are adopted by WQCC as water quality standards for a specific segment.

In cases where the WQCC decides the statewide criteria are not appropriate values to assign to a particular segment, it can develop site-specific standards for that respective segment. These site-specific standards by stream segment are summarized in WQCC's Regulation 38, *Classifications and Numeric Standards*. Regulation 38 contains a table for each stream segment in the State, and identifies the use classifications for that reach, and show each water quality parameter as either (1) TVS (Regulation 31 Basic Standard) or (2) having an ambient quality-based standard or site-specific criteria for the particular stream segment. Figures 2-4 shows each of the three stream segments and the corresponding WQCC's Regulation 38 stream classifications and water quality standards associated for the respective segment. A copy of Regulation 38 and the site-specific standard tables for the three stream segments evaluated as part of SPSS are presented in Appendix B.

The Regulation 38 Water Quality Standards presented in Appendix B are highlighted to show and support the identification of key parameters to be used for the screening-level assessment presented herein. LRE recommends using the most stringent criteria under all of the designated use classifications in the stream segment for each parameter because of the high likelihood that the project evaluated and screened as part of the SPSS projects will be used for multiple types of beneficial use.

*Impaired Waters*

Under Section 303(d) of the Federal Clean Water Act, the State of Colorado is required to list waters where water quality standards are not met. Section 303(d) Impairment List integrates the WQCC stream segments to identify areas of impaired waters based on an evaluation of biological, chemical, and/or physical data. An additional list, the Monitoring and Evaluation List (M&E List), is comprised of waters for which there is some data available suggesting water quality problems may exist; however, the data are inadequate to support a determination of nonattainment at the time of evaluation by the State of Colorado. WQCC's Regulation 93, *Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List*, identifies all parameters by stream segments that do not meet water quality standards (i.e., 303(d) Impairment List) and/or have been placed on the M&E list. Figures 2-4 show each of the three stream segments and the identification of waters included on the Section 303(d) Impairment List. Copies of the Standard Attainment Assessment Summaries from Regulation 93 for the stream segments evaluated herein are included in Appendix C.

## WQCC Stream Segments Review of Classifications and Water Quality Standards

The information obtained from the data sources described above was compiled and used to identify key parameters within each SPSS stream segment. In addition, LRE reviewed publically available water quality data within each of the SPSS stream segments to understand the ambient water quality and to compare the ambient water quality to the water quality standards and the water quality criteria for each of the associated use classifications. Additional information about each stream segment and the selection of key parameters for the stream segments are further described below and summarized in Table 2. A detailed table compiling key information and selection of key parameters for each stream segment is presented in Appendix D.

*COSPMS01B Stream Segment*

COSPMS01B comprises the mainstem of the South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan County Line, as shown on Figure 2. The stream segment has agriculture, aquatic life warm 2, recreation E, and water supply as classified uses, as described in Table 1. COSPMS01B is listed as impaired for *E. coli* (physical and biological parameter) and two metal parameters: arsenic and manganese. No parameters are listed on the M&E List. Arsenic does have temporary modification for the stream segment which is set to expire in 2021 under Regulation 38.

WQCD has determined that the water is segment COSPMS01B does not meet the water quality standard for three constituents. COSPMS01B does not meet the chronic water quality standard for domestic water supply for arsenic and manganese, nor does it meet the E. coli standard for recreation.

Review of ambient water quality data for stream segment COSPMS01B found that, while water quality does meet the domestic water use water quality criteria for sulfate, it only barely meets the water quality standard. For this reason, sulfate has been added to the list of key parameters for COSPMS01B.

The WQCD found segment COSPMS01B was in attainment of acute water quality standards for aquatic life, water supply, and agriculture for aluminum, ammonia, arsenic, nitrate + nitrite, cadmium, copper, lead, manganese, nickel, selenium, silver, uranium, and zinc.

The WQCD found segment COSPMS01B was in attainment of chronic water quality standards for aquatic life, water supply, recreation, and agriculture for pH, dissolved oxygen, aluminum, cadmium, copper, iron, lead, molybdenum, nickel, selenium, silver, sulfate, uranium, zinc, and ammonia.

*COSPLS01 Stream Segment*

COSPLS01 covers the mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border, as shown on Figure 3. The stream segment has agriculture, aquatic life warm 2, recreation E, and water supply as classified uses, as described in Table 1. COSPLS01 is listed as impaired for three metal parameters: manganese, selenium, and uranium. Sulfate is listed on the M&E List. Arsenic does have temporary modification for the stream segment which is set to expire in 2021.

WQCD has determined that the water is segment COSPLS01 does not meet the water quality standard for four (4) constituents. COSPLS01 does not meet the chronic water quality standard for domestic water supply for manganese, selenium, uranium, and sulfate. In addition, the water quality in COSPLS01 does not meet the selenium water quality standard for agriculture.

Review of ambient water quality data for stream segment COSPLS01 found that, while water quality does meet the aquatic life warm 2 water quality criteria for selenium, it only barely meets the water quality standard. For this reason, selenium has been added to the list of key parameters for COSPLS01.

The WQCD found segment COSPLS01 was in attainment of acute water quality standards for aquatic life, water supply, and agriculture for aluminum, ammonia, arsenic, nitrate + nitrite, cadmium, copper, lead, manganese, nickel, selenium, silver, uranium, and zinc. However, the segment was retained on the 303(d) list in 2016 for selenium by the WQCC.

The WQCD found segment COSPLS01 was in attainment of chronic water quality standards for aquatic life, water supply, recreation, and agriculture for pH, dissolved oxygen, aluminum, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, zinc, and ammonia.

*COSPLS03 Stream Segment*

COSPLS03 includes the Jackson Reservoir, Prewitt Reservoir, North Sterling Reservoir, Jumbo (Julesburg), Riverside Reservoir, Empire Reservoir, and Vancil Reservoir, as shown on Figure 4. The stream segment has agriculture, aquatic life warm 1, recreation E, and water supply as classified uses, as described in Table 1. COSPLS03 is listed as impaired at Jackson and North Sterling. Jackson Reservoir is listed as 303(d) impaired list for pH only and North Sterling is listed on the 303(d) impairment list for Dissolved Oxygen and selenium. Jumbo (Julesburg) Reservoir is listed for selenium on the M&E List.

WQCD has determined that the water is segment COSPLS03 does not meet the water quality standard for three (3) constituents. The water in North Sterling Reservoir does not meet the chronic water quality standard for domestic water supply Dissolved Oxygen. The water in Jackson Reservoir does not meet the acute standard for agriculture, aquatic life, recreation, or water supply for pH. The water in North Sterling Reservoir does not meet the chronic selenium water quality standard for aquatic life.

The WQCD found that Jackson Reservoir in section COSPLS03 was in attainment of the selenium standard, for which it had previously been listed for non-compliance.

*Summary*

Based on the review of WQCC's Regulations 31, 38, and 93, LRE has identified the key water quality parameters to be considered when screening SPSS sites and solutions. These key parameters and the designated uses for which the parameter are identified as being key, are summarized in Table 2 below. The impact of the water quality on the eventual use of these waters captured in a future storage site is further described below.

**Table 2 – Key Water Quality Parameters by WQCC Stream Segment**

| WQCC Stream Segment | Description | Key Parameter and Designated Use |
|---|---|---|
| COSPMS01B | Mainstem of the SPR from point immediately below confluence w/ St Vrain Creek to the Weld/Morgan County Line | **Arsenic** – Domestic Water Supply<br>**E. Coli** – Recreation<br>**Manganese** – Domestic Water Supply<br>**Sulfate** – Domestic Water Supply |
| COSPLS01 | Mainstem of the SPR from the Weld/Morgan County line to the CO/NE border | **Manganese** – Domestic Water Supply<br>**Selenium** – Aquatic Life<br>**Uranium** – Domestic Water Supply<br>**Sulfate** – Domestic Water Supply |
| COSPLS03 | Jackson Reservoir | **pH** – Aquatic Life & Domestic Water Supply |
| COSPLS03 | North Sterling Reservoir | **Dissolved Oxygen** – Agriculture, Aquatic Life, Domestic Water Supply, & Recreation<br>**Selenium** – Aquatic Life |

**Treatment and Use Considerations**

Utilizing the list of key parameters summarized in Table 2, we next considered the potential methods of use and associated treatment and use considerations. Table 3 below summarizes the treatment and regulatory considerations that should be considered for each of the key parameters as well as a relative cost of the potential treatment options.

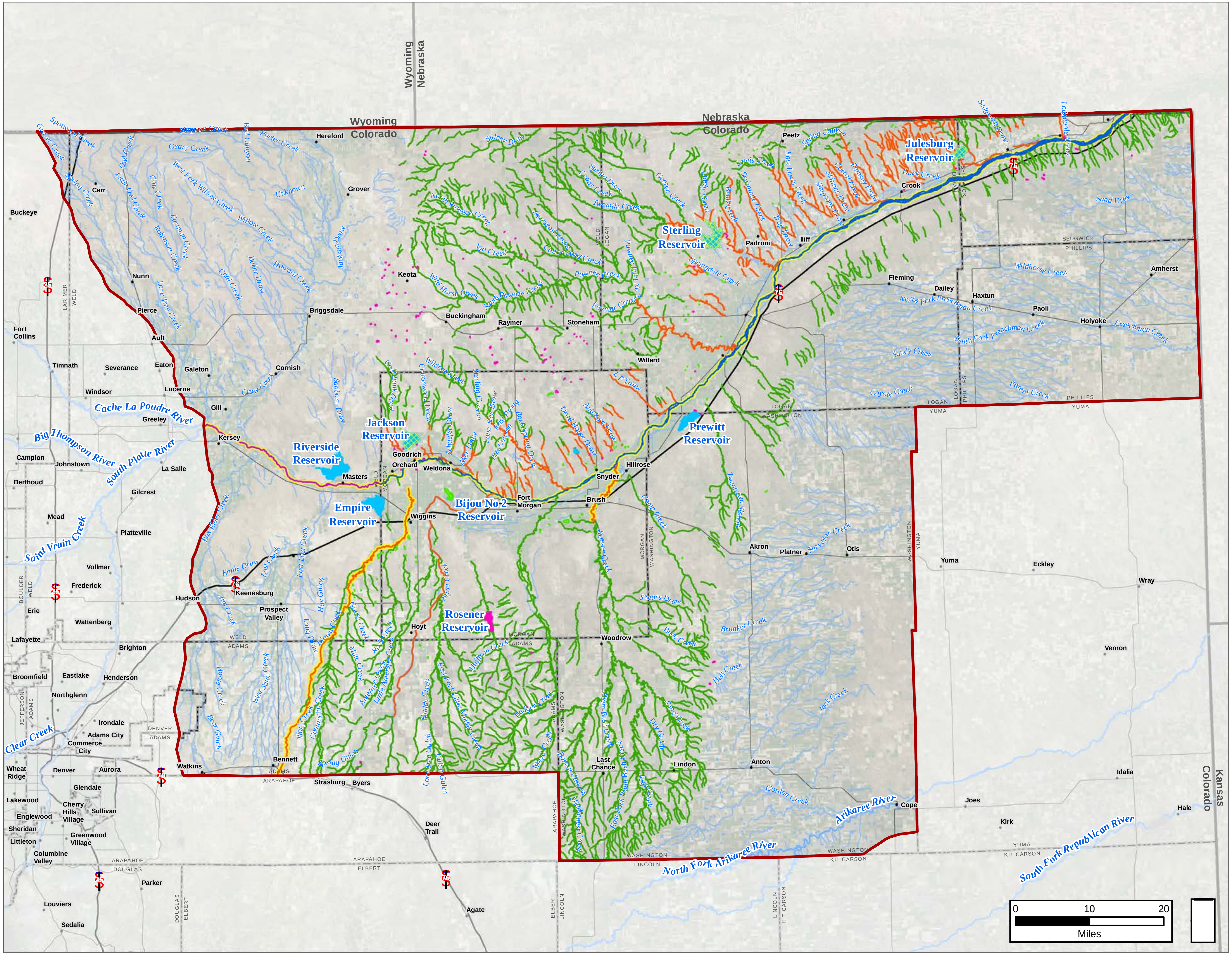
Table 3 below provides insight into potential constraints of water sources for specific beneficial use types. While LRE cannot provide confirmation as to the exact form/type of treatment that would be required by impaired use(s), it is understood arsenic, selenium, and uranium could require costly treatment methods when the source water is used for domestic water supply. Sulfate is a secondary standard largely based on physical properties (e.g., taste, color, odor), unlike arsenic, selenium, and uranium which have direct impacts to human and/or aquatic health based on contact. Sulfate is classified under the secondary maximum contaminate level standards; therefore, while high levels of sulfate are not as serve to health, the impacts on taste, color, odor can be costly to treat prior to use as a domestic water supply.

## Table 3 – Potential Treatment and Use Considerations

| Key Parameter | Method of Use | Potential Treatment Alternatives And Regulatory Needs |
|---|---|---|
| Arsenic | *Domestic Water Supply* – Assumed direct feed to WTP | **HIGH LEVEL TREATMENT NEEDS - HIGH COST** (e.g., reverse osmosis, ion exchange, activated alumina, etc.)<br><br>**RESIDUALS TREATMENT &/OR DISPOSAL - HIGH COST** (e.g., permitted discharge to sewer, deep well injection, evaporation pond, land application, zero liquid discharge, etc.) |
| Dissolved Oxygen | *Agriculture, Aquatic Life, Recreation* – Assumed surface water discharge to receiving water for direct use, augmentation use, or exchange<br>*Domestic Water Supply* – Assumed direct feed to WTP | **CONVENTIONAL TREATMENT METHODS - LOW COST** |
| E. Coli | *Recreation* – Assumed surface water discharge to receiving water for direct use, augmentation use, or exchange | * Initial recommendation – Obtain legal determination as to whether or not the use of water constitutes an "exercise of water rights."<br><br>**CONVENTIONAL TREATMENT METHODS - LOW COST** |
| Manganese | *Domestic Water Supply* – Assumed direct feed to WTP | **MEDIUM LEVELTREATMENT NEEDS - MEDIUM COST** (e.g., green sand filters, enhanced coagulation , etc.) |
| pH | *Aquatic Life* – Assumed surface water discharge to receiving water for direct use, augmentation use, or exchange<br>*Domestic Water Supply* – Assumed direct feed to WTP | * Initial recommendation – Obtain legal determination as to whether or not the use of water constitutes an "exercise of water rights."<br><br>**CONVENTIONAL TREATMENT METHODS - LOW COST** |
| Selenium | *Domestic Water Supply* – Assumed direct feed to WTP | **HIGH LEVEL TREATMENT NEEDS - HIGH COST** (e.g., reverse osmosis, ion exchange, activated alumina, etc.)<br><br>**RESIDUALS TREATMENT &/OR DISPOSAL - HIGH COST** (e.g., permitted discharge to sewer, deep well injection, evaporation pond, land application, zero liquid discharge, etc.) |
| Sulfate | *Domestic Water Supply* – Assumed direct feed to WTP | **HIGH LEVEL TREATMENT NEEDS - HIGH COST** (e.g., reverse osmosis, ion exchange, activated alumina, etc.) |
| Uranium | *Domestic Water Supply* – Assumed direct feed to WTP | **HIGH LEVEL TREATMENT NEEDS - HIGH COST** (e.g., reverse osmosis, ion exchange, activated alumina, etc.)<br><br>**RESIDUALS TREATMENT &/OR DISPOSAL - HIGH COST** (e.g., permitted discharge to sewer, deep well injection, evaporation pond, land application, zero liquid discharge, etc.) |

FIGURE 1
WATER QUALITY BY
WQCC STREAM SEGMENTS

SOUTH PLATTE STORAGE
STUDY




Study Area

**WQCC Stream Segments Within Study Area**

Other Stream Segments
COSPLS01
COSPLS02a
COSPLS02b
COSPMS01b
COSPLS03
COSPLS04
COSPLS05

**List of Impaired Waters (303d Features)**

303d Waterways
303d Lakes/Reservoirs

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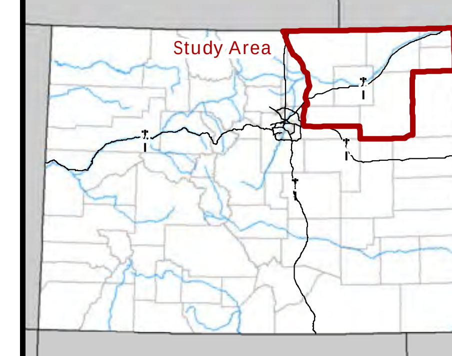




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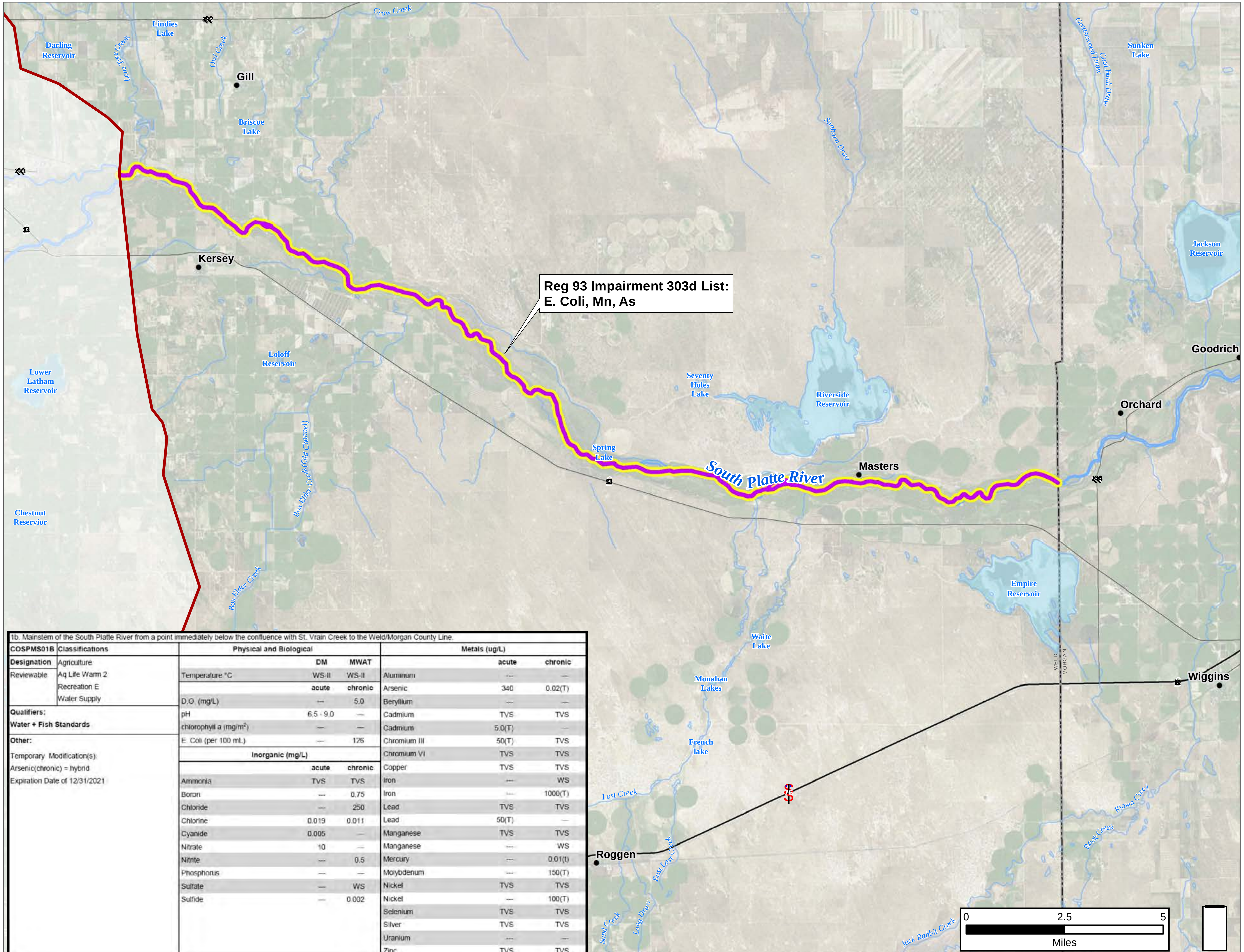
FIGURE 2
COSPMS01B
STREAM SEGMENT

SOUTH PLATTE STORAGE STUDY




1b. Mainstem of the South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan County Line.

| COSPMS01B | Classifications |
|---|---|
| Designation | Agriculture |
| Reviewable | Aq Life Warm 2 |
| | Recreation E |
| | Water Supply |
| **Qualifiers:** | |
| **Water + Fish Standards** | |
| **Other:** | |
| Temporary Modification(s): | |
| Arsenic(chronic) = hybrid | |
| Expiration Date of 12/31/2021 | |

| Physical and Biological | DM | MWAT |
|---|---|---|
| Temperature °C | WS-II | WS-II |
| | **acute** | **chronic** |
| D.O. (mg/L) | — | 5.0 |
| pH | 6.5 - 9.0 | — |
| chlorophyll a (mg/m²) | — | — |
| E. Coli (per 100 mL) | — | 126 |

| Inorganic (mg/L) | acute | chronic |
|---|---|---|
| Ammonia | TVS | TVS |
| Boron | — | 0.75 |
| Chloride | — | 250 |
| Chlorine | 0.019 | 0.011 |
| Cyanide | 0.005 | — |
| Nitrate | 10 | — |
| Nitrite | — | 0.5 |
| Phosphorus | — | — |
| Sulfate | — | WS |
| Sulfide | — | 0.002 |

| Metals (ug/L) | acute | chronic |
|---|---|---|
| Aluminum | — | — |
| Arsenic | 340 | 0.02(T) |
| Beryllium | — | — |
| Cadmium | TVS | TVS |
| Cadmium | 5.0(T) | — |
| Chromium III | 50(T) | TVS |
| Chromium VI | TVS | TVS |
| Copper | TVS | TVS |
| Iron | — | WS |
| Iron | — | 1000(T) |
| Lead | TVS | TVS |
| Lead | 50(T) | — |
| Manganese | TVS | TVS |
| Manganese | — | WS |
| Mercury | — | 0.01(t) |
| Molybdenum | — | 150(T) |
| Nickel | TVS | TVS |
| Nickel | — | 100(T) |
| Selenium | TVS | TVS |
| Silver | TVS | TVS |
| Uranium | — | — |
| Zinc | TVS | TVS |

Study Area

**WQCC Stream Segment**

COSPMS01b

**List of Impaired Waters (303d Features)**

303d Waterways

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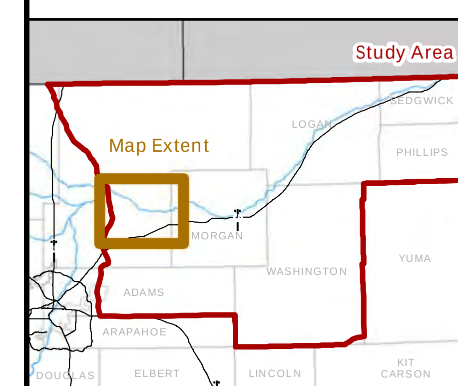


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# FIGURE 3
# COSPLS01 STREAM SEGMENT

SOUTH PLATTE STORAGE STUDY

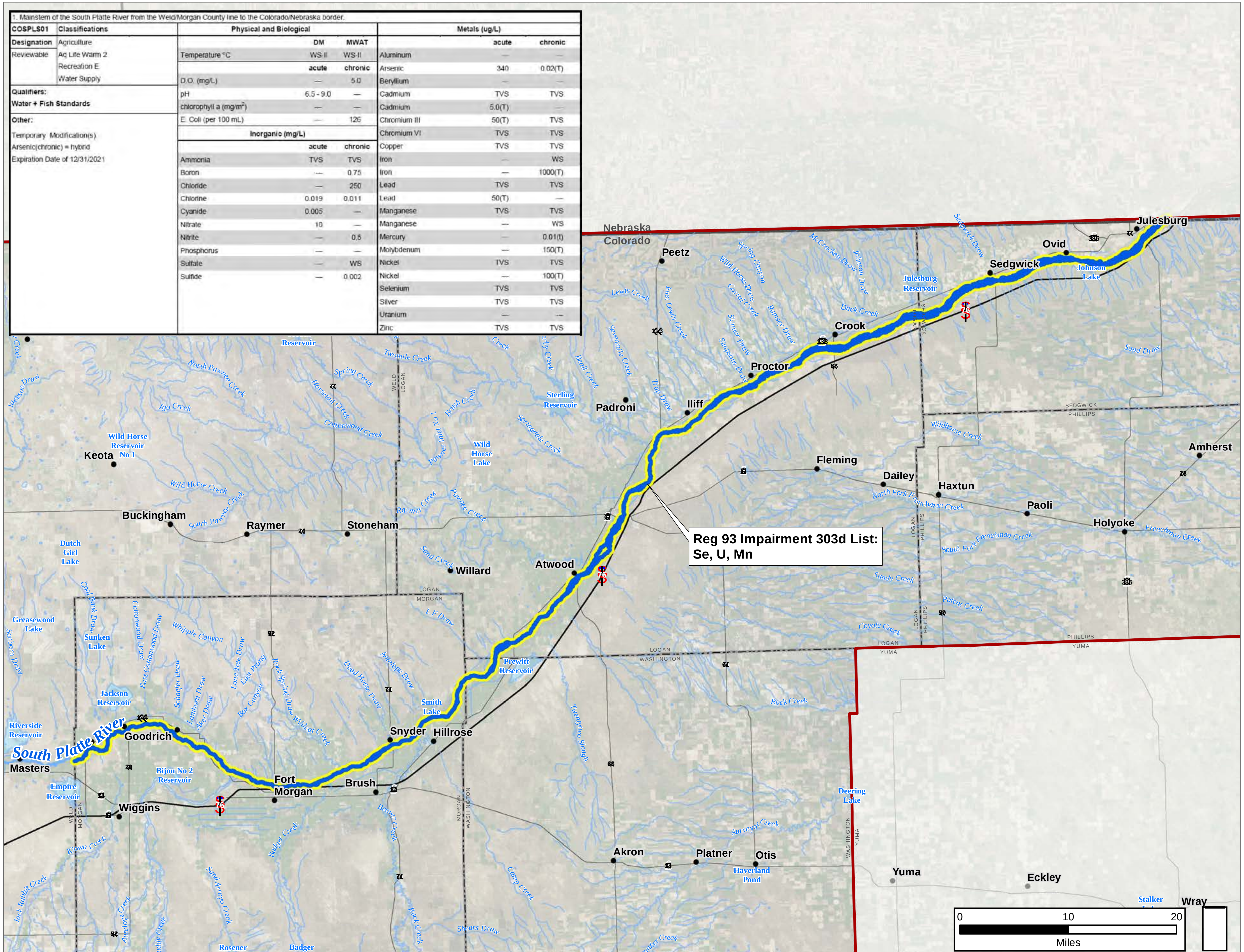
1. Mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border.

| COSPLS01 | Classifications |
|---|---|
| Designation | Agriculture |
| Reviewable | Aq Life Warm 2 |
| | Recreation E |
| | Water Supply |
| **Qualifiers:** | |
| **Water + Fish Standards** | |
| **Other:** | |
| Temporary Modification(s) | |
| Arsenic(chronic) = hybrid | |
| Expiration Date of 12/31/2021 | |

| Physical and Biological | | |
|---|---|---|
| | DM | MWAT |
| Temperature °C | WS-II | WS-II |
| | acute | chronic |
| D.O. (mg/L) | — | 5.0 |
| pH | 6.5 - 9.0 | — |
| chlorophyll a (mg/m²) | — | — |
| E. Coli (per 100 mL) | — | 126 |

| Inorganic (mg/L) | | |
|---|---|---|
| | acute | chronic |
| Ammonia | TVS | TVS |
| Boron | — | 0.75 |
| Chloride | — | 250 |
| Chlorine | 0.019 | 0.011 |
| Cyanide | 0.005 | — |
| Nitrate | 10 | — |
| Nitrite | — | 0.5 |
| Phosphorus | — | — |
| Sulfate | — | WS |
| Sulfide | — | 0.002 |

| Metals (ug/L) | | |
|---|---|---|
| | acute | chronic |
| Aluminum | — | — |
| Arsenic | 340 | 0.02(T) |
| Beryllium | — | — |
| Cadmium | TVS | TVS |
| Cadmium | 5.0(T) | — |
| Chromium III | 50(T) | TVS |
| Chromium VI | TVS | TVS |
| Copper | TVS | TVS |
| Iron | — | WS |
| Iron | — | 1000(T) |
| Lead | TVS | TVS |
| Lead | 50(T) | — |
| Manganese | TVS | TVS |
| Manganese | — | WS |
| Mercury | — | 0.01(t) |
| Molybdenum | — | 150(T) |
| Nickel | TVS | TVS |
| Nickel | — | 100(T) |
| Selenium | TVS | TVS |
| Silver | TVS | TVS |
| Uranium | — | — |
| Zinc | TVS | TVS |



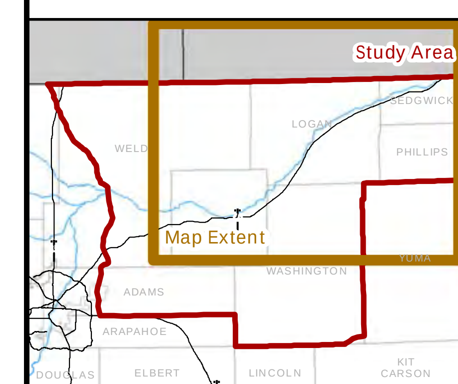

Study

**WQCC Stream Segment**

COSPLS01

**List of Impaired Waters (303d Features)**

303d Waterways

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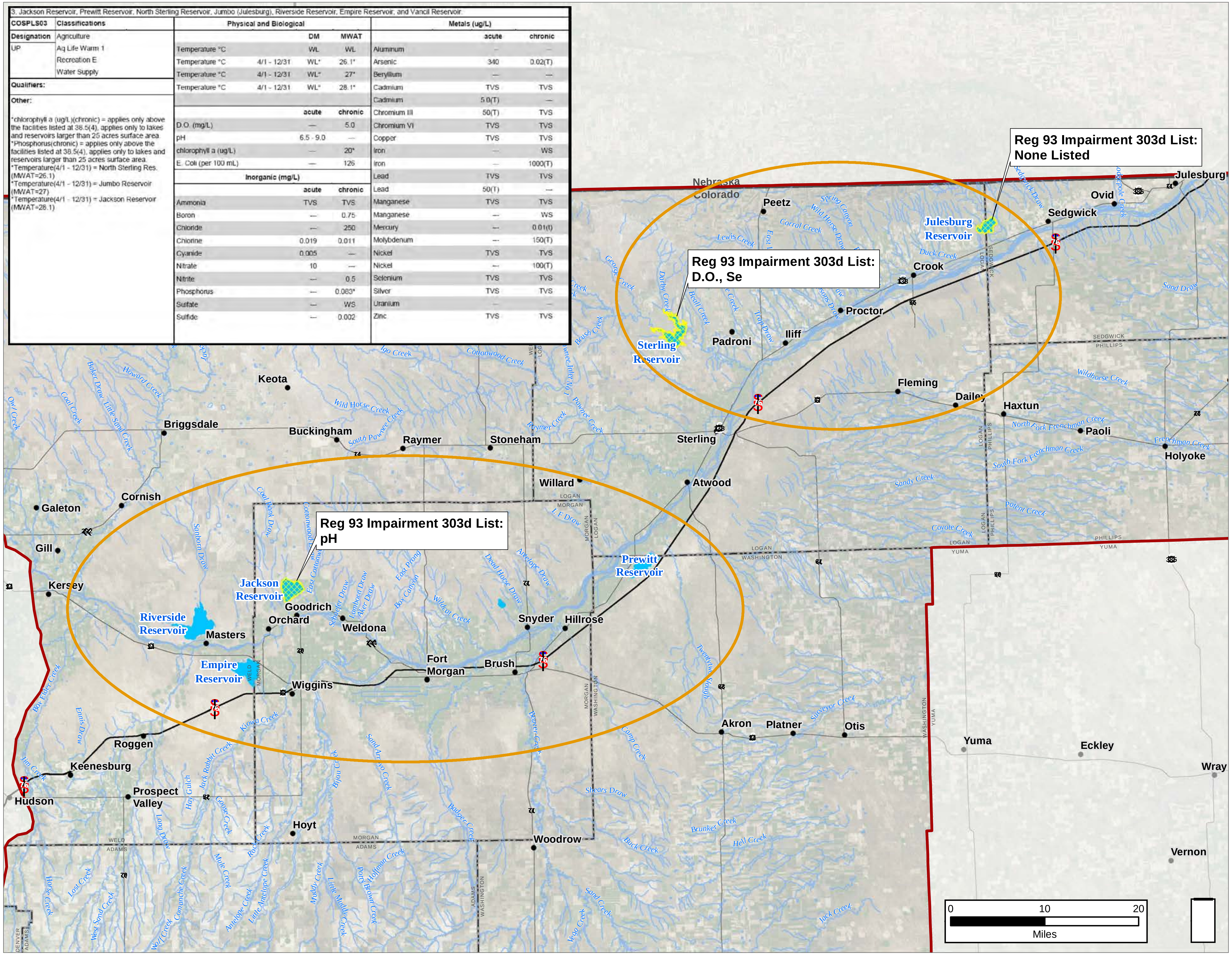
# FIGURE 4
# COSPLS03
# LAKES/RESERVOIRS

SOUTH PLATTE STORAGE STUDY




| 3. Jackson Reservoir, Prewitt Reservoir, North Sterling Reservoir, Jumbo (Julesburg), Riverside Reservoir, Empire Reservoir, and Vancil Reservoir | |
|---|---|
| **COSPLS03** | **Classifications** |
| **Designation** | Agriculture |
| UP | Aq Life Warm 1 |
| | Recreation E |
| | Water Supply |
| **Qualifiers:** | |
| **Other:** | |

*chlorophyll a (ug/L)(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.
*Phosphorus(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.
*Temperature(4/1 - 12/31) = North Sterling Res. (MWAT=26.1)
*Temperature(4/1 - 12/31) = Jumbo Reservoir (MWAT=27)
*Temperature(4/1 - 12/31) = Jackson Reservoir (MWAT=28.1)

**Physical and Biological**

| | | DM | MWAT |
|---|---|---|---|
| Temperature °C | | WL | WL |
| Temperature °C | 4/1 - 12/31 | WL* | 26.1* |
| Temperature °C | 4/1 - 12/31 | WL* | 27* |
| Temperature °C | 4/1 - 12/31 | WL* | 28.1* |

| | acute | chronic |
|---|---|---|
| D.O. (mg/L) | — | 5.0 |
| pH | 6.5 - 9.0 | — |
| chlorophyll a (ug/L) | — | 20* |
| E. Coli (per 100 mL) | — | 126 |

**Inorganic (mg/L)**

| | acute | chronic |
|---|---|---|
| Ammonia | TVS | TVS |
| Boron | — | 0.75 |
| Chloride | — | 250 |
| Chlorine | 0.019 | 0.011 |
| Cyanide | 0.005 | — |
| Nitrate | 10 | — |
| Nitrite | — | 0.5 |
| Phosphorus | — | 0.083* |
| Sulfate | — | WS |
| Sulfide | — | 0.002 |

**Metals (ug/L)**

| | acute | chronic |
|---|---|---|
| Aluminum | — | — |
| Arsenic | 340 | 0.02(T) |
| Beryllium | — | — |
| Cadmium | TVS | TVS |
| Cadmium | 5.0(T) | — |
| Chromium III | 50(T) | TVS |
| Chromium VI | TVS | TVS |
| Copper | TVS | TVS |
| Iron | — | WS |
| Iron | — | 1000(T) |
| Lead | TVS | TVS |
| Lead | 50(T) | — |
| Manganese | TVS | TVS |
| Manganese | — | WS |
| Mercury | — | 0.01(t) |
| Molybdenum | — | 150(T) |
| Nickel | TVS | TVS |
| Nickel | — | 100(T) |
| Selenium | TVS | TVS |
| Silver | TVS | TVS |
| Uranium | — | — |
| Zinc | TVS | TVS |

Study

**WQCC Lakes/Reservoirs**

COSPLS03

WQCC 303d Lakes/Reservoirs

1265MWH02
April 2017

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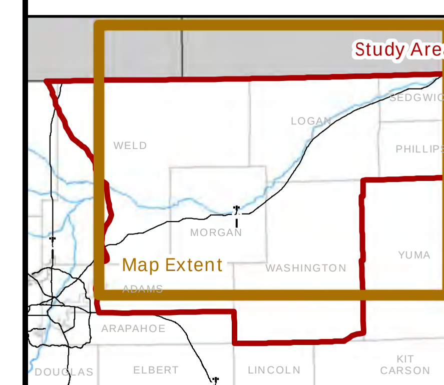




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# SPSS Subtask 2.2 -

# Water Quality Analysis

# Appendix A

# WQCC Regulation 31

# COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

# WATER QUALITY CONTROL COMMISSION

## REGULATION NO. 31

## THE BASIC STANDARDS AND METHODOLOGIES FOR SURFACE WATER (5 CCR 1002-31)


| | |
|---|---|
| ADOPTED: May 22, 1979 | EFFECTIVE: July 10, 1979 |
| AMENDED: December 12, 1983 | EFFECTIVE: January 30, 1984 |
| AMENDED: June 2, 1987 | EFFECTIVE: July 31, 1988 |
| AMENDED: June 6, 1988 | EFFECTIVE: July 31, 1988 |
| AMENDED: August 1, 1988 | EFFECTIVE: September 30, 1988 |
| AMENDED: August 7, 1989 | EFFECTIVE: September 30, 1989 |
| AMENDED: October 8, 1991 | EFFECTIVE: November 30, 1991 |
| AMENDED: May 4, 1993 | EFFECTIVE: June 30, 1993 |
| AMENDED: August 2, 1993 | EFFECTIVE: September 30, 1993 |
| AMENDED: October 4, 1993 | EFFECTIVE: November 30, 1993 |
| AMENDED: December 6, 1993 | EFFECTIVE: January 31, 1994 |
| AMENDED: January 10, 1995 | EFFECTIVE: March 2, 1995 |
| AMENDED: January 8, 1996 | EFFECTIVE: March 1, 1996 |
| AMENDED: January 13, 1997 | EFFECTIVE: March 3, 1997 |
| AMENDED: July 14, 1997 | EFFECTIVE: August 30, 1997 |
| AMENDED: January 12, 1998 | EFFECTIVE: March 2, 1998 |
| AMENDED: January 11, 1999 | EFFECTIVE: March 2, 1999 |
| AMENDED: August 15, 2000 | EFFECTIVE: December 22, 2000 |
| AMENDED: November 7, 2000 | EFFECTIVE: March 20, 2001 |
| EMERGENCY AMENDMENT: November 8, 2000 | EFFECTIVE: November 8, 2001 |
| AMENDED: February 13, 2001 | EFFECTIVE: March 30, 2001 |
| EMERGENCY AMENDMENT: May 14, 2001 | EFFECTIVE: May 14, 2001 |
| AMENDED: September 10, 2001 | EFFECTIVE: October 30, 2001 |
| AMENDED: November 8, 2004 | EFFECTIVE: March 22, 2005 |
| AMENDED: August 8, 2005 | EFFECTIVE: December 31, 2005 |
| AMENDED: August 8, 2005 | EFFECTIVE: December 31, 2007 |
| AMENDED: February 12, 2007 | EFFECTIVE: July 1, 2007 |
| AMENDED: January 14, 2008 | EFFECTIVE: May 31, 2008 |
| AMENDED: October 13, 2009 | EFFECTIVE: November 30, 2009 |
| AMENDED: August 9, 2010 | EFFECTIVE: January 1, 2011 |
| AMENDED: June 13, 2011 | EFFECTIVE: January 1, 2012 |
| AMENDED: June 11, 2012 | EFFECTIVE: September 30, 2012 |
| AMENDED: September 11, 2012 | EFFECTIVE: January 31, 2013 |
| AMENDED: May 9, 2016 | EFFECTIVE: June 30, 2016 |
| AMENDED: August 8, 2016 | EFFECTIVE: December 31, 2016 |

TABLE I PHYSICAL AND BIOLOGICAL PARAMETERS

| Parameter | Recreational | | | Aquatic Life | | | Agriculture | Domestic Water Supply |
|---|---|---|---|---|---|---|---|---|
| | CLASS E (Existing Primary Contact) and CLASS U (Undetermined Use) | CLASS P (Potential Primary Contact Use) | CLASS N (Not Primary Contact Use) | CLASS 1 COLD WATER BIOTA | CLASS 1 WARM WATER BIOTA | CLASS 2 | | |
| PHYSICAL | | | | | | | | |
| D.O. (mg/l)(1)(9) | 3.0(A) | 3.0(A) | 3.0(A) | 6.0(2)(G) 7.0(spawning) | 5.0(2)(G) | 5.0(A) | 3.0(A) | 3.0(A) |
| pH (Std. Units)(3) | 6.5–9.0 (Bm) | 6.5–9.0 (Bm) | 6.5–9.0 (Bm) | 6.5–9.0(A) | 6.5–9.0(A) | 6.5–9.0(A) | | 5.0–9.0(A) |
| Suspended Solids(4) | | | | | | | | |
| Temperature (°C) (5) | | | | **Rivers & Streams: Tier I[a,g]:** June-Sept = 17.0 (ch), 21.7 (ac)<br><br>Oct –May = 9.0 (ch), 13.0 (ac)<br><br>**Tier II[b,g]:** Apr-Oct =18.3 (ch), 24.3 (ac)<br><br>Nov-Mar = 9.0 (ch), 13.0 (ac)<br><br>**Lakes & Res[h]:** Apr-Dec = 17.0 (ch), 21.2 (ac)<br><br>Jan-Mar = 9.0 (ch), 13.0 (ac)<br><br>**Large Lakes & Res[c,h]:** Apr-Dec = 18.3 (ch), 24.2 (ac)<br><br>Jan-Mar = 9.0 (ch), 13.0 (ac) | **Rivers & Streams: Tier I[d]:** Mar-Nov = 24.2 (ch), 29.0 (ac)<br><br>Dec-Feb = 12.1 (ch), 24.6 (ac)<br><br>**Tier II[e]:** Mar-Nov = 27.5 (ch), 28.6(ac)<br><br>Dec-Feb = 13.8 (ch), 25.2 (ac)<br><br>**Tier III[f]:** Mar-Nov = 28.7 (ch), 31.8 (ac)<br><br>Dec-Feb = 14.3 (ch), 24.9 (ac)<br><br>**Lakes & Res:** Apr-Dec = 26.2 (ch), 29.3 (ac)<br><br>Jan-Mar = 13.1 (ch), 24.1 (ac) | Same as Class 1 | | |

TABLE I PHYSICAL AND BIOLOGICAL PARAMETERS

| Parameter | Recreational | | | Aquatic Life | | | Agriculture | Domestic Water Supply |
|---|---|---|---|---|---|---|---|---|
| | CLASS E (Existing Primary Contact) and CLASS U (Undetermined Use) | CLASS P (Potential Primary Contact Use) | CLASS N (Not Primary Contact Use) | CLASS 1 COLD WATER BIOTA | CLASS 1 WARM WATER BIOTA | CLASS 2 | | |
| BIOLOGICAL: | | | | | | | | |
| *E. coli* per 100 ml | 126[(7)] | 205[(7)] | 630[(7)] | | | | | 630 |
| Note: Capital letters In parentheses refer to references listed in section 31.16(3); Numbers in parentheses refer to Table 1 footnotes. | | | | | | | | |

Temperature Definitions

[a] Cold Stream Tier I temperature criteria apply where cutthroat trout and brook trout are expected to occur.

[b] Cold Stream Tier II temperature criteria apply where cold-water aquatic species, excluding cutthroat trout or brook trout, are expected to occur.

[c] Large Cold Lakes temperature criteria apply to lakes and reservoirs with a surface area equal to or greater than 100 acres surface area.

[d] Warm Stream Tier I temperature criteria apply where common shiner, johnny darter, or orangethroat darter, or stonecat are expected to occur.

[e] Warm Stream Tier II temperature criteria apply where brook stickleback, central stoneroller, creek chub, finescale dace, longnose dace, mountain sucker, Nnorthern redbelly dace, razorback sucker, or white sucker are expected occur, and none of the more thermally sensitive species in Tier I are expected to occur.

[f] Warm Stream Tier III temperature criteria apply where warm-water aquatic species are expected to occur, and none of the more thermally sensitive species in Tiers I and II are expected to occur.

[g] Mountain whitefish-based summer temperature criteria [16.9 (ch), 21.2 (ac)] apply when and where spawning and sensitive early life stages of this species are known to occur.

[h] Lake trout-based summer temperature criteria [16.6 (ch), 22.4 (ac)] apply where appropriate and necessary to protect lake trout from thermal impacts.

**<u>Table I – Footnotes</u>**

(1) Standards for dissolved oxygen are minima, unless specified otherwise. For the purposes of permitting, dissolved oxygen may be modeled for average conditions of temperature and flow for the worst case time period. Where dissolved oxygen levels less than these levels occur naturally, a discharge shall not cause a further reduction in dissolved oxygen in receiving water. (For lakes, also see footnote 9.)

(2) A 7.0 mg/liter standard (minimum), during periods of spawning of cold water fish, shall be set on a case-by-case basis as defined in the NPDES or CDPS permit for those dischargers whose effluent would affect fish spawning.

(3) The pH standards of 6.5 (or 5.0) and 9.0 are an instantaneous minimum and maximum, respectively to be applied as effluent limits. In determining instream attainment of water quality standards for pH, appropriate averaging periods may be applied, provided that beneficial uses will be fully protected.

(4) Suspended solid levels will be controlled by Effluent Limitation Regulations, Basic Standards, and Best Management Practices (BMPs).

(5) Temperature shall maintain a normal pattern of diel and seasonal fluctuations and spatial diversity with no abrupt changes and shall have no increase in temperature of a magnitude, rate, and duration deleterious to the resident aquatic life. These criteria shall not be interpreted or applied in a manner inconsistent with section 25-8-104, C.R.S.

a. The MWAT of a waterbody shall not exceed the chronic temperature criterion more frequently than one event in three years on average.

b. The DM of a waterbody shall not exceed the acute temperature criterion more frequently than one event in three years on average.

c. The following shall not be considered an exceedance of the criteria:

i. Air temperature excursion: ambient water temperature may exceed the criteria in Table 1 or the applicable site-specific standard when the daily maximum air temperature exceeds the 90th percentile value of the monthly maximum air temperatures calculated using at least 10 years of air temperature data.

ii. Low-flow excursion: ambient water temperature may exceed the criteria in Table 1 or the applicable site-specific standard when the daily stream flow falls below the acute critical low flow or monthly average stream flow falls below the chronic critical low flow, calculated pursuant to Regulation 31.9(1)

iii. Winter shoulder-season excursion: For the purposes of assessment, ambient water temperatures in cold streams may exceed the winter criteria in Table 1 or applicable site-specific winter standard for 30-days before the winter/summer transition, and 30-days after the summer/winter transition**,** provided that the natural seasonal progression of temperature is maintained and that temperature exceedances during these periods are not the result of anthropogenic activities in the watershed**.**

(6) Deleted

(7) *E.coli* criteria and resulting standards for individual water segments, are established as indicators of the potential presence of pathogenic organisms. Standards for *E. coli* are expressed as a two-month geometric mean. Site-specific or seasonal standards are also two-month geometric means unless otherwise specified.

(8) Deleted

(9) The dissolved oxygen standard applies to lakes and reservoirs as follows.

a. Recreation: In the upper portion of a lake or reservoir, dissolved oxygen shall not be less than the criteria in Table 1 or the applicable site-specific standard. In the lower portion of a lake or reservoir, dissolved oxygen may be less than the applicable standard except where a site-specific standard has been adopted. A site-specific dissolved oxygen standard will be established for the lower portion of a lake or reservoir where there is evidence that primary contact occurs within the lower portion.

b. Agriculture: In the upper portion of a lake or reservoir, dissolved oxygen shall not be less than the criteria in Table 1 or the applicable site-specific standard. In the lower portion of a lake or reservoir, dissolved oxygen may be less than the applicable standard except where a site-specific standard has been adopted. A site-specific dissolved oxygen standard will be established for the lower portion of a lake or reservoir where there is evidence that livestock watering or irrigation water is pumped from the lower portion.

c. Aquatic Life: In the upper portion of a lake or reservoir, dissolved oxygen shall not be less than the criteria in Table I or the applicable site-specific standard. In the lower portion of a lake or reservoir, dissolved oxygen may be less than the applicable standard as long as there is adequate refuge. Adequate refuge means that there is concurrent attainment of the applicable Table I temperature and dissolved oxygen criteria. A site-specific dissolved oxygen standard will be established for the lower portion of a lake or reservoir where the expected aquatic community has habitat requirements within the lower portion.

i. Fall turnover exclusion: Dissolved oxygen may drop 1 mg/l below the criteria in Table 1 in the upper portion of a lake or reservoir for up to seven consecutive days during fall turnover provided that profile measurements are taken at a consistent location within the lake or reservoir 7-days before, and 7-days after the profile with low dissolved oxygen. The profile measurements taken before and after the profile with low dissolved oxygen must attain the criteria in Table 1 in the upper portion of the lake or reservoir. The fall turnover exclusion does not apply to lakes or reservoirs with fish species that spawn in the fall unless there are data to show that adequate dissolved oxygen is maintained in all spawning areas, for the entire duration of fall turnover.

d. Water Supply: The dissolved oxygen criteria is intended to apply to the epilmnion and metalimnion strata of lakes and reservoirs. Dissolved oxygen in the hypolimnion may, due to the natural conditions, be less than the table criteria. No reductions in dissolved oxygen levels due to controllable sources is allowed.

| TABLE II INORGANIC PARAMETERS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PARAMETER | AQUATIC LIFE | | | | | | AGRICULTURE | DOMESTIC WATER SUPPLY |
| | CLASS 1 Cold Water Biota | | CLASS 1 Warm Water Biota | | CLASS 2 | | | |
| INORGANICS: | | | | | | | | |
| Ammonia (mg/l as N) Total | chronic = elsp or elsa [1] acute = sp [1] (N) | | chronic = Apr 1-Aug 31=elsp[1] Sept 1-Mar 29=elsa[1] acute = sa[1] (N) | | Class 2 Cold/Warm have the same standards as Class 1 Cold/Warm (N) | | | |
| Total residual Chlorine (mg/l) | 0.019 (L) (1-day) | 0.011 (L) (30-day) | 0.019 (L) (1-day) | 0.011 (L) (30-day) | 0.019 (L) (1-day) | 0.011 (L) (30-day) | | |
| Cyanide - Free (mg/l) | 0.005(H) (1-day) | | 0.005(H) (1-day) | | 0.005(H) (1-day) | | 0.2(G) (1-day) | 0.2(B,D[m]) (1-day) |
| Fluoride (mg/l) | | | | | | | | 2.0[3](E) (1-day) |
| Nitrate (mg/l as N) | | | | | | | 100([2])(B) | 10[4](K) (1-day) |
| Nitrite (mg/l as N) | TO BE ESTABLISHED ON A CASE BY CASE BASIS ([3]) | | | | A CASE BY CASE BASIS [3] | | 10([2])(B) (1-day) | 1.0(2)[4](K) (1-day) |
| Sulfide as $H_2S$ (mg/l) | 0.002 undissociated(A) (30-day) | | 0.002 undissociated(A) (30-day) | | 0.002 undissociated(A) (30-day) | | | 0.05(F) (30-day) |
| Boron (mg/l) | | | | | | | 0.75(A,B) (30-day) | |
| Chloride (mg/l) | | | | | | | | 250(F) (30-day) |
| Sulfate (mg/l) | | | | | | | | 250(F) (30-day) |
| Asbestos | | | | | | | | 7,000,000 fibers/L[5] |
| NOTE: Capital letters in parentheses refer to references listed 31.16(3); numbers in parentheses refer to table II footnotes. | | | | | | | | |

**Table II – Footnotes**

(1)

Chronic:

For Fish Early Life Stage Present (elsp):

$$chronic\ elsp = \left( \frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}} \right) * MIN\left(2.85, 1.45 * 10^{0.028(25-T)}\right)$$

For Fish Early Life Stage Absent (elsa):

$$chronic\ elsa = \left( \frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}} \right) * 1.45 * 10^{0.028*(25-MAX(T,7))}$$

Acute:

For salmonids present (sp):

$$acute\ sp = \frac{0.275}{1+10^{7.204-pH}} + \frac{39.0}{1+10^{pH-7.204}}$$

For salmonids absent (sa):

$$acute\ sa = \frac{0.411}{1+10^{7.204-pH}} + \frac{58.4}{1+10^{pH-7.204}}$$

(2) In order to provide a reasonable margin of safety to allow for unusual situations such as extremely high water ingestion or nitrite formation in slurries, the $NO_3$-N plus $NO_2$-N content in drinking waters for livestock and poultry should be limited to 100ppm or less, and the NO2-N content alone be limited to 10ppm or less.

(3) Salmonids and other sensitive fish species present:

Acute= 0.10 (0.59 * [Cl- ]+3.90) mg/l NO2-N

Chronic= 0.10 (0.29 * [Cl- ]+0.53) mg/l NO2-N

(upper limit for Cl- =40 mg/l)

Salmonids and other sensitive fish species absent:

Acute= 0.20 (2.00 * [Cl- ]+0.73) mg/l NO2-N

Chronic=0.10 (2.00 *[Cl- ]+0.73) mg/l NO2-N

[Cl- ] = Chloride ion concentration

(upper limit for Cl- =22 mg/l)

(4) The nitrate limit shall be calculated to meet the relevant standard in accordance with the provisions of Section 31.10 of this regulation, unless (this subsection 4 is repealed effective 12/31/2022):

a. The permittee provides documentation that a reasonable level of inquiry demonstrates that there is no actual domestic water supply use of the waters in question or of hydrologically connected ground water, or

b. The combined total of nitrate plus nitrite at the point of intake to the domestic water supply will not exceed 10 mg/l as demonstrated through modeling or other scientifically supportable analysis

(5) Asbestos standard applies to fibers 10 micrometers or longer.

TABLE III METAL PARAMETERS (Concentration in µg/l)

| METAL[1] | AQUATIC LIFE[1][3][4][J] | | AGRICULTURE[2] | DOMESTIC WATER-SUPPLY[2] | WATER + FISH[7] | FISH INGESTION[10] |
|---|---|---|---|---|---|---|
| | ACUTE | CHRONIC | | | | |
| Aluminum | $e^{(1.3695[\ln(hardness)]+1.8308)}$ (tot.rec.) | 87 or $e^{(1.3695[\ln(hardness)]-0.1158}$ (tot.rec.)[11] | | | --- | --- |
| Antimony | | | | 6.0 (30-day) | 5.6 | 640 |
| Arsenic | 340 | 150 | 100[A] (30-day) | 0.02 – 10[13] (30-day) | 0.02 | 7.6 |
| Barium | | | | 1,000[E](1-day) 490 (30-day) | --- | --- |
| Beryllium | | | 100[A,B] (30-day) | 4.0 (30-day) | --- | --- |
| Cadmium | (1.136672-[ln(hardness) x (0.041838)] )x $e^{0.9151[\ln(hardness)]-3.1485}$ (Trout)=(1.136672-[ln(hardness)x (0.041838)] )x $e^{0.9151[\ln(hardness)]-3.6236}$ | (1.101672-[ln(hardness) x(0.041838)] x $e^{0.7998[\ln(hardness)]-4.4451}$ | 10[B] (30-day) | 5.0[E] (1-day) | --- | --- |
| Chromium III[5] | $e^{(0.819[\ln(hardness)]+2.5736)}$ | $e^{(0.819[\ln(hardness)]+0.5340)}$ | 100[B] (30-day) | 50[E] (1-day) | --- | --- |
| Chromium VI[5] | 16 | 11 | 100[B] (30-day) | 50[E] (1-day) | 100(30-day) | --- |
| Copper | $e^{(0.9422[\ln(hardness)]-1.7408)}$ | $e^{(0.8545[\ln(hardness)]-1.7428)}$ | 200[B] | 1,000[F] (30-day) | 1,300 | --- |
| Iron | | 1,000(tot.rec.)[A,C] | | 300(dis)[F] (30-day) | --- | --- |
| Lead | (1.46203-[(ln(hardness)*(0.145712)])*$e^{(1.273[\ln(hardness)]-1.46)}$ | (1.46203-[(ln(hardness)*(0.145712)])*$e^{(1.273[\ln(hardness)]-4.705)}$ | 100[B] (30-day) | 50[E] (1-day) | — | --- |
| Manganese | $e^{(0.3331[\ln(hardness)]+6.4676)}$ | $e^{(0.3331[\ln(hardness)]+5.8743)}$ | 200[B] (30-day)[12] | 50(dis)[F] (30-day) | — | --- |
| Mercury | | FRV(fish)[6] = 0.01 (Total) | | 2.0[E] (1-day) | — | --- |
| Molybdenum | | | 300[O] (30-day)[15] | 210 (30-day) | | |

| TABLE III METAL PARAMETERS (Concentration in µg/l) | | | | | | |
|---|---|---|---|---|---|---|
| METAL[1] | AQUATIC LIFE[1][3][4][J] | | AGRICULTURE[2] | DOMESTIC WATER-SUPPLY[2] | WATER + FISH[7] | FISH INGESTION[10] |
| | ACUTE | CHRONIC | | | | |
| Nickel | $e^{(0.846[\ln(hardness)]+2.253)}$ | $e^{(0.846[\ln(hardness)]+0.0554)}$ | 200[B] (30-day) | 100[E] (30-day) | 610 | 4,600 |
| Selenium[9] | 18.4 | 4.6 | 20[B,D] (30-day) | 50[E] (30-day) | 170 | 4,200 |
| Silver | $\frac{1}{2}e^{(1.72[\ln(hardness)]-6.52)}$ | $e^{(1.72[\ln(hardness)]-9.06)}$ (Trout) = $e^{(1.72[\ln(hardness)]-10.51)}$ | | 100[F] (1-day) | — | --- |
| Thallium | | 15[C] | | 0.5 (30-day) | 0.24 | 0.47 |
| Uranium[16] | $e^{(1.1021[\ln(hardness)]+2.7088)}$ | $e^{(1.1021[\ln(hardness)]+2.2382)}$ | | 16.8 – 30[13] (30-day) | --- | --- |
| Zinc | $0.978*e^{(0.9094[\ln(hardness)]+0.9095)}$ | $0.986*e^{(0.9094[\ln(hardness)]+0.6235)}$ (sculpin)[14] = $e^{(2.140[\ln(hardness)]-5.084)}$ | 2000[B] (30-day) | 5,000[F] (30-day) | 7,400 | 26,000 |
| NOTE: Capital letters in parentheses refer to references listed in section 31.16(3); Numbers in parentheses refer to Table III footnote | | | | | | |

**Table III – Footnotes**

(1) Metals for aquatic life use are stated as dissolved unless otherwise specified.

Where the hardness-based equations in Table III are applied as table value water quality standards for individual water segments, those equations define the applicable numerical standards. As an aid to persons using this regulation, Table IV provides illustrative examples of approximate metals values associated with a range of hardness levels. This table is provided for informational purposes only.

(2) Metals for agricultural and domestic uses are stated as total recoverable unless otherwise specified.

(3) Hardness values to be used in equations are in mg/l as calcium carbonate and shall be no greater than 400 mg/l. The exception is for aluminum, where the upper cap on calculations is a hardness of 220 mg/l. For permit effluent limit calculations, the hardness values used in calculating the appropriate metal standard should be based on the lower 95 percent confidence limit of the mean hardness value at the periodic low flow criteria as determined from a regression analysis of site-specific data. Where insufficient site-specific data exists to define the mean hardness value at the periodic low flow criteria, representative regional data shall be used to perform the regression analysis. Where a regression analysis is not possible, a site-specific method should be used, e.g., where hardness data exists without paired flow data, the mean of the hardness during the low flow season established in the permit shall be used. In calculating a hardness value, regression analyses should not be extrapolated past the point that data exist. For determination of standards attainment, where paired metal/hardness data is available, attainment will be determined for individual sampling events. Where paired data is not available, the mean hardness will be used.

(4) Both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average.

(5) Unless the stability of the chromium valence state in receiving waters can be clearly demonstrated, the standard for chromium should be in terms of chromium VI. In no case can the sum of the instream levels of hexavalent and trivalent chromium exceed the water supply standard of 50 µg/l chromium in those waters classified for domestic water use.

(6) FRV means Final Residue Value and should be expressed as "Total" because many forms of mercury are readily converted to toxic forms under natural conditions. The FRV value of 0.01 µg/liter is the maximum allowed concentration of total mercury in the water. This value is estimated to prevent bioaccumulation of methylmercury in edible fish or shellfish tissue above the fish tissue standard for methylmercury of 0.3 mg/kg.

In waters supporting populations of fish or shellfish with a potential for human consumption, the Commission can adopt the FRV as the stream standard to be applied as a 30-day average. Alternatively, the Commission can adopt site-specific ambient based standards for mercury in accordance with section 31.7(1)(b)(ii) and (iii). Site-specific water-column standards shall be calculated from the site-specific bioaccumulation factor, using measured water column concentrations of total mercury and measured fish tissue concentrations of methylmercury. Fish tissue data shall be collected from species of the highest trophic level present in the water body. Fish tissue samples should include older, larger individuals present in the water body. A bioaccumulation factor should be calculated separately for each species sampled, and the highest bioaccumulation factor should be used to calculate the site-specific water column standard in order to prevent the average fish tissue concentrations from exceeding 0.3 mg/kg for all species.

(7) Applicable to all Class 1 aquatic life segments which also have a water supply classification or Class 2 aquatic life segments which also have a water supply classification designated by the Commission after rulemaking hearing. These Class 2 segments will generally be those where fish of a catchable size and which are normally consumed are present, and where there is evidence that fishing takes place on a recurring basis. The Commission may also consider additional evidence that may be relevant to a determination whether the conditions applicable to a particular segment are similar enough to the assumptions underlying the water plus fish ingestion criteria to warrant the adoption of water plus fish ingestion standards for the segment in question.

(8) The use of 0.1 micron pore size filtration for determining dissolved iron is allowed as an option in assessing compliance with the drinking water standard.

(9) Selenium is a bioaccumulative metal and subject to a range of toxicity values depending upon numerous site-specific variables.

(10) Applicable to the following segments which do not have a water supply classification: all Class 1 aquatic life segments or Class 2 aquatic life segments designated by the Commission after rulemaking hearing. These class 2 segments will generally be those where fish of a catchable size and which are normally consumed are present, and where there is evidence that fishing takes place on a recurring basis. The Commission may also consider additional evidence that may be relevant to a determination whether the conditions applicable to a particular segment are similar enough to the assumptions underlying the fish ingestion criteria to warrant the adoption of fish ingestion standards for the segment in question.

(11) Where the pH is equal to or greater than 7.0 in the receiving water after mixing, the chronic hardness-dependent equation will apply. Where pH is less than 7.0 in the receiving water after mixing, either the 87 µg/l chronic total recoverable aluminum criterion or the criterion resulting from the chronic hardness-dependent equation will apply, whichever is more stringent.

(12) This standard is only appropriate where irrigation water is applied to soils with pH values lower than 6.0.

(13) Whenever a range of standards is listed and referenced to this footnote, the first number in the range is a strictly health-based value, based on the Commission's established methodology for human health-based standards. The second number in the range is a maximum contaminant level, established under the federal Safe Drinking Water Act that has been determined to be an acceptable level of this chemical in public water supplies, taking treatability and laboratory detection limits into account. Control requirements, such as discharge permit effluent limitations, shall be established using the first number in the range as the ambient water quality target, provided that no effluent limitation shall require an "end-of-pipe" discharge level more restrictive than the second number in the range. Water bodies will be considered in attainment of this standard, and not included on the Section 303(d) List, so long as the existing ambient quality does not exceed the second number in the range.

(14) The chronic zinc equation for sculpin applies in areas where mottled sculpin are expected to occur and hardness is less than 102 ppm $CaCO_3$. The regular chronic zinc equation applies in areas where mottled sculpin are expected to occur, but the hardness is greater than 102 ppm $CaCO_3$.

(15) In determining whether adoption of a molybdenum standard is appropriate for a segment, the Commission will consider whether livestock or irrigated forage is present or expected to be present. The table value assumes that copper and molybdenum concentrations in forage are 7 mg/kg and 0.5 mg/kg respectively, forage intake is 6.8 kg/day, copper concentration in water is 0.008 mg/l, water intake is 54.6 l/day, copper supplementation is 48 mg/day, and that a Cu:Mo ratio of 4:1 is appropriate with a 0.075 mg/l molybdenum margin of safety. Numeric standards different than the table-value may be adopted on a site-specific basis where appropriate

justification is presented to the Commission. In evaluating site-specific standards, the relevant factors that should be considered include the presence of livestock or irrigated forage, and the total intake of copper, molybdenum, and sulfur from all sources (i.e., food, water, and dietary supplements). In general, site-specific standards should be based on achieving a safe copper:molybdenum total exposure ratio, with due consideration given to the sulfur exposure. A higher Cu:Mo ratio may be necessary where livestock exposure to sulfur is also high. Species specific information shall be considered where cattle are not the most sensitive species.

(16) When applying the table value standards for uranium to individual segments, the Commission shall consider the need to maintain radioactive materials at the lowest practical level as required by Section 31.11(2) of the Basic Standards regulation.

| Table IV<br>Table Value Standards for Selected Hardnesses<br>(concentration in ug/L, dissolved) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean Hardness in mg/L calcium carbonate | | | | | | | | | |
| | | 25 | 50 | 75 | 100 | 150 | 200 | 250 | 300 | 350 | 400 |
| Aluminum | Acute | 512 | 1324 | 2307 | 3421 | 5960 | 8838 | 10071 | 10071 | 10071 | 10071 |
| | Chronic | 73 | 189 | 329 | 488 | 851 | 1262 | 1438 | 1438 | 1438 | 1438 |
| Cadmium | Acute trout | 0.5 | 0.9 | 1.3 | 1.7 | 2.4 | 3.1 | 3.8 | 4.4 | 5.1 | 5.7 |
| | Acute | 0.8 | 1.5 | 2.1 | 2.7 | 3.9 | 5.0 | 6.1 | 7.1 | 8.1 | 9.2 |
| | Chronic | .15 | .25 | 0.34 | 0.42 | 0.58 | 0.72 | 0.85 | 0.97 | 1.1 | 1.2 |
| Chromium III | Acute | 183 | 323 | 450 | 570 | 794 | 1005 | 1207 | 1401 | 1590 | 1773 |
| | Chronic | 24 | 42 | 59 | 74 | 103 | 131 | 157 | 182 | 207 | 231 |
| Copper | Acute | 3.6 | 7.0 | 10 | 13 | 20 | 26 | 32 | 38 | 44 | 50 |
| | Chronic | 2.7 | 5.0 | 7.0 | 9.0 | 13 | 16 | 20 | 23 | 26 | 29 |
| Lead | Acute | 14 | 30 | 47 | 65 | 100 | 136 | 172 | 209 | 245 | 281 |
| | Chronic | 0.5 | 1.2 | 1.8 | 2.5 | 3.9 | 5.3 | 6.7 | 8.1 | 9.5 | 11 |
| Manganese | Acute | 1881 | 2370 | 2713 | 2986 | 3417 | 3761 | 4051 | 4305 | 4532 | 4738 |
| | Chronic | 1040 | 1310 | 1499 | 1650 | 1888 | 2078 | 2238 | 2379 | 2504 | 2618 |
| Nickel | Acute | 145 | 260 | 367 | 468 | 660 | 842 | 1017 | 1186 | 1351 | 1513 |
| | Chronic | 16 | 29 | 41 | 52 | 72 | 94 | 113 | 132 | 150 | 168 |
| Silver | Acute | 0.19 | 0.62 | 1.2 | 2.0 | 4.1 | 6.7 | 9.8 | 13 | 18 | 22 |
| | Chronic Trout | 0.01 | 0.02 | 0.05 | 0.08 | 0.15 | 0.25 | 0.36 | 0.50 | 0.65 | 0.81 |
| | Chronic | 0.03 | 0.10 | 0.20 | 0.32 | 0.64 | 1.0 | 1.6 | 2.1 | 2.8 | 3.5 |
| Uranium | Acute | 521 | 1119 | 1750 | 2402 | 3756 | 5157 | 6595 | 8062 | 9555 | 11070 |
| | Chronic | 326 | 699 | 1093 | 1501 | 2346 | 3221 | 4119 | 5036 | 5968 | 6915 |
| Zinc | Acute | 45 | 85 | 123 | 160 | 231 | 301 | 368 | 435 | 500 | 565 |
| | Chronic sculpin | 6.1 | 27 | 64 | 118 | N/A | N/A | N/A | N/A | N/A | N/A |
| | Chronic | 34 | 65 | 93 | 121 | 175 | 228 | 279 | 329 | 379 | 428 |
| Shaded values exceed drinking water supply standards. | | | | | | | | | | | |

# SPSS Subtask 2.2 -

# Water Quality Analysis

# Appendix B

# WQCC Regulation 38

# COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

# WATER QUALITY CONTROL COMMISSION

## 5 CCR 1002-38

## REGULATION NO. 38
## CLASSIFICATIONS AND NUMERIC STANDARDS
## FOR
## SOUTH PLATTE RIVER BASIN, LARAMIE RIVER BASIN
## REPUBLICAN RIVER BASIN, SMOKY HILL RIVER BASIN

| | | | |
|---|---|---|---|
| ADOPTED: | April 6, 1981 | EFFECTIVE: | May 16, 1981 |
| AMENDED: | April 12, 1982 | EFFECTIVE: | May 16, 1982 through May 30, 1982 |
| AMENDED: | December 6, 1982 | EFFECTIVE: | January 30, 1983 |
| SEPARATELY AMENDED: | December 6, 1982 | EFFECTIVE: | January 30, 1983 |
| AMENDED: | May 9, 1983 | EFFECTIVE: | July 16, 1983 |
| AMENDED: | December 12, 1983 | EFFECTIVE: | January 30, 1984 |
| AMENDED: | May 15, 1984 | EFFECTIVE: | June 30, 1984 |
| AMENDED: | August 14, 1984 | EFFECTIVE: | September 30, 1984 |
| AMENDED: | April 1, 1985 | EFFECTIVE: | May 30, 1985 |
| AMENDED: | March 7, 1986 | EFFECTIVE: | April 30, 1986 |
| AMENDED: | April 8, 1986 | EFFECTIVE: | May 30, 1986 |
| AMENDED: | May 9, 1986 | EFFECTIVE: | June 30, 1986 |
| AMENDED: | September 18, 1986 | EFFECTIVE: | October 30, 1986 |
| AMENDED: | August 4, 1987 | EFFECTIVE: | September 30, 1987 |
| AMENDED: | November 3, 1987 | EFFECTIVE: | December 30, 1987 |
| AMENDED: | May 2, 1988 | EFFECTIVE: | June 30, 1988 |
| AMENDED: | February 6, 1989 | EFFECTIVE: | March 30, 1989 |
| EMERGENCY AMENDED: | February 6, 1989 | EFFECTIVE: | February 6, 1989 through August 30, 1989 |
| AMENDED: | March 6, 1989 | EFFECTIVE: | April 30, 1989 |
| AMENDED: | June 5, 1989 | EFFECTIVE: | July 30, 1989 |
| EMERGENCY AMENDED: | July 11, 1989 | EFFECTIVE: | July 11, 1989 through March 30, 1990 |
| AMENDED: | February 5, 1990 | EFFECTIVE: | March 30, 1990 |
| AMENDED: | September 5, 1991 | EFFECTIVE: | October 30, 1991 |
| AMENDED: | January 6, 1992 | EFFECTIVE: | March 1, 1992 |
| AMENDED: | June 2, 1992 | EFFECTIVE: | July 30, 1992 |
| AMENDED: | July 6, 1992 | EFFECTIVE: | August 30, 1992 |
| AMENDED: | December 7, 1992 | EFFECTIVE: | January 30, 1993 |
| AMENDED: | March 1, 1993 | EFFECTIVE: | April 30, 1993 |
| AMENDED: | August 2, 1993 | EFFECTIVE: | September 30, 1993 |
| AMENDED: | September 7, 1993 | EFFECTIVE: | October 30, 1993 |
| AMENDED: | March 7, 1994 | EFFECTIVE: | April 30, 1994 |
| AMENDED: | May 2, 1994 | EFFECTIVE: | June 30, 1994 |
| AMENDED: | February 13, 1995 | EFFECTIVE: | March 30, 1995 |
| AMENDED: | June 12, 1995 | EFFECTIVE: | July 30, 1995 |
| AMENDED: | July 10, 1995 | EFFECTIVE: | August 30, 1995 |
| AMENDED: | December 11, 1995 | EFFECTIVE: | January 30, 1996 |

AMENDED: May 13, 1996 EFFECTIVE: June 30, 1996
AMENDED: August 12, 1996 EFFECTIVE: September 30, 1996
AMENDED: January 13, 1997 EFFECTIVE: March 3, 1997
AMENDED: April 14, 1997 EFFECTIVE: May 30, 1997
AMENDED: May 12, 1997 EFFECTIVE: June 30, 1997
AMENDED: July 14, 1997 EFFECTIVE: August 30, 1997
AMENDED: November 9, 1998 EFFECTIVE: December 30, 1998
AMENDED: May 11, 1999 EFFECTIVE: June 30, 1999
AMENDED: October 10, 2000 EFFECTIVE: February 20, 2001
AMENDED: February 13, 2001 EFFECTIVE: June 20, 2001
EMERGENCY AMENDMENT: May 14, 2001 EFFECTIVE: May 14, 2001
AMENDED: September 10, 2001 EFFECTIVE: October 30, 2001
AMENDED: December 10, 2001 EFFECTIVE: January 30, 2002
AMENDED: September 13, 2004 (Clear Creek seg. 5 and Middle South Platte segs. 1a & 1b)
EFFECTIVE: November 1, 2004
AMENDED: September 13, 2004 (all other segments)
EFFECTIVE: January 20, 2005
AMENDED: December 12, 2005 EFFECTIVE: March 2, 2006
AMENDED: August 14, 2006 EFFECTIVE: September 30, 2006
AMENDED: February 12, 2007 EFFECTIVE: July 1, 2007
AMENDED: April 9, 2007 EFFECTIVE: September 1, 2007
AMENDED: August 13, 2007 EFFECTIVE: September 30, 2007
AMENDED: January 14, 2008 EFFECTIVE: March 1, 2008
AMENDED: February 9, 2009 EFFECTIVE: March 30, 2009
AMENDED: August 10, 2009 EFFECTIVE: January 1, 2010
AMENDED: February 8, 2010 EFFECTIVE: June 30, 2010
AMENDED: April 12, 2010 EFFECTIVE: June 30, 2010
AMENDED: July 12, 2010 EFFECTIVE: November 30, 2010
AMENDED: January 10, 2011 EFFECTIVE: June 30, 2011
EMERGENCY AMENDMENT: December 13, 2011 EFFECTIVE: December 13, 2011
AMENDED: June 13, 2011 EFFECTIVE: January 1, 2012
AMENDED: August 13, 2012 EFFECTIVE: December 31, 2012
AMENDED: October 9, 2012 EFFECTIVE: March 1, 2013
AMENDED: January 14, 2013 EFFECTIVE: June 30, 2013
EMERGENCY AMENDMENT: May 13.2013 EFFECTIVE: May 13, 2013
AMENDED: May 1, 2013 EFFECTIVE: September 30, 2013
AMENDED: March 11, 2014 EFFECTIVE: April 30, 2014
AMENDED: March 11, 2014 EFFECTIVE: June 30, 2014
AMENDED: January 12, 2015 EFFECTIVE: June 30, 2015
AMENDED: August 10, 2015 EFFECTIVE: December 31, 2015
AMENDED: January 11, 2016 EFFECTIVE: March 1, 2016
AMENDED: January 11, 2016 EFFECTIVE: June 30, 2016

# WATER QUALITY CONTROL COMMISSION

## 5 CCR 1002-38

## REGULATION NO. 38
## CLASSIFICATIONS AND NUMERIC STANDARDS
## FOR
## SOUTH PLATTE RIVER BASIN, LARAMIE RIVER BASIN
## REPUBLICAN RIVER BASIN, SMOKY HILL RIVER BASIN

### 38.1 AUTHORITY

These regulations are promulgated pursuant to section 25-8-101 et seq C.R.S., as amended, and in particular, 25-8-203 and 25-8-204.

### 38.2 PURPOSE

These regulations establish classification and numeric standards for the South Platte River, the Laramie River, the Republican River and the Smoky Hill River, including all tributaries and standing bodies of water as indicated in section 38.6. The classifications identify the actual beneficial uses of the water. The numeric standards are assigned to determine the allowable concentrations of various parameters. Discharge permits will be issued by the Water Quality Control Division to comply with basic, narrative, and numeric standards and control regulations so that all discharges to waters of the state protect the classified uses. (See section 31.14). It is intended that these and all other stream classifications and numeric standards be used in conjunction with and be an integral part of Regulation 31.0 - BASIC STANDARDS AND METHODOLOGIES FOR SURFACE WATER.

### 38.3 INTRODUCTION

These regulations and Tables present the classifications and numeric standards assigned to stream segments listed in the attached Tables (See section 38.6). As additional stream segments are classified and numeric standards for this drainage system are adopted, they will be added to or replace the numeric standards in the Tables in section 38.6. Any additions or revisions of classifications or numeric standards can be accomplished only after public hearing by the Commission and proper consideration of evidence and testimony as specified by the statute and the “basic regulations”.

### 38.4 DEFINITIONS

See the Colorado Water Quality Control Act and the codified water quality regulations for definitions.

### 38.5 BASIC STANDARDS

(1) TEMPERATURE

All waters of the South Platte, Laramie, Republican and Smoky Hill River Basins are subject to the following standard for temperature. (Discharges regulated by permits, which are within the permit limitations, shall not be subject to enforcement proceedings under this standard.) Temperature shall maintain a normal pattern of diurnal and seasonal fluctuations with no abrupt changes and shall have no increase in temperature of a magnitude, rate, and duration deemed deleterious to the resident aquatic life. This standard shall not be interpreted or applied in a manner inconsistent with section 25-8-104, C.R.S.

(2) QUALIFIERS

See Basic Standards and Methodologies for Surface Water for a listing of organic standards at 31.11 and metal standards found at 31.16 Table III. The column in the tables headed "Water + Fish" are presumptively applied to all aquatic life class 1 streams which also have a water supply classification, and are applied to aquatic life class 2 streams which also have a water supply classification, on a case-by-case basis as shown in the Tables 38.6. The column in the tables at 31.11 headed "Fish Ingestion" is presumptively applied to all aquatic life class 1 streams which do not have a water supply classification, and are applied to aquatic life class 2 streams which do not have a water supply classification, on a case-by-case basis, as shown in the Tables in 38.6.

(3) URANIUM

(a) All waters of the South Platte River Basin are subject to the following basic standard for uranium, unless otherwise specified by a water quality standard applicable to a particular segment. However, discharges of uranium regulated by permits which are within these permit limitations shall not be a basis for enforcement proceedings under this basic standard.

(b) Uranium level in surface waters shall be maintained at the lowest practicable level.

(c) In no case shall uranium levels in waters assigned a water supply classification be increased by any cause attributable to municipal, industrial, or agricultural discharges so as to exceed 16.8-30 µg/l or naturally-occurring concentrations (as determined by the State of Colorado), whichever is greater.

(i) The first number in the 16.8-30 µg/l range is a strictly health-based value, based on the Commission's established methodology for human health-based standards. The second number in the range is a maximum contaminant level, established under the federal Safe Drinking Water Act that has been determined to be an acceptable level of this chemical in public water supplies, taking treatability and laboratory detection limits into account. Control requirements, such as discharge permit effluent limitations, shall be established using the first number in the range as the ambient water quality target, provided that no effluent limitation shall require an "end-of-pipe" discharge level more restrictive than the second number in the range. Water bodies will be considered in attainment of this standard, and not included on the Section 303(d) List, so long as the existing ambient quality does not exceed the second number in the range.

(4) NUTRIENTS

Prior to May 31, 2022, interim nutrient values will be considered for adoption only in the limited circumstances defined at 31.17(e). These circumstances include headwaters, Direct Use Water Supply (DUWS) Lakes and Reservoirs, and other special circumstances determined by the Commission. Additionally, prior to May 31, 2017, only total phosphorus and chlorophyll *a* will be considered for adoption. After May 31, 2017, total nitrogen will be considered for adoption per the circumstances outlined in 31.17(e).

Prior to May 31, 2022, nutrient criteria will be adopted for headwaters on a segment by segment basis for the South Platte River Basin. Moreover, pursuant to 31.17(e), nutrient standards will only be adopted for waters upstream of all permitted domestic wastewater treatment facilities discharging prior to May 31, 2012 or with preliminary effluent limits requested prior to May 31, 2012, and any non-domestic facilities subject to Regulation 85 effluent limits and discharging prior to May 31, 2012. The following is a list of all permitted domestic wastewater treatment facilities discharging prior to May 31, 2012 or with preliminary effluent limits requested prior to May 31, 2012, and any non-domestic facilities subject to Regulation 85 effluent limits and discharging prior to May 31, 2012 in the South Platte River Basin:

| Segment | Permittee | Facility name | Permit No. |
|---|---|---|---|
| COSPUS01a | Alma Town of | ALMA, TOWN OF | CO0035769 |
| COSPUS01a | Fairplay Sanitation District | FAIRPLAY SANITATION DISTRICT WWTF | CO0040088 |
| COSPUS01a | Boy Scouts of America Pikes Peak Council | CAMP ALEXANDER | COG588036 |
| COSPUS02a | Florissant Water and San Dist | FLORISSANT WATER & SAN DIST | CO0041416 |
| COSPUS02a | Teller County | TELLER COUNTY WW UTILITY BOARD | CO0044211 |
| COSPUS03 | Woodland Park City of | WOODLAND PARK, CITY OF | CO0043214 |
| COSPUS03 | YMCA Camp Shady Brook | CAMP SHADY BROOK | CO0045993 |
| COSPUS03 | Lost Valley Ranch Corporation | LOST VALLEY RANCH | COG588122 |
| COSPUS04 | Will-O-Wisp Metro District | WILL-O-WISP METRO DISTRICT | CO0041521 |
| COSPUS04 | Bailey WSD | BAILEY WSD WWTF | COG588056 |
| COSPUS04 | Platte Canyon School Dist 1 | PLATTE CANYON SCHOOL DIST 1 | COG588114 |
| COSPUS05c | Mountain Water and Sanitation District | MOUNTAIN WATER & SAN DISTRICT | CO0022730 |
| COSPUS06a | Roxborough Water and Sanitation District | ROXBOROUGH PARK WATER & SAN WWTF | CO0041645 |
| COSPUS10a | Plum Creek Water Reclamation Authority | PLUM CREEK WW AUTHORITY WWTF | CO0038547 |
| COSPUS10a | Perry Park Water and Sanitation District | SAGEPORT WWTF | CO0043044 |
| COSPUS11b | Perry Park Water and Sanitation District | WAUCONDAH WWTP | CO0022551 |
| COSPUS14 | Littleton/Englewood Cities of | LITTLETON/ENGLEWOOD, CITIES OF | CO0032999 |
| COSPUS15 | Metro Waste Water Reclamation District | METRO WASTEWATER RECLAM DIST | CO0026638 |
| COSPUS15 | Brighton City of | BRIGHTON WWTF | CO0021547 |
| COSPUS15 | South Adams County WSD | WILLIAMS MONOCO WWTF | CO0026662 |
| COSPUS15 | Metro Waste Water Reclamation District | NORTHERN TREATMENT PLANT | CO0048959 |
| COSPUS16c | Ascentia Real Estate Holding Company LLC | FOXRIDGE FARMS MH COMMUNITY | CO0028908 |
| COSPUS16c | SouthWest Water Company | HI-LAND ACRES W&SD WWTF | COG589072 |
| COSPUS16c | Mile High Racing and Enter dba Arapahoe Park | ARAPAHOE PARK RACETRACK | COG589073 |
| COSPUS16c | Rangeview Metro District | COAL CREEK WW RECLAMATION FAC | COG589108 |
| COSPUS16g | Centennial Water and San Dist | MARCY GULCH WWTF | CO0037966 |
| COSPUS16i | Aurora City of - Aurora Water | SAND CREEK WATER REUSE FACILTY | CO0026611 |
| COSPCH01 | Stonegate Village Metropolitan District | STONEGATE VILLAGE WWTF | CO0040291 |

| Segment | Permittee | Facility name | Permit No. |
|---|---|---|---|
| COSPCH01 | Pinery Water and Wastewater District | PINERY WWTF | CO0041092 |
| COSPCH01 | Parker Water and Sanitation District | PARKER NORTH WRF | CO0046507 |
| COSPCH04 | Arapahoe County W and WW Authority | LONE TREE CREEK WWTP | CO0040681 |
| COSPBE01a | Amen Real Estate LLC | SINGIN' RIVER RANCH WWTF | CO0035971 |
| COSPBE01b | Morrison Town of | MORRISON TOWN OF | CO0041432 |
| COSPBE01e | Kittredge Sanitation and Water District | KITTREDGE SAN & WATER DISTRICT | CO0023841 |
| COSPBE01e | Bruce & Jayne Hungate DBA Bear Creek Cabins | BEAR CREEK CABINS | CO0030856 |
| COSPBE01e | Evergreen Metropolitan District | EVERGREEN METROPOLITAN DIST WWTF | CO0031429 |
| COSPBE04a | Genesee WSD | GENESEE WATER & SAN DISTRICT | CO0022951 |
| COSPBE04a | Forest Hills Metro District | FOREST HILLS METROPOLITAN DIST | CO0037044 |
| COSPBE05 | West Jefferson County MD | W. JEFFERSON COUNTY METRO DIST | CO0020915 |
| COSPBE05 | Historic Brook Forest Inn LLC | BROOK FOREST INN | CO0030261 |
| COSPBE06a | Tiny Town Foundation Inc | TINY TOWN | CO0036129 |
| COSPBE06a | Aspen Park Metropolitan District | ASPEN PARK METROPOLITAN DISTRICT | CO0000001 |
| COSPBE06b | Jefferson County Public Schools R-1 | CONIFER HIGH SCHOOL WW REC PLT | CO0047988 |
| COSPCL01 | Colorado Dept of Transportation | EISENHOWER/JOHNSON MEMORIAL TUNNELS | CO0026069 |
| COSPCL01 | Clear Creek Skiing Corp | LOVELAND SKI AREA WWTF | CO0040835 |
| COSPCL02a | Georgetown Town of | GEORGETOWN WWTF | CO0027961 |
| COSPCL02c | Central Clear Creek SD | CENTRAL CLEAR CREEK SD WWTF | COG588055 |
| COSPCL05 | Empire Town of | EMPIRE TOWN OF | COG588065 |
| COSPCL09a | St Marys Glacier WSD | ST. MARYS GLACIER WSD | CO0023094 |
| COSPCL10 | Shwayder Camp Wastewater | SHWAYDER CAMP WWTF | CO0047473 |
| COSPCL11 | Idaho Springs City of | IDAHO SPRINGS WWTF | CO0041068 |
| COSPCL12 | Clear Creek WWTP | CLEAR CREEK WWTP | CO0046574 |
| COSPCL13b | Black Hawk/Central City Sanitation District | BLACK HAWK/CENTRAL CITY SD WWTF | CO0046761 |
| COSPCL14a | MillerCoors LLC | MILLERCOORS GOLDEN FACILITY | CO0001163 |
| COSPBD01 | Westminster City of | BIG DRY CREEK WWTF | CO0024171 |
| COSPBD01 | Broomfield City and County | BROOMFIELD WWTF | CO0026409 |
| COSPBD01 | Northglenn City of | NORTHGLENN WWTF | CO0036757 |
| COSPBO02b | San Lazaro Park Properties LLP c/o | SAN LAZARO MHP WWTF | CO0020184 |
| COSPBO02b | BaseCamp Ventures LLC | BOULDER MOUNTAIN LODGEWWTF | CO0040819 |

| Segment | Permittee | Facility name | Permit No. |
|---|---|---|---|
| COSPBO02b | Mueller Red Lion Inn | RED LION INN WWTF | COG588118 |
| COSPBO03 | Nederland Town of | NEDERLAND TOWN OF WWTF | CO0020222 |
| COSPBO04b | Eldorado Springs Wastewater | ELDORADO SPRINGS WWTF | CO0047651 |
| COSPBO04b | San Souci MHP | SAN SOUCI MHP | COG588101 |
| COSPBO07b | Louisville City of | LOUISVILLE WWTF | CO0023078 |
| COSPBO07b | Lafayette City of | LAFAYETTE WWTF | CO0023124 |
| COSPBO07b | Erie Town of | ERIE WWTF | CO0045926 |
| COSPBO08 | Superior Metropolitan District No 1 | SUPERIOR METROPOLITAN DIST NO1 | CO0043010 |
| COSPBO09 | Boulder City of | 75TH ST WWTP | CO0024147 |
| COSPBO10 | Erie Town of | ERIE NORTH WATER RECLAMATION FACILITY | CO0048445 |
| COSPBO10 | B & B Mobile Home and RV Park | B & B MOBILE HOME & RV PARK | COG588107 |
| COSPBO14 | Lake Eldora WSD | LAKE ELDORA WSD WWTF | CO0020010 |
| COSPSV02a | Peaceful Valley Ranch LLC | PEACEFUL VALLEY RANCH WWTF | CO0048828 |
| COSPSV02a | Seventh-Day Adventist Assoc of Colorado | GLACIER VIEW RANCH | CO0030112 |
| COSPSV02a | Aspen Lodge at Estes Park Corp | ASPEN LODGE AT ESTES PARK CORP | CO0042820 |
| COSPSV02b | Lyons Town of | LYONS TOWN OF | CO0020877 |
| COSPSV03 | Longmont City of | LONGMONT WWTF | CO0026671 |
| COSPSV03 | St Vrain Sanitation District | ST VRAIN SANITATION DISTRICT | CO0041700 |
| COSPSV06 | Niwot Sanitation District | NIWOT SANITATION DISTRICT | CO0021695 |
| COSPSV06 | Mead  Town of | LAKE THOMAS SUBDIVISION WWTF | CO0046868 |
| COSPSV06 | Mead Town of | MEAD, TOWN OF | CO0046876 |
| COSPSV06 | Fairways Metro Dist | FAIRWAYS WWTF | CO0048411 |
| COSPMS01a | Fort Lupton  City of | FORT LUPTON WWTF | CO0021440 |
| COSPMS01b | Evans City of | EVANS CITY OF WWTF | CO0020508 |
| COSPMS01b | Kersey Town of | KERSEY WWTF | CO0021954 |
| COSPMS01b | Platteville Town of | PLATTEVILLE WWTF | CO0040355 |
| COSPMS01b | Evans City of | HILL-N-PARK SANITATION DIST. | CO0047287 |
| COSPMS01b | La Salle Town of | LA SALLE TOWN OF | COG588058 |
| COSPMS01b | Gilcrest Town of | GILCREST WWTF | COG588121 |
| COSPMS03a | Elizabeth Town of | GOLD CREEK | COG589037 |
| COSPMS03a | Galeton Water and Sanitation District | GALETON WATER & SAN DISTRICT | CO0043320 |
| COSPMS03a | Orica USA Inc | ORICA USA, INC. | CO0046221 |
| COSPMS03a | Spring Valley Ranch | SPRING VALLEY RANCH WWTF | CO0046965 |

| Segment | Permittee | Facility name | Permit No. |
|---|---|---|---|
| COSPMS03a | Front Range Airport WWTF | FRONT RANGE AIRPORT WWTF | CO0047741 |
| COSPMS04 | Lochbuie Town of | LOCHBUIE TOWN OF | CO0047198 |
| COSPMS05a | Swift Beef Company | SWIFT BEEF - LONE TREE | CO0027707 |
| COSPMS05c | Hudson WWTF | HUDSON MECHANICAL WWTF | COG589104 |
| COSPMS06 | Keenesburg Town of | KEENESBURG TOWN OF | CO0041254 |
| COSPMS06 | Bennett Town of | BENNETT TOWN OF | COG589069 |
| COSPBT02 | Estes Park Sanitation District | ESTES PARK SANITATION DISTRICT | CO0020290 |
| COSPBT02 | Upper Thompson Sanitation District | UTSD WWTF | CO0031844 |
| COSPBT04c | Loveland City of | LOVELAND WWTP | CO0026701 |
| COSPBT05 | Milliken Town of | MILLIKEN SANITATION DISTRICT | CO0042528 |
| COSPBT05 | Johnstown Town of | LOW POINT WWTP | CO0047058 |
| COSPBT07 | Hidden View Estates HOA | HIDDEN VIEW ESTATES HOA WWTF | CO0048861 |
| COSPBT09 | Johnstown Town of | JOHNSTOWN CENTRAL WWTF | CO0021156 |
| COSPBT09 | Riverglen Homeowners Assoc | RIVERGLEN HOA WWTF | CO0029742 |
| COSPBT09 | Berthoud Town of | BERTHOUD, TOWN OF | CO0046663 |
| COSPBT10 | Berthoud Town of | SERENITY RIDGE WWTF | CO0047007 |
| COSPBT10 | Western Mini-Ranch/Vaquero Estates Sewer Assoc. | WESTERN MINI-RANCH/VAQUERO EST | COG589095 |
| COSPBT10 | Berthoud Estates Community Assoc | BERTHOUD ESTATES WWTF | COG589097 |
| COSPCP08 | Fox Acres Community Services Corp | FOX ACRES WWTF | COG589112 |
| COSPCP08 | Girl Scouts of Colorado | MAGIC SKY RANCH G.S. CAMP | CO0047317 |
| COSPCP11 | Fort Collins City of | MULBERRY WWTP | CO0026425 |
| COSPCP11 | Fort Collins City of | DRAKE WWTP | CO0047627 |
| COSPCP12 | Windsor, Town of | WINDSOR TOWN OF WWTF | CO0020320 |
| COSPCP12 | Greeley City of | GREELEY CITY OF | CO0040258 |
| COSPCP12 | Leprino Foods Company | LEPRINO GREELEY FACILITY WWTF | CO0048860 |
| COSPCP13a | Anheuser Busch Inc | NUTRI-TURF, INC. | CO0039977 |
| COSPCP13a | Eaton Town of | EATON, TOWN OF | CO0047414 |
| COSPCP13a | Saddler Ridge Metro Dist Water Reclamation Facility | SADDLER RIDGE METRO DIST WATER RECLAMATION FACILITY | COG589107 |
| COSPCP13b | Boxelder Sanitation District | BOXELDER SANITATION DISTRICT WWTF | CO0020478 |
| COSPCP13b | Wellington Town of | WELLINGTON WWTF | CO0046451 |
| COSPCP22 | South Fort Collins Sanitation District | SOUTH FORT COLLINS SAN DIST | CO0020737 |
| COSPLS01 | Western Sugar Cooperative | FORT MORGAN FACILITY | CO0041351 |

| Segment | Permittee | Facility name | Permit No. |
|---|---|---|---|
| COSPLS01 | Cargill Meat Solutions | FORT MORGAN BEEF PLANT | CO0044270 |
| COSPLS01 | Julesburg Town of | JULESBURG TOWN OF | CO0021113 |
| COSPLS01 | Brush City of | BRUSH CITY OF | CO0021245 |
| COSPLS01 | Sterling City of | STERLING CITY OF | CO0026247 |
| COSPLS01 | Fort Morgan City of | FORT MORGAN CITY OF | CO0044849 |
| COSPLS01 | Snyder Sanitation District | SNYDER SANITATION DISTRICT | COG588016 |
| COSPLS01 | Morgan Heights WSD | MORGAN HEIGHTS WATER&SEWER INC | COG588040 |
| COSPLS01 | Ovid Town of | OVID TOWN OF | COG588106 |
| COSPLS02a | Leprino Foods Company | FORT MORGAN CHEESE FACILITY | CO0043958 |
| COSPLS02a | Deer Trail Town of | DEER TRAIL WWTF | COG589002 |
| COSPLS02a | Hillrose Town of | HILLROSE WWTF | COG589030 |
| COSPLS02a | Byers Water and Sanitation District | BYERS WATER AND SANITATION DISTRICT | COG589033 |
| COSPLS02a | Eastern Adams County Metro District | EASTERN ADAMS CO METRO DIST WWTF | COG589035 |
| COSPLS02b | Kiowa Town of | KIOWA WWTF | CO0033405 |
| COSPLS02b | Elbert Water Sanitation District | ELBERT WATER & SANITATION DIST WWTF | COG589065 |
| COSPRE03 | Wray City of | WRAY CITY OF | CO0023833 |
| COSPRE06 | Flagler Town of | FLAGER WWTF | COG589036 |
| COSPRE06 | Arriba Town of | ARRIBA WWTF | COG589055 |
| COSPRE06 | Holyoke City of | HOLYOKE, CIY OF | COG589059 |
| COSPRE06 | Akron Town of | AKRON WWTF | COG589061 |
| COSPRE06 | Haxtun Town of | HAXTUN, TOWN OF | COG589062 |
| COSPRE06 | Stratton Town of | STRATTON WWTF | COG589100 |
| COSPRE06 | Burlington City of | BURLINGTON CITY OF WWTF | COG589114 |
| COSPRE06 | Seibert Town of | SEIBERT WWTF | COG589120 |
| COSPRE07 | Cheyenne Wells Sanitation District No 1 | CHEYENNE WELLS SANITATION DIST | COG589039 |
| Unclassified | Silco Oil Co | TOMAHAWK TRUCK STOP | COG589003 |

Prior to May 31, 2022:

- For segments located entirely above these facilities, nutrient standards apply to the entire segment.
- For segments with portions downstream of these facilities, *nutrient standards only apply above these facilities*. A footnote was added to the total phosphorus and chlorophyll *a* standards in these segments. The footnote references the table of qualified facilities at 38.5(4).
- For segments located entirely below these facilities, nutrient standards do not apply.

A footnote was added to the total phosphorus and chlorophyll *a* standards in lakes segments as nutrients standards apply only to lakes and reservoirs larger than 25 acres surface area.

## 38.6 TABLES

(1) Introduction

The numeric standards for various parameters in this regulation and in the tables in Appendix 38-1 were assigned by the Commission after a careful analysis of the data presented on actual stream conditions and on actual and potential water uses.

Numeric standards are not assigned for all parameters listed in the Tables attached to 31.0. If additional numeric standards are found to be needed during future periodic reviews, they can be assigned by following the proper hearing procedures.

(2) Abbreviations:

(a) The following abbreviations are used in this regulation and in the tables in Appendix 38-1:

| | | |
|---|---|---|
| ac | = | acute (1-day) |
| $^oC$ | = | degrees celsius |
| ch | = | chronic (30-day) |
| CL | = | cold lake temperature tier |
| CLL | = | cold large lake temperature tier |
| CS-I | = | cold stream temperature tier one |
| CS-II | = | cold stream temperature tier two |
| D.O. | = | Dissolved oxygen |
| DM | = | daily maximum |
| DUWS | = | direct use water supply |
| E. coli | = | Eschericia coli |
| mg/l | = | milligrams per liter |
| MWAT | = | maximum weekly average temperature |
| OW | = | outstanding waters |
| sp | = | Spawning |
| SSE | = | site-specific equation |
| T | = | total recoverable |
| t | = | total |
| tr | = | trout |
| TVS | = | table value standard |
| µg/l | = | micrograms per liter |
| UP | = | use-protected |
| WAT | = | weekly average temperature |
| WL | = | warm lake temperature tier |
| WS | = | water supply |
| WS-I | = | warm stream temperature tier one |
| WS-II | = | warm stream temperature tier two |
| WS-III | = | warm stream temperature tier three |

(b) In addition, the following abbreviations are used:

| | | |
|---|---|---|
| Fe(ch) | = | WS |
| Mn(ch) | = | WS |
| $SO_4$ | = | WS |

These abbreviations mean: For all surface waters with an actual water supply use, the less restrictive of the following two options shall apply as numerical standards, as specified in the Basic Standards and Methodologies at 31.11(6);

(i) existing quality as of January 1, 2000; or

(ii) Iron = 300 µg/l (dissolved)
Manganese = 50 µg/l (dissolved)
$SO_4$ = 250 mg/l

For all surface waters with a "water supply" classification that are not in actual use as a water supply, no water supply standards are applied for iron, manganese or sulfate, unless the Commission determines as the result of a site-specific rulemaking hearing that such standards are appropriate.

(c) Temporary Modification for Water + Fish Chronic Arsenic Standard

(i) The temporary modification for chronic arsenic standards applied to segments with an arsenic standard of 0.02 µg/l that has been set to protect the Water+Fish qualifier is listed in the temporary modification and qualifiers column as As(ch)=hybrid.

(ii) For discharges existing on or before 6/1/2013, the temporary modification is: As(ch)=current condition, expiring on 12/31/2021.

(iii) For new or increased discharges commencing on or after 6/1/2013, the temporary modification is: As(ch)=0.02-3.0 µg/l (Trec), expiring on 12/31/2021.

(a) The first number in the range is the health-based water quality standard previously adopted by the Commission for the segment.

(b) The second number in the range is a technology based value established by the Commission for the purpose of this temporary modification.

(c) Control requirements, such as discharge permit effluent limitations, shall be established using the first number in the range as the ambient water quality target, provided that no effluent limitation shall require an "end-of-pipe" discharge level more restrictive than the second number in the range.

(3) Table Value Standards

In certain instances in the tables in Appendix 38-1, the designation "TVS" is used to indicate that for a particular parameter a "table value standard" has been adopted. This designation refers to numerical criteria set forth in the Basic Standards and Methodologies for Surface Water. The criteria for which the TVS are applicable are on the following table.

**TABLE VALUE STANDARDS**
**(Concentrations in µg/l unless noted)**

| **PARAMETER**[(1)] | **TABLE VALUE STANDARDS** [(2)(3)] |
|---|---|
| Aluminum (T) | Acute = $e^{(1.3695[\ln(hardness)]+1.8308)}$<br><br>pH equal to or greater than 7.0 |

| | |
|---|---|
| | Chronic=$e^{(1.3695[\ln(hardness)]-0.1158)}$<br>pH less than 7.0<br>Chronic= $e^{(1.3695[\ln(hardness)]-0.1158)}$ or 87, whichever is more stringent |
| Ammonia [4] | Cold Water = (mg/l as N)Total<br>$acute = \frac{0.275}{1+10^{7.204-pH}} + \frac{39.0}{1+10^{pH-7.204}}$<br>$chronic = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right) * MIN\left(2.85,\ 1.45 * 10^{0.028(25-T)}\right)$ |
| | Warm Water = (mg/l as N)Total<br>$acute = \frac{0.411}{1+10^{7.204-pH}} + \frac{58.4}{1+10^{pH-7.204}}$ |
| | $chronic\ \ (Apr\,1 - Aug\,31) = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right) * MIN\left(2.85,\ 1.45 * 10^{0.028(25-T)}\right)$<br>$chronic\ (Sep\,1 - Mar\,31) = \left(\frac{0.0577}{1+10^{7.688-pH}} + \frac{2.487}{1+10^{pH-7.688}}\right) * 1.45 * 10^{0.028*(25-MAX(T,\ 7))}$ |
| Cadmium | Acute = (1.136672-[ln(hardness) x (0.041838)])*$e^{(0.9151[\ln(hardness)]-3.1485)}$<br>Acute(Trout) = (1.136672-[ln(hardness) x (0.041838)])*$e^{(0.9151[\ln(hardness)]-3.6236)}$<br>Chronic = (1.101672-[ln(hardness) x (0.041838)])*$e^{(0.7998[\ln(hardness)]-4.4451)}$ |
| Chromium III[5] | Acute = $e^{(0.819[\ln(hardness)]+2.5736)}$<br>Chronic = $e^{(0.819[\ln(hardness)]+0.5340)}$ |
| Chromium VI[5] | Acute = 16<br>Chronic = 11 |
| Copper | Acute = $e^{(0.9422[\ln(hardness)]-1.7408)}$<br>Chronic = $e^{(0.8545[\ln(hardness)]-1.7428)}$ |
| Lead | Acute = (1.46203-[ln(hardness)*(0.145712)])*$e^{(1.273[\ln(hardness)]-1.46)}$<br>Chronic = (1.46203-[(ln hardness)* (0.145712)])*$e^{(1.273[\ln(hardness)]-4.705)}$ |
| Manganese | Acute= $e^{(0.3331[\ln(hardness)]+6.4676)}$<br>Chronic= $e^{(0.3331[\ln(hardness)]+5.8743)}$ |
| Nickel | Acute = $e^{(0.846[\ln(hardness)]+2.253)}$<br>Chronic = $e^{(0.846[\ln(hardness)]+0.0554)}$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Selenium[6] | Acute = 18.4<br>Chronic = 4.6 | | | | | |
| Silver | Acute = ½ $e^{(1.72[\ln(hardness)]-6.52)}$<br>Chronic = $e^{(1.72[\ln(hardness)]-9.06)}$<br>Chronic(Trout) = $e^{(1.72[\ln(hardness)]-10.51)}$ | | | | | |
| Temperature | **TEMPERATURE TIER** | **TIER CODE** | **SPECIES EXPECTED TO BE PRESENT** | **APPLICABLE MONTHS** | **TEMPERATURE STANDARD ($^{o}$C)** | |
| | | | | | (MWAT) | (DM) |
| | Cold Stream Tier I | CS-I | brook trout, cutthroat trout | June – Sept. | 17.0 | 21.7 |
| | | | | Oct. - May | 9.0 | 13.0 |
| | Cold Stream Tier II | CS-II | all other cold-water species | April – Oct. | 18.3 | 23.9 |
| | | | | Nov. - March | 9.0 | 13.0 |
| | Cold Lake | CL | brook trout, brown trout, cutthroat trout, lake trout, rainbow trout, Arctic grayling, sockeye salmon | April – Dec. | 17.0 | 21.2 |
| | | | | Jan. - March | 9.0 | 13.0 |
| Temperature | Cold Large Lake (>100 acres surface area) | CLL | brown trout, lake trout, rainbow trout | April – Dec. | 18.3 | 23.8 |
| | | | | Jan. - March | 9.0 | 13.0 |
| | Warm Stream Tier I | WS-I | common shiner, Johnny darter, orangethroat darter | March – Nov. | 24.2 | 29.0 |
| | | | | Dec. – Feb. | 12.1 | 14.5 |
| | Warm Stream Tier II | WS-II | brook stickleback, central stoneroller, creek chub, longnose dace, Northern redbelly dace, finescale dace,razorback sucker, white sucker | March – Nov. | 27.5 | 28.6 |
| | | | | Dec. – Feb. | 13.8 | 14.3 |
| | Warm Stream Tier III | WS-III | all other warm-water species | March – Nov. | 28.7 | 31.8 |
| | | | | Dec. – Feb. | 14.3 | 15.9 |
| | Warm Lakes | WL | Yellow perch, walleye, pumpkinseed, smallmouth bass, striped bass, white bass, largemouth bass, bluegill, spottail shiner, Northern pike, tiger muskellunge, black crappie, common carp, gizzard shad, sauger, white crappie, wiper | April – Dec. | 26.3 | 29.5 |
| | | | | Jan. - March | 13.2 | 14.8 |
| Uranium | Acute = $e^{(1.1021[\ln(hardness)]+2.7088)}$<br>Chronic = $e^{(1.1021[\ln(hardness)]+2.2382)}$ | | | | | |
| Zinc | Acute = $0.978 * e^{(0.9094[\ln(hardness)]+0.9095)}$<br>Chronic = $0.986 * e^{(0.9094[\ln(hardness)]+0.6235)}$ | | | | | |

*TABLE VALUE STANDARDS - FOOTNOTES*

*(1) Metals are stated as dissolved unless otherwise specified.*

*(2) Hardness values to be used in equations are in mg/l as calcium carbonate and shall be no greater than 400 mg/L except for aluminum for which hardness shall be no greater than 220 mg/L. The hardness values used in calculating the appropriate metal standard should be based on the lower 95 per cent confidence limit of the mean hardness value at the periodic low flow criteria as determined from a regression analysis of site-specific data. Where insufficient site-specific data exists to define the mean hardness value at the periodic low flow criteria, representative regional data shall be used to perform the regression analysis. Where a regression analysis is not appropriate, a site-specific method should be used. In calculating a hardness value, regression analyses should not be extrapolated past the point that data exist.*

*(3) Both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average.*

*(4) For acute conditions the default assumption is that salmonids could be present in cold water segments and should be protected, and that salmonids do not need to be protected in warm water segments. For chronic conditions, the default assumptions are that early life stages could be present all year in cold water segments and should be protected. In warm water segments the default assumption is that early life stages are present and should be protected only from April 1 through August 31. These assumptions can be modified by the Commission on a site-specific basis where appropriate evidence is submitted.*

*(5) Unless the stability of the chromium valence state in receiving waters can be clearly demonstrated, the standard for chromium should be in terms of chromium VI. In no case can the sum of the instream levels of Hexavalent and Trivalent Chromium exceed the water supply standard of 50 µg/l total chromium in those waters classified for domestic water use.*

*(6) Selenium is a bioaccumulative metal and subject to a range of toxicity values depending upon numerous site-specific variables.*

*(7) E.coli criteria and resulting standards for individual water segments, are established as indicators of the potential presence of pathogenic organisms. Standards for E. coli are expressed as a two-month geometric mean. Site-specific or seasonal standards are also two-month geometric means unless otherwise specified.*

*(8) All phosphorus standards are based upon the concentration of total phosphorus.*

*(9) The pH standards of 6.5 (or 5.0) and 9.0 are an instantaneous minimum and maximum, respectively to be applied as effluent limits. In determining instream attainment of water quality standards for pH, appropriate averaging periods may be applied, provided that beneficial uses will be fully protected.*

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(4) Assessment Criteria

The following criteria shall be used when assessing whether a specified waterbody is in attainment of the specified standard.

(a) Upper South Platte Segment 6b, Chatfield Reservoir: Assessment Thresholds

chlorophyll = 11.2 µg/l, summer average, 1 in 5 year allowable exceedance frequency
phosphorus(Tot) = 0.035 mg/l, summer average, 1 in 5 year allowable exceedance frequency.

(b) Upper South Platte Segment 16h: Selenium Standards and Assessment Locations

Selenium Standards:

# REGULATION #38 STREAM CLASSIFICATIONS and WATER QUALITY STANDARDS
## Middle South Platte River Basin

1a. Mainstem of the South Platte River from a point immediately below the confluence with Big Dry Creek to the confluence with St. Vrain Creek.

| COSPMS01A | Classifications |
|---|---|
| **Designation** | Agriculture |
| UP | Aq Life Warm 2 |
| | Recreation E |
| | Water Supply |

**Qualifiers:**

**Water + Fish Standards**

**Other:**

Temporary Modification(s):
Arsenic(chronic) = hybrid
Expiration Date of 12/31/2021

*Ammonia(acute) = See attached table for site-specific standards.
*Ammonia(chronic) = See attached table for site-specific standards.
*Copper(acute) = Copper BLM-based FMB
Cu FMB(ac)=35.1 ug/l
*Copper(chronic) = Copper BLM-based FMB
Cu FMB(ch)= 23.5 ug/l
*D.O. (mg/L)(acute) = See attached table for site-specific standards.
*D.O. (mg/L)(chronic) = See attached table for site-specific standards.

**Physical and Biological**

| | DM | MWAT |
|---|---|---|
| Temperature °C | WS-II | WS-II |
| | **acute** | **chronic** |
| D.O. (mg/L) | varies* | varies* |
| pH | 6.5 - 9.0 | --- |
| chlorophyll a (mg/m$^2$) | --- | --- |
| E. Coli (per 100 mL) | --- | 126 |

**Inorganic (mg/L)**

| | acute | chronic |
|---|---|---|
| Ammonia | TVS* | TVS* |
| Boron | --- | 0.75 |
| Chloride | --- | 250 |
| Chlorine | 0.019 | 0.011 |
| Cyanide | 0.005 | --- |
| Nitrate | 10 | --- |
| Nitrite | --- | 0.5 |
| Phosphorus | --- | --- |
| Sulfate | --- | WS |
| Sulfide | --- | 0.002 |

**Metals (ug/L)**

| | acute | chronic |
|---|---|---|
| Aluminum | --- | --- |
| Arsenic | 340 | 0.02(T) [A] |
| Beryllium | --- | --- |
| Cadmium | TVS | TVS |
| Cadmium | 5.0(T) | --- |
| Chromium III | 50(T) | TVS |
| Chromium VI | TVS | TVS |
| Copper | --- | 23.5* |
| Copper | 35.1* | --- |
| Iron | --- | WS |
| Iron | --- | 1000(T) |
| Lead | TVS | TVS |
| Lead | 50(T) | --- |
| Manganese | TVS | TVS |
| Manganese | --- | WS |
| Mercury | --- | 0.01(t) |
| Molybdenum | --- | 150(T) |
| Nickel | TVS | TVS |
| Nickel | --- | 100(T) |
| Selenium | TVS | TVS |
| Silver | TVS | TVS |
| Uranium | --- | --- |
| Zinc | TVS | TVS |

1b. Mainstem of the South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan County Line.

| COSPMS01B | Classifications |
|---|---|
| **Designation** | Agriculture |
| Reviewable | Aq Life Warm 2 |
| | Recreation E |
| | Water Supply |

**Qualifiers:**

**Water + Fish Standards**

**Other:**

Temporary Modification(s):
Arsenic(chronic) = hybrid
Expiration Date of 12/31/2021

**Physical and Biological**

| | DM | MWAT |
|---|---|---|
| Temperature °C | WS-II | WS-II |
| | **acute** | **chronic** |
| D.O. (mg/L) | --- | 5.0 |
| pH | 6.5 - 9.0 | --- |
| chlorophyll a (mg/m$^2$) | --- | --- |
| E. Coli (per 100 mL) | --- | 126 |

**Inorganic (mg/L)**

| | acute | chronic |
|---|---|---|
| Ammonia | TVS | TVS |
| Boron | --- | 0.75 |
| Chloride | --- | 250 |
| Chlorine | 0.019 | 0.011 |
| Cyanide | 0.005 | --- |
| Nitrate | 10 | --- |
| Nitrite | --- | 0.5 |
| Phosphorus | --- | --- |
| Sulfate | --- | WS |
| Sulfide | --- | 0.002 |

**Metals (ug/L)**

| | acute | chronic |
|---|---|---|
| Aluminum | --- | --- |
| Arsenic | 340 | 0.02(T) |
| Beryllium | --- | --- |
| Cadmium | TVS | TVS |
| Cadmium | 5.0(T) | --- |
| Chromium III | 50(T) | TVS |
| Chromium VI | TVS | TVS |
| Copper | TVS | TVS |
| Iron | --- | WS |
| Iron | --- | 1000(T) |
| Lead | TVS | TVS |
| Lead | 50(T) | --- |
| Manganese | TVS | TVS |
| Manganese | --- | WS |
| Mercury | --- | 0.01(t) |
| Molybdenum | --- | 150(T) |
| Nickel | TVS | TVS |
| Nickel | --- | 100(T) |
| Selenium | TVS | TVS |
| Silver | TVS | TVS |
| Uranium | --- | --- |
| Zinc | TVS | TVS |



All metals are dissolved unless otherwise noted.
T = total recoverable
t = total
tr = trout

D.O. = dissolved oxygen
DM = daily maximum
MWAT = maximum weekly average temperature
See 38.6 for details on TVS, TVS(tr), WS, temperature standards.

1. Mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border.

| COSPLS01 | Classifications |
|---|---|
| **Designation** | Agriculture |
| Reviewable | Aq Life Warm 2 |
| | Recreation E |
| | Water Supply |

**Qualifiers:**

**Water + Fish Standards**

**Other:**

Temporary Modification(s):
Arsenic(chronic) = hybrid
Expiration Date of 12/31/2021

**Physical and Biological**

| | DM | MWAT |
|---|---|---|
| Temperature °C | WS-II | WS-II |
| | **acute** | **chronic** |
| D.O. (mg/L) | --- | 5.0 |
| pH | 6.5 - 9.0 | --- |
| chlorophyll a (mg/m$^2$) | --- | --- |
| E. Coli (per 100 mL) | --- | 126 |

**Inorganic (mg/L)**

| | acute | chronic |
|---|---|---|
| Ammonia | TVS | TVS |
| Boron | --- | 0.75 |
| Chloride | --- | 250 |
| Chlorine | 0.019 | 0.011 |
| Cyanide | 0.005 | --- |
| Nitrate | 10 | --- |
| Nitrite | --- | 0.5 |
| Phosphorus | --- | --- |
| Sulfate | --- | WS |
| Sulfide | --- | 0.002 |

**Metals (ug/L)**

| | acute | chronic |
|---|---|---|
| Aluminum | --- | --- |
| Arsenic | 340 | 0.02(T) |
| Beryllium | --- | --- |
| Cadmium | TVS | TVS |
| Cadmium | 5.0(T) | --- |
| Chromium III | 50(T) | TVS |
| Chromium VI | TVS | TVS |
| Copper | TVS | TVS |
| Iron | --- | WS |
| Iron | --- | 1000(T) |
| Lead | TVS | TVS |
| Lead | 50(T) | --- |
| Manganese | TVS | TVS |
| Manganese | --- | WS |
| Mercury | --- | 0.01(t) |
| Molybdenum | --- | 150(T) |
| Nickel | TVS | TVS |
| Nickel | --- | 100(T) |
| Selenium | TVS | TVS |
| Silver | TVS | TVS |
| Uranium | --- | --- |
| Zinc | TVS | TVS |

2a. All tributaries to the South Platte River, including all wetlands, from the Weld/Morgan County line to the Colorado/Nebraska border, except for the specific listings in Segment 2b.

| COSPLS02A | Classifications |
|---|---|
| **Designation** | Agriculture |
| UP | Aq Life Warm 2 |
| | Recreation P |
| | Water Supply |

**Qualifiers:**

**Other:**

*chlorophyll a (mg/m$^2$)(chronic) = applies only above the facilities listed at 38.5(4).
*Phosphorus(chronic) = applies only above the facilities listed at 38.5(4).

**Physical and Biological**

| | DM | MWAT |
|---|---|---|
| Temperature °C | WS-II | WS-II |
| | **acute** | **chronic** |
| D.O. (mg/L) | --- | 5.0 |
| pH | 6.5 - 9.0 | --- |
| chlorophyll a (mg/m$^2$) | --- | 150* |
| E. Coli (per 100 mL) | --- | 205 |

**Inorganic (mg/L)**

| | acute | chronic |
|---|---|---|
| Ammonia | --- | --- |
| Boron | --- | 0.75 |
| Chloride | --- | 250 |
| Chlorine | --- | --- |
| Cyanide | 0.2 | --- |
| Nitrate | 10 | --- |
| Nitrite | --- | 1.0 |
| Phosphorus | --- | 0.17* |
| Sulfate | --- | WS |
| Sulfide | --- | 0.05 |

**Metals (ug/L)**

| | acute | chronic |
|---|---|---|
| Aluminum | --- | --- |
| Arsenic | 340 | 0.02-10(T) [A] |
| Beryllium | --- | 4.0(T) |
| Cadmium | 5.0(T) | 10(T) |
| Chromium III | 50(T) | 100(T) |
| Chromium VI | 50(T) | 100(T) |
| Copper | --- | 200(T) |
| Iron | --- | WS |
| Lead | 50(T) | 100(T) |
| Manganese | --- | WS |
| Mercury | --- | --- |
| Molybdenum | --- | 150(T) |
| Nickel | --- | 100(T) |
| Selenium | --- | 20(T) |
| Silver | 100(T) | --- |
| Uranium | --- | --- |
| Zinc | --- | 2000(T) |

All metals are dissolved unless otherwise noted.
T = total recoverable
t = total
tr = trout

D.O. = dissolved oxygen
DM = daily maximum
MWAT = maximum weekly average temperature
See 38.6 for details on TVS, TVS(tr), WS, temperature standards.

2b. All tributaries to the South Platte River, including all wetlands, north of the South Platte River and below 4,500 feet in elevation in Morgan County, north of the South Platte River in Washington County, north of the South Platte River and below 4,200 feet in elevation in Logan County, north of the South Platte River and below 3,700 feet in elevation in Sedgwick County, and the mainstems of Beaver Creek, Bijou Creek and Kiowa Creek from their sources to the confluence with the South Platte River, except for the portion of Beaver Creek from its source to the Fort Morgan Canal.

| COSPLS02B | Classifications |
|---|---|
| Designation | Agriculture |
| UP | Aq Life Warm 2 |
| | Recreation E |

**Qualifiers:**

**Other:**

*chlorophyll a ($mg/m^2$)(chronic) = applies only above the facilities listed at 38.5(4).
*Phosphorus(chronic) = applies only above the facilities listed at 38.5(4).

| Physical and Biological | | DM | MWAT |
|---|---|---|---|
| Temperature °C | | WS-II | WS-II |
| | | acute | chronic |
| D.O. (mg/L) | | --- | 5.0 |
| pH | | 6.5 - 9.0 | --- |
| chlorophyll a ($mg/m^2$) | | --- | 150* |
| E. Coli (per 100 mL) | | --- | 126 |

| Inorganic (mg/L) | acute | chronic |
|---|---|---|
| Ammonia | TVS | TVS |
| Boron | --- | 0.75 |
| Chloride | --- | --- |
| Chlorine | 0.019 | 0.011 |
| Cyanide | 0.005 | --- |
| Nitrate | 100 | --- |
| Nitrite | --- | 0.5 |
| Phosphorus | --- | 0.17* |
| Sulfate | --- | --- |
| Sulfide | --- | 0.002 |

| Metals (ug/L) | acute | chronic |
|---|---|---|
| Aluminum | --- | --- |
| Arsenic | 340 | 100(T) |
| Beryllium | --- | --- |
| Cadmium | TVS | TVS |
| Chromium III | TVS | TVS |
| Chromium III | --- | 100(T) |
| Chromium VI | TVS | TVS |
| Copper | TVS | TVS |
| Iron | --- | 1000(T) |
| Lead | TVS | TVS |
| Manganese | TVS | TVS |
| Mercury | --- | 0.01(t) |
| Molybdenum | --- | 150(T) |
| Nickel | TVS | TVS |
| Selenium | TVS | TVS |
| Silver | TVS | TVS |
| Uranium | --- | --- |
| Zinc | TVS | TVS |

3. Jackson Reservoir, Prewitt Reservoir, North Sterling Reservoir, Jumbo (Julesburg), Riverside Reservoir, Empire Reservoir, and Vancil Reservoir.

| COSPLS03 | Classifications |
|---|---|
| Designation | Agriculture |
| UP | Aq Life Warm 1 |
| | Recreation E |
| | Water Supply |

**Qualifiers:**

**Other:**

*chlorophyll a (ug/L)(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.
*Phosphorus(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.
*Temperature(4/1 - 12/31) = North Sterling Res. (MWAT=26.1)
*Temperature(4/1 - 12/31) = Jumbo Reservoir (MWAT=27)
*Temperature(4/1 - 12/31) = Jackson Reservoir (MWAT=28.1)

| Physical and Biological | | DM | MWAT |
|---|---|---|---|
| Temperature °C | | WL | WL |
| Temperature °C | 4/1 - 12/31 | WL* | 26.1* |
| Temperature °C | 4/1 - 12/31 | WL* | 27* |
| Temperature °C | 4/1 - 12/31 | WL* | 28.1* |
| | | | |
| | | acute | chronic |
| D.O. (mg/L) | | --- | 5.0 |
| pH | | 6.5 - 9.0 | --- |
| chlorophyll a (ug/L) | | --- | 20* |
| E. Coli (per 100 mL) | | --- | 126 |

| Inorganic (mg/L) | acute | chronic |
|---|---|---|
| Ammonia | TVS | TVS |
| Boron | --- | 0.75 |
| Chloride | --- | 250 |
| Chlorine | 0.019 | 0.011 |
| Cyanide | 0.005 | --- |
| Nitrate | 10 | --- |
| Nitrite | --- | 0.5 |
| Phosphorus | --- | 0.083* |
| Sulfate | --- | WS |
| Sulfide | --- | 0.002 |

| Metals (ug/L) | acute | chronic |
|---|---|---|
| Aluminum | --- | --- |
| Arsenic | 340 | 0.02(T) |
| Beryllium | --- | --- |
| Cadmium | TVS | TVS |
| Cadmium | 5.0(T) | --- |
| Chromium III | 50(T) | TVS |
| Chromium VI | TVS | TVS |
| Copper | TVS | TVS |
| Iron | --- | WS |
| Iron | --- | 1000(T) |
| Lead | TVS | TVS |
| Lead | 50(T) | --- |
| Manganese | TVS | TVS |
| Manganese | --- | WS |
| Mercury | --- | 0.01(t) |
| Molybdenum | --- | 150(T) |
| Nickel | TVS | TVS |
| Nickel | --- | 100(T) |
| Selenium | TVS | TVS |
| Silver | TVS | TVS |
| Uranium | --- | --- |
| Zinc | TVS | TVS |

All metals are dissolved unless otherwise noted.
T = total recoverable
t = total
tr = trout

D.O. = dissolved oxygen
DM = daily maximum
MWAT = maximum weekly average temperature
See 38.6 for details on TVS, TVS(tr), WS, temperature standards.

4. All lakes and reservoirs tributary to the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border, except for specific listings in Segments 3 and 5.

| COSPLS04 | Classifications |
|---|---|
| **Designation** | Agriculture |
| Reviewable | Aq Life Warm 2 |
| | Recreation P |
| | Water Supply |

**Qualifiers:**

**Other:**

*chlorophyll a (ug/L)(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.
*Phosphorus(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.

| Physical and Biological | DM | MWAT |
|---|---|---|
| Temperature °C | WL | WL |
| | **acute** | **chronic** |
| D.O. (mg/L) | --- | 5.0 |
| pH | 6.5 - 9.0 | --- |
| chlorophyll a (ug/L) | --- | 20* |
| E. Coli (per 100 mL) | --- | 205 |

| Inorganic (mg/L) | acute | chronic |
|---|---|---|
| Ammonia | --- | --- |
| Boron | --- | 0.75 |
| Chloride | --- | 250 |
| Chlorine | --- | --- |
| Cyanide | 0.2 | --- |
| Nitrate | 10 | --- |
| Nitrite | --- | 0.5 |
| Phosphorus | --- | 0.083* |
| Sulfate | --- | WS |
| Sulfide | --- | 0.002 |

| Metals (ug/L) | acute | chronic |
|---|---|---|
| Aluminum | --- | --- |
| Arsenic | 340 | 0.02-10(T) [A] |
| Beryllium | --- | 4.0(T) |
| Cadmium | 5.0(T) | 10(T) |
| Chromium III | 50(T) | 100(T) |
| Chromium VI | 50(T) | 100(T) |
| Copper | --- | 200(T) |
| Iron | --- | WS |
| Iron | --- | 1000(T) |
| Lead | 50(T) | 100(T) |
| Manganese | TVS | TVS |
| Manganese | --- | WS |
| Mercury | --- | 0.01(t) |
| Molybdenum | --- | 150(T) |
| Nickel | --- | 100(T) |
| Selenium | --- | 20(T) |
| Silver | 100(T) | --- |
| Uranium | --- | --- |
| Zinc | --- | 2000(T) |

5. All lakes and reservoirs tributary to the South Platte River north of the South Platte River and below 4,500 feet in elevation in Morgan County, north of the South Platte River in Washington County, north of the South Platte River and below 4,200 feet in elevation in Logan County, north of the South Platte River and below 3,700 feet in elevation in Sedgwick County, and the mainstems of Beaver Creek, Bijou Creek and Kiowa Creek from their sources to the confluence with the South Platte River, except for those specific listings in Segment 3.

| COSPLS05 | Classifications |
|---|---|
| **Designation** | Agriculture |
| Reviewable | Aq Life Warm 2 |
| | Recreation E |
| | Water Supply |

**Qualifiers:**

**Other:**

*chlorophyll a (ug/L)(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.
*Phosphorus(chronic) = applies only above the facilities listed at 38.5(4), applies only to lakes and reservoirs larger than 25 acres surface area.

| Physical and Biological | DM | MWAT |
|---|---|---|
| Temperature °C | WL | WL |
| | **acute** | **chronic** |
| D.O. (mg/L) | --- | 5.0 |
| pH | 6.5 - 9.0 | --- |
| chlorophyll a (ug/L) | --- | 20* |
| E. Coli (per 100 mL) | --- | 126 |

| Inorganic (mg/L) | acute | chronic |
|---|---|---|
| Ammonia | TVS | TVS |
| Boron | --- | 0.75 |
| Chloride | --- | 250 |
| Chlorine | 0.019 | 0.011 |
| Cyanide | 0.005 | --- |
| Nitrate | 10 | --- |
| Nitrite | --- | 0.5 |
| Phosphorus | --- | 0.083* |
| Sulfate | --- | WS |
| Sulfide | --- | 0.002 |

| Metals (ug/L) | acute | chronic |
|---|---|---|
| Aluminum | --- | --- |
| Arsenic | 340 | 0.02-10(T) [A] |
| Beryllium | --- | --- |
| Cadmium | TVS | TVS |
| Cadmium | 5.0(T) | --- |
| Chromium III | 50(T) | TVS |
| Chromium VI | TVS | TVS |
| Copper | TVS | TVS |
| Iron | --- | WS |
| Iron | --- | 1000(T) |
| Lead | TVS | TVS |
| Lead | 50(T) | --- |
| Manganese | TVS | TVS |
| Manganese | --- | WS |
| Mercury | --- | 0.01(t) |
| Molybdenum | --- | 150(T) |
| Nickel | TVS | TVS |
| Nickel | --- | 100(T) |
| Selenium | TVS | TVS |
| Silver | TVS | TVS |
| Uranium | --- | --- |
| Zinc | TVS | TVS |

# SPSS Subtask 2.2 -

# Water Quality Analysis

# Appendix C

# Regulation 93

# Standards Attainment Assessment Summaries

# Exhibit 1-38
# South Platte River Basin

Rationales for Segments and Parameters Proposed
For Inclusion in
Regulation No. 93

Water-Quality-Limited Segments Requiring
Total Maximum Daily Loads
(2016 303(d) List)

October 6, 2015

# Standards Attainment Assessment Summary

**Segment Waterbody ID:** COSPMS01b **Hydrologic Unit Code (HUC):** 10190003

**Segment Number & Description:** 1b: Mainstem of the South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan County Line.

**Use Classifications:** Aquatic Life Warm 2
Water Supply
Recreation E
Agriculture

| Table 1. Summary of Proposed Action | | | | |
|---|---|---|---|---|
| **Assessed portion** | **Listed portion** | **M&E parameters** | **303(d) parameters** | **Delisted parameters** |
| ALL | ALL | None | *E. coli*<br>Manganese<br>Arsenic | Selenium |

**Attainment Summary:**

The segment was listed on the 2012 303(d) List for selenium. Recent data for the segment shows that the segment is currently in attainment of the aquatic life use standard for selenium. The assessment included data from 14 stations (see Table 2 below) with a total of 46 data points. The previous listing for selenium was based on 78 data point from a period of record from 2003 through 2009. After further analysis of data from the previous listing cycle, it appears that there must have been an event in July 2005 that resulted in a spike of selenium levels at site 22. The elevated levels gradually decreased by 2007 and remained below the standard since March 2007. The current period of record (2008-2014) shows no individual exceedances in the standard in any of the data points at all stations. Thus the division proposes that this segment is delisted for selenium.

The 85$^{th}$ percentile of the ambient dissolved manganese concentrations for this segment is 108.64 ug/L. For the assessment of the water supply standard for manganese, the least stringent value of either the table value standard of 50 ug/L or existing quality as of the year 2000 is used to assess attainment. For this segment, the existing quality from 2000 is 35.85 ug/L, so the table value standard of 50 ug/L is less stringent. Current ambient conditions exceed this table value standard and the division is proposing this segment for the 303(d) List for manganese.

The 50$^{th}$ percentile of the ambient sulfate data for this segment is 320 ug/L. For the assessment of the water supply standard for sulfate, the least stringent value of either the table value standard of 250 ug/L or existing quality from 2000 is used to assess attainment. For this segment, the existing quality of sulfate concentrations from 2000 is 329.5 ug/L; the table value standard of 250 ug/L is more stringent. Current conditions do not exceed existing quality from the year 2000 so the division is not proposing this segment for the 303(d) List for sulfate.

Data for arsenic was collected from all thirteen stations in this period of record with a total of 53 data points. However, detection limits for arsenic data collected and analyzed by River Watch are not sufficiently low enough to allow for a comparison of this data to the current standard. As such, this data was removed from this assessment, per Section III.D.5.a of the 2016 Section 303(d) Listing Methodology. After removing the River Watch arsenic data from this assessment 24 valid data points remained. The 50$^{th}$ percentile of the remaining arsenic data for this segment is 1.1 ug/L, which is greater than the water supply standard of 0.02. As such, the Division proposes to place this segment on the 303(d) List for arsenic.

For *E. coli* data assessment there are not enough data points for to make an attainment decision for two-month intervals. Thus the assessment is done on the seasonal basis, looking at the data from May through October. For the months of May through October for the period of record, the *E. coli* geometric mean value of 256.2 cfu/100 mL exceeded the recreation use-based standard of 126 cfu/100 mL with the sample size of eleven. Therefore, the division recommends this segment be added to the 303(d) List for *E. coli*.

**Table 2. Water Quality Station Information**

| Site ID | Site Description | Org | Latitude | Longitude |
|---|---|---|---|---|
| SP85 | South Platte at US Hwy 85 in Greeley | EPA | 40.365810 | -104.696620 |
| 5165 | At Eagle Nest | River Watch | 40.312327 | -104.351652 |
| 5115 | Below 37th St Br | River Watch | 40.379285 | -104.672418 |
| 5113 | Below Conf Poudre | River Watch | 40.421177 | -104.600722 |
| 5195 | Centennial SWA | River Watch | 40.374500 | -104.445600 |
| 5157 | Downstream CR 61 Bridge | River Watch | 40.378719 | -104.467041 |
| 5140 | Klein Property | River Watch | 40.421179 | -104.601111 |
| 5187 | Mitani SWA | River Watch | 40.421100 | -104.600600 |
| Kersey | South Platte at Hwy 37 at Kersey | MWRD | 40.412000 | -104.563000 |
| Miliken | South Platte at Hwy 60 near Miliken | MWRD | 40.320020 | -104.811000 |
| 117 | Twin Bridge | River Watch | 40.320300 | -104.812100 |
| 22 | South Platte River near Kersey, CO | WQCD | 40.412222 | -104.562778 |
| 06754000 | South Platte River near Kersey, CO | USGS | 40.411925 | -104.562737 |
| SP-KER | South Platte River at Kersey, below confluence with the Poudre River | Northern | 40.4125 | -104.5632 |

| Table 3. Assessment of Attainment of Acute or One-day Standards | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **# of samples** | **Aquatic Life** | **Water Supply** | **Agriculture** | **# of Exceedances** |
| Aluminum, ug/L | 7 | - | - | - | None |
| Ammonia, mg/L as N | 53 | 8.82 | - | - | None |
| Arsenic, ug/L | 26 | 340 | - | - | None |
| Nitrate + Nitrite, mg/L as N | 47 | - | - | - | None |
| Cadmium, ug/L | 33 | 8.74 | - | - | None |
| Copper, ug/L | 32 | 47.24 | - | - | None |
| Lead, ug/L | 30 | 266.23 | - | - | None |
| Manganese, ug/L | 39 | 4656.53 | - | - | None |
| Nickel, ug/L | 9 | 1447.74 | - | - | None |
| Selenium, ug/L | 46 | 18.4 | - | - | None |
| Silver, ug/L | 13 | 20.14 | - | - | None |
| Uranium, ug/L | 12 | - | - | - | None |
| Zinc, ug/L | 37 | 538.39 | - | - | None |

| Table 4. Assessment of Attainment of Chronic or 30-day Standards | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **# of samples** | **Aquatic Life** | **Water Supply** | **Recreation** | **Agriculture** | **Ambient[1]** | **Exceeding Standard?** |
| pH s.u. | 62 | 6.5-9 | 6.5-9 | 6.5-9 | - | 7.8 - 8.3 | No |
| D.O. mg/L[2] | 63 | - | 3 | 3 | 3 | 7.7 | No |
| Hardness, mg/L | 52 | - | - | - | - | 379.72 | No |
| Aluminum, ug/L | 7 | - | - | - | - | 46.4 | No |
| **Arsenic, ug/L** | **26** | **150** | **0.02** | **-** | **100** | **1.1** | **Yes** |
| Cadmium, ug/L | 33 | 1.16 | 5 | - | 10 | 0.45 | No |
| Copper, ug/L | 32 | 28.01 | 1000 | - | 200 | 4.59 | No |
| Iron (Trec), ug/L | 30 | 1000 | - | - | - | 544.5 | No |
| Iron (dis), ug/L | 49 | - | 300 | - | - | 38.48 | No |
| Lead, ug/L | 30 | 10.37 | - | 50 | 100 | 0.40 | No |

| Table 4. Assessment of Attainment of Chronic or 30-day Standards | | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | # of samples | Aquatic Life | Water Supply | Recreation | Agriculture | Ambient[1] | Exceeding Standard? |
| Molybdenum, ug/L | - | - | - | - | - | - | No |
| **Manganese, ug/L** | **39** | **2572.74** | **50** | **-** | **200** | **108.64** | **Yes** |
| Nickel, ug/L | 9 | 160.8 | 100 | - | 200 | 1.98 | No |
| Selenium, ug/L | 46 | 4.6 | 50 | - | 20 | 2.5 | No |
| Silver, ug/L | 13 | 3.18 | 100 | - | - | 0.09 | No |
| Sulfate, mg/L | 37 | - | 329.5[3] | - | - | 320 | No |
| Uranium, ug/L | 12 | - | 16.8 | - | - | 26.7 | No |
| Zinc, ug/L | 37 | 407.78 | 5000 | - | 2000 | 32.6 | No |
| Ammonia (mg/l as N) | 53 | 2.57 | - | - | - | 0.475 | No |

1 - Ambient (statistic) = (e.g., 15th, 50th, 85th percentile or geometric mean)
2 - Class 1/Cold Water Biota D.O. during spawning 7.0 mg/l
3 - Standard represents existing quality from 2000 for SO4 from1995 to 1999 with a sample size of 70.

| Table 5. *E.coli* Assessment Segment Std: 126 cfu/100 mL | | | | | | | |
|---|---|---|---|---|---|---|---|
| Months | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 5 year |
| Jan-Feb | 0\ 0 | 1\ 101.2 | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 | 1\ 101.2 |
| Mar-Apr | 0\ 0 | 1\ 45.9 | 0\ 0 | 0\ 0 | 1\ 44.8 | 2\ 18.8 | 4\ 29.2 |
| May-Jun | 0\ 0 | 1\ 204.6 | 0\ 0 | 0\ 0 | 1\ 102 | 2\ 688.8 | 4\ 315.5 |
| July-Aug | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 | 2\ 595.8 | 2\ 414.2 | 4\ 496.7 |
| Sep-Oct | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 | 1\ 70 | 2\ 86 | 3\ 80.3 |
| Nov-Dec | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 | 1\ 45.7 | 0\ 0 | 1\ 45.7 |
| POR Seasonal (May-Oct) | 11\ 256.2 | | | | | | |
| POR Geomean | 17\ 131.5 | | | | | | |
| | Sample size\Geomean (cfu/100 mL) | | | | | | |

# Standards Attainment Assessment Summary

**Segment Waterbody ID:** COSPLS01 **HUC Code (HUC):** 10190003,10190012, 10190018

**Segment Number & Description:** 1. Mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border.

**Use Classifications:** Aquatic Life Warm 2
Water Supply
Recreation E
Agriculture

| Table 1. Summary of Proposed Action | | | | |
|---|---|---|---|---|
| **Assessed portion** | **Listed portion** | **M&E parameters** | **303(d) parameters** | **Delisted parameters** |
| ALL | ALL | None | Mn[1], U, $SO_4$ | Se, Aquatic Life |

[1] This parameter was originally proposed for the 303(d) List in a previous cycle and the division is proposing to retain the listing.

**Attainment Summary:** The segment is currently on the M&E list for not meeting the aquatic life use and on the 303(d) list as being impaired for selenium (Se) and manganese (Mn).

Assessment during this period of record shows the segment is not in attainment of the water supply use-based standards for sulfate, manganese and uranium. Using information from historical records from the 2009 South Platte River RMH it was determined that the sulfate existing quality as of January 1, 2000 is equal to 411 mg/l. This was calculated from the 50$^{th}$ percentile during the period January 1, 1998 to December 31, 2002 of which there were 92 values. Current water quality for sulfate is equal to 744 ug/L and exceeds the standard. The division is proposing to add sulfate to the 303(d) list.

The 85$^{th}$ percentile of the manganese data for this segment is 69 ug/L, from 62 samples, which is greater than the chronic standard of 50 ug/L. The year 2000 ambient concentration for manganese was 25 ug/L based on 48 samples from 1995 to 1999. This is less than the manganese TVS. The division is proposing to add manganese to the 303(d) list.

The 85$^{th}$ percentile of the uranium data for this segment is 43.35 ug/L, from 12 samples, which is greater than the chronic standard of 30 ug/L. The division is proposing to add uranium to the 303(d) list.

Current data indicates the segment is attaining the selenium standard and should be delisted. The 85$^{th}$ percentile of the selenium data for this segment is 4.09 ug/L which is less than the chronic standard of 4.6 ug/L. The division is proposing to delist selenium from the 303(d) list. This change was not considered in the initial proposal.

| Table 2. Water Quality Station Information | | | | |
|---|---|---|---|---|
| **Site ID** | **Site Description** | **Org** | **Latitude** | **Longitude** |
| 187 | South Platte River at Ft Morgan Riverside Pk | River Watch | 40.26852648 | -103.8012175 |

| Table 2. Water Quality Station Information | | | | |
|---|---|---|---|---|
| **Site ID** | **Site Description** | **Org** | **Latitude** | **Longitude** |
| 188 | South Platte River at Narrows | River Watch | 40.32205065 | -103.9222225 |
| 223 | South Platte River at Proctor | River Watch | 40.79279928 | -102.9460105 |
| 5119 | South Platter River nr Snyder Brush SWA | River Watch | 40.3123 | -103.6206 |
| 5121 | South Platte River nr Red Lion | River Watch | 40.87028719 | -102.6874677 |
| 5122 | South Platte River at Crook Hwy 55 Br | River Watch | 40.84339487 | -102.8051749 |
| 5123 | South Platte River nr Atwood Hwy 63 Br | River Watch | 40.53798712 | -103.265293 |
| 5124 | South Platte River at Atwood SWA #608 | River Watch | 40.51178162 | -103.2985919 |
| 5134 | South Platte River nr Merino Smith Ranch | River Watch | 40.47078217 | -103.3518942 |
| 5141 | South Platte River abv Julesburg Pony Express SWA | River Watch | 40.95179263 | -102.3005643 |
| 5159 | South Platte River Abv Hwy 52 Br at Reid nr Log Lane Village | River Watch | 40.27926938 | -103.8423151 |
| 5160 | South Platte River at Wachorne Property blw Juleburg | River Watch | 40.99559583 | -102.2260006 |
| 5162 | South Platte River at Crook Abv Hwy 55 Br | River Watch | 40.84174901 | -102.8034145 |
| 5163 | South Platte River at Tamarack SWA Spot #22 nr Proctor | River Watch | 40.80872191 | -102.919711 |
| 5186 | South Platte River nr Ovid Julesburg SWA | River Watch | 40.95506 | -102.38744 |
| 5190 | South Platte River nr Sedgwick Hwy 59 Br | River Watch | 40.9266 | -102.5195 |
| 5193 | South Platte River nr Sterling Bravo SWA | River Watch | 40.6776 | -103.1337 |
| 5194 | South Platte River at Red Lion SWA | River Watch | 40.8836 | -102.6522 |
| 5196 | South Platte River at Log Lane Village Boyd Ponds SWA | River Watch | 40.2739 | -103.829 |
| Julesburg | South Platte at Hwy 385 at Julesburg | MWRD | 40.973 | -102.251 |
| Hillrose | South Platte River at County Road 33 at Hillrose | MWRD | 40.3584 | -103.503 |
| Iliff | South Platte River at County Road 55 at Iliff | MWRD | 40.7475 | -103.056 |
| FtMorgan | South Platte River at Ft Morgan | MWRD | 40.2683 | -103.8015 |
| Goodrich | South Platte River at Goodrich | MWRD | 40.3418 | -104.06 |
| Crook | South Platte River at Highway 55 at Crook | MWRD | 40.8416 | -102.8052 |
| 6758500 | SOUTH PLATTE RIVER NEAR WELDONA, CO | USGS | 40.2684028 | -103.8011917 |
| 403709103111900 | SOUTH PLATTE RIVER AT HWY 6 AT STERLING, CO | USGS | 40.6191529 | -103.1890977 |
| 21 | SOUTH PLATTE RIVER AT BALZAC | WQCD | 40.40667 | -103.466 |

| Table 2. Water Quality Station Information | | | | |
|---|---|---|---|---|
| **Site ID** | **Site Description** | **Org** | **Latitude** | **Longitude** |
| 128 | SOUTH PLATTE R BELOW STERLING | WQCD | 40.74737 | -103.05598 |
| 5005 | SOUTH PLATTE RIVER AT OVID | WQCD | 40.95428333 | -102.3873833 |
| 5006 | SOUTH PLATTE RIVER AT TAMARACK SWA | WQCD | 40.8416 | -102.805 |
| 5015 | SOUTH PLATTE AT COOPER | WQCD | 40.3575 | -103.5286111 |
| 5020 | SOUTH PLATTE RIVER AT MASTERS | WQCD | 40.32235 | -103.5936017 |
| 5030 | SOUTH PLATTE RIVER AT MESSEX SWA | WQCD | 40.42131667 | -103.42015 |
| 5040 | SOUTH PLATTE RIVER AT BRUSH SWA | WQCD | 40.30933333 | -103.6265167 |
| 5049 | S PLATTE R AT US HWY 395 NR JULESBURG | WQCD | 40.97335 | -102.25115 |

| Table 3. Assessment of Attainment of Acute or One-day Standards (COSPLS01) | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **# of samples** | **Aquatic Life** | **Water Supply** | **Agriculture** | **# of Exceedances** |
| Aluminum, µg/L | 12 | NS | - | - | 0 |
| Ammonia, mg/L as N) | 50 | TVS | - | - | 0 |
| Arsenic, µg/L | 59 | 340 | - | - | 0 |
| Nitrate + Nitrite (mg/L) | 54 | - | 10 | 100 | 0 |
| Cadmium (dis), µg/L | 62 | 9.15 | 10 | - | 0 |
| Copper (dis), µg/L | 62 | 49.62 | - | - | 0 |
| Chromium-III, µg/L | 0 | NS | - | - | 0 |
| Chromium-IV, µg/L | 0 | 16 | - | - | 0 |
| Lead (dis), µg/L | 62 | 280.85 | 50 | - | 0 |
| Manganese (dis), µg/L | 62 | 4737.94 | - | - | 0 |
| Nickel, µg/L | 12 | 1512.89 | - | - | 0 |
| Selenium (dis), µg/L | 62 | 18.4 | - | - | 0 |
| Silver, µg/L | 24 | 22.02 | - | - | 0 |
| Uranium, µg/L | 12 | NS | - | - | 0 |
| Zinc (dis), µg/L | 62 | 564.47 | - | - | 0 |

| Table 4. Assessment of Attainment of Chronic or 30-day Standards (All) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **# of samples** | **Aquatic Life** | **Water Supply** | **Recreation** | **Agriculture** | **Ambient*** | **Exceeding Standard?** |
| pH, s.u. | 71 | 6.5 - 9 | 5 - 9 | 6.5-9.0 | - | 8.03 | Attainment |
| D.O., mg/L | 71 | 5 | 3 | 3 | 3 | 7.81 | Attainment |
| Hardness, mg/L | 61 | - | - | - | - | - | N/A |
| **Sulfate, mg/l** | **40** | **-** | **411**** | **-** | **-** | **744** | **Yes** |
| Aluminum, µg/L | 12 | NS | - | - | - | 0 | No |
| Arsenic, µg/L | 59 | 150 | 10 | - | 100 | 0 | No |
| Cadmium (dis), µg/L | 62 | 1.2 | - | - | 10 | 0.50 | No |
| Copper (dis), µg/L | 62 | 29.28 | 1000 | - | 200 | 6.96 | No |
| Chromium-III, µg/L | 0 | 230.67 | 50 | - | 100 | N/A | - |
| Chromium-IV, µg/L | 0 | 11 | 50 | - | 100 | N/A | - |
| Iron (Trec), µg/L | 58 | 1000 | - | - | - | 412.5 | No |

| Table 4. Assessment of Attainment of Chronic or 30-day Standards (All) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | # of samples | Aquatic Life | Water Supply | Recreation | Agriculture | Ambient* | Exceeding Standard? |
| Iron (dis), µg/L | 62 | - | 300 | - | - | 21.43 | No |
| Lead (dis), µg/L | 62 | 10.94 | - | - | 100 | 1.55 | No |
| Molybdenum, µg/L | 0 | NS | 210 | - | 300 | N/A | No |
| **Manganese (dis), µg/L** | **62** | **2617.71** | **50** | **-** | **200** | **69.12** | **Yes** |
| Nickel, µg/L | 12 | 168.04 | 100 | - | 200 | 2.35 | No |
| Selenium (dis), µg/L | 62 | 4.6 | 50 | - | 20 | 4.09 | No |
| Silver, µg/L | 24 | 3.47 | 100 | - | - | 0 | No |
| **Uranium, µg/L** | **12** | **NS** | **30** | **-** | **-** | **43.35** | **Yes** |
| Zinc (dis), µg/L | 62 | 427.54 | 5000 | - | 2000 | 31.9 | No |
| Ammonia (mg/l as N) | 50 | TVS | - | - | - | 0 Chronic Exceedances | |

* Ambient (statistic) = (e.g., 15th, 50th, 85th percentile or geometric mean)
** 2009 South Platte River RMH it was determined that the sulfate existing quality as of January 1, 2000 is equal to 411 mg/l.

| **Table 5. *E. coli* Assessment (*COSPLS01*) Segment Std: 126 cfu/100 mL** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Months | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 5 year |
| Jan-Feb | 0\ 0 | 1\ 8.7 | 1\ 5.3 | 0\ 0 | 0\ 0 | 0\ 0 | 2\ 6.8 |
| Mar-Apr | 0\ 0 | 1\ 21.8 | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 | 1\ 21.8 |
| May-Jun | 0\ 0 | 1\ 102.2 | 1\ 175.2 | 0\ 0 | 0\ 0 | 0\ 0 | 2\ 133.8 |
| July-Aug | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 |
| Sep-Oct | 1\ 57.2 | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 | 1\ 57.2 |
| Nov-Dec | 1\ 23.8 | 1\ 22.8 | 0\ 0 | 0\ 0 | 0\ 0 | 0\ 0 | 2\ 23.3 |
| POR Seasonal (May-Oct) | - | - | - | - | - | - | 3\ 100.8 |
| POR Geomean | - | - | - | - | - | - | 8\ 29.4 |
| | Sample size\Geomean (cfu/100 mL) | | | | | | |

# Standards Attainment Assessment Summary

**Segment Waterbody ID:** COSPLS01 **Hydrologic Unit Code:** 10190012

**Segment Number & Description**: 1. Mainstem of the South Platte River from the Weld/Morgan County line to the Colorado/Nebraska border.

**Use Classifications:** Aquatic Life Warm 2
Recreation E
Water Supply
Agriculture

| Table 1. Summary of Proposed Action | | | | |
|---|---|---|---|---|
| **Assessed portion** | **Listed portion** | **303(d) parameters** | **M&E parameters** | **Delisted parameters** |
| All | All | None | None | Aquatic Life |

**Attainment Summary:**
The Multimetric Index (MMI) scores were calculated for the 2016 303(d) List based on the Water Quality Control Commission Policy 10-1, Aquatic Life Use Attainment. There are four stations within the segment with data in the current period of record. All the stations are located in Biotype 3 and have an attainment threshold of 37 and an impairment threshold of 22 (Table 4). The MMI scores for stations 5005, 5030 and 5040 are above the attainment threshold for Biotype 3 (Table 4). Station 5006 has an MMI score of 34.5, which falls between the attainment and impairment threshold for Biotype 3. Since this segment is a Class 2 waterbody, the "gray zone" does not apply and the MMI score is considered attaining. Since the most recent data from all four stations are attaining, the Division is proposes to remove this segment from the Monitoring and Evaluation list for aquatic life use.

**Existing Water Quality Data:**
Please refer to the previous pages of the rationale package to see a detailed description of the water quality impairments for this segment.

| Table 2. Water Quality Macroinvertebrate Station Information | | | | | |
|---|---|---|---|---|---|
| **Station ID** | **Site Description** | **Organization** | **Latitude** | **Longitude** | **Biotype** |
| 5005 | South Platte River at Ovid | WQCD | 40.9543 | -102.3874 | 3 |
| 5006 | South Platte River at Tamarack SWA | WQCD | 40.8416 | -102.805 | 3 |
| 5030 | South Platte River at Messex SWA | WQCD | 40.4213 | -103.42015 | 3 |
| 5040 | South Platte River at Brush SWA | WQCD | 40.309 | -103.626 | 3 |
| **Waterbody Class: 2** | | | | | |

| Table 3. Multimetric Index Score (MMI) | | | | |
|---|---|---|---|---|
| **Station ID** | **Collection Date** | **MMI score** | **Hilsenhoff Biotic Index (HBI)** | **Shannon Diversity Index** |
| 5005 | 9/21/2010 | 48.1 | N/A | N/A |
| 5006 | 9/21/2010 | 34.5 | N/A | N/A |
| 5030 | 9/21/2010 | 41.9 | N/A | N/A |
| 5040 | 9/21/2010 | 38.6 | N/A | N/A |
| Rows in bold indicate impairment either due to failing MMI scores or failing HBI or SDI scores. Rows that include HBI and SDI scores are in the "Gray Zone" and those metrics have been reviewed. | | | | |

**Comparison with Aquatic Life Thresholds**: Thresholds are established based on analysis of the biological condition at reference sites in each of three biotypes.

| Table 4. Aquatic Life Use Thresholds | | | |
|---|---|---|---|
| Biotype | | Attainment Threshold | Impairment Threshold |
| 1 | Transition | 52 | 42 |
| 2 | Mountains | 50 | 42 |
| 3 | Plains & Xeric | 37 | 22 |

- Class 2 water bodies: When the MMI score falls within the gray zone (between the attainment and impairment thresholds discussed above) and the site is from a Class 2 stream, the stream is considered to be in support of the use.

# Standards Attainment Assessment Summary

**Segment Waterbody ID:** COSPLS03 **Hydrologic Unit Code (HUC):** 10190003, 10190012

**Segment Number & Description: 3.** Jackson Reservoir, Prewitt Reservoir, North Sterling Reservoir, Jumbo (Julesburg), Riverside Reservoir, Empire Reservoir, and Vancil Reservoir.

**Use Classifications:** Aquatic Life Warm 1
Recreation E
Water Supply
Agriculture

**Table 1. Summary of Proposed Action**

| Assessed portion | Listed portion | M&E parameters | 303(d) parameters | Delisted parameters |
|---|---|---|---|---|
| ALL | Jackson Reservoir | None | pH[1] | M&E -Se |
| ALL | North Sterling Reservoir | None | DO, Se | None |
| ALL | Jumbo Reservoir | Se[1] | None | None |

[1] This parameter was included on the 303(d) list or M&E list in a previous cycle and the division is proposing to retain the listing.

**Attainment Summary:** North Sterling Reservoir was previously on the M&E list as potentially impaired by selenium. Sampling results during this assessment period (data period of record=2009-2012) from the top two meters indicate that North Sterling Reservoir is exceeding the selenium standard with a sample size of six (Table 4). Additionally, based on the profile measurements from 9/5/2012, the reservoir does not attain the dissolved oxygen (DO) standard of 5.0 mg/L . The DO profile measurements from 0.5 to 1.5 meters on this date were all below 5.0 mg/L (Table 3). The division proposes adding North Sterling Reservoir to the 303(d) list for selenium and DO.

Jackson Reservoir data confirms the reservoir continues to be impaired because it exceeds the pH standard. The ambient pH for the upper layer of Jackson Reservoir exceeds the pH standard of 9.0 s.u. The 85$^{th}$ percentile of the daily average samples in the top two meters is 9.03 s.u. based on five sampling days (Table 5). From these five sampling events during the current period of record (data period of record=2009-2012), the division concludes that Jackson Reservoir continues to be impaired by high pH and proposes retaining it on the 303(d) List.

Jackson Reservoir is in attainment of the aquatic life selenium standard. The 85$^{th}$ percentile of the selenium data is 4.4 µg/L, (n=5), a value less than the chronic standard of 4.6 µg/L. The previous assessment included four samples that indicated non attainment of the standard. The division proposes removing the selenium listing for Jackson Reservoir from the M&E list.

*Jackson Reservoir 2016 303(d)-pH, M&E-de-list Se*
*North Sterling Reservoir 2016 303(d)-D.O. and Se*
*Jumbo Reservoir M & E –Se*

Jumbo Reservoir is currently on the M&E list for selenium because, in the previous assessment, the 85th percentile was 6.27 µg/L (n=4), which exceeded the chronic standard of 4.6 µg/L. For the current assessment, two additional data points were collected that indicate attainment of the selenium standards for Jumbo Reservoir (Table 6). However, additional data collection is needed to remove it from the M&E list. Therefore the division proposes to retain the selenium listing on the M&E list.

| Table 2. Water Quality Information | | | | | | |
|---|---|---|---|---|---|---|
| **Site ID** | **Site Description** | **Org** | **Latitude** | **Longitude** | **Datum** | **POR** |
| 5040A | North Sterling Reservoir | WQCD | 40.8333333 | -103.25 | -- | 7/6/2009 - 9/05/2012 |
| 5050A | Jackson Reservoir | WQCD | 40.39167 | -104.07289 | -- | 7/6/2009 – 7/16/2012 |
| 5030A | Jumbo Reservoir | WQCD | 40.912801 | -102.667117 | -- | 8/16/2010 – 7/17/2012 |

**Data Tables for North Sterling Reservoir:**

| Table. 3 Surface Probe Data for North Sterling Reservoir | | | | | |
|---|---|---|---|---|---|
| **LAKE** | **DATE** | **DEPTH (M)** | **TEMP C** | **DO mg/L** | **pH** |
| NORTH STERLING | 7/6/2009 | 1 | 22.72 | 11.88 | 8.53 |
| NORTH STERLING | | 2 | 22.4 | 10.32 | 8.44 |
| NORTH STERLING | 8/17/2009 | 1 | 22.87 | 9.36 | 8.53 |
| NORTH STERLING | | 2 | 22.68 | 8.4 | 8.51 |
| NORTH STERLING | 9/28/2009 | 0.5 | 15.78 | 9.13 | 8.54 |
| NORTH STERLING | | 1 | 15.54 | 9.29 | 8.52 |
| NORTH STERLING | | 1.5 | 15.03 | 8.71 | 8.5 |
| NORTH STERLING | | 2 | 15.08 | 8.77 | 8.5 |
| NORTH STERLING | 7/29/2010 | 0.5 | 24.44 | 6.35 | 8.61 |
| NORTH STERLING | | 1 | 24.32 | 6.24 | 8.63 |
| NORTH STERLING | | 1.5 | 24.25 | 6.03 | 8.57 |
| NORTH STERLING | | 2 | 24.14 | 5.56 | 8.54 |
| NORTH STERLING | 7/16/2012 | 0.5 | 26.39 | 10.01 | 8.85 |
| NORTH STERLING | | 1 | 25.93 | 9.84 | 8.77 |
| NORTH STERLING | | 1.5 | 25.18 | 5.19 | 8.31 |
| NORTH STERLING | | 2 | 25.04 | **4.64** | 8.14 |
| NORTH STERLING | 8/7/2012 | 0.5 | 25.94 | 12.22 | 8.95 |
| NORTH STERLING | | 1 | 24.88 | 6.41 | 8.51 |
| NORTH STERLING | | 1.5 | 24.68 | **4.77** | 8.24 |

| Table. 3 Surface Probe Data for North Sterling Reservoir | | | | | |
|---|---|---|---|---|---|
| LAKE | DATE | DEPTH (M) | TEMP C | DO mg/L | pH |
| NORTH STERLING | 9/5/2012 | 0.5 | 22.35 | **3.61** | 7.77 |
| NORTH STERLING | | 1 | 22.09 | **1.34** | 7.61 |
| NORTH STERLING | | 1.5 | 21.97 | **1.08** | 7.58 |

| Table 4. Assessment of Attainment of Chronic or 30-day Standards for North Sterling Reservoir-Upper | | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | # of samples | Aquatic Life | Water Supply | Recreation | Agriculture | Ambient* | Exceeding Standard? |
| Selenium (ug/L) | 6 | 4.6 | 50 | | 20 | 5.725 | Yes |
| *Ambient (statistic) = the 85th percentile | | | | | | | |

**Data Table for Jackson Reservoir:**

| Table. 5 Surface Probe Data for Jackson Reservoir | | | | | |
|---|---|---|---|---|---|
| LAKE | DATE | Depth (m) | Temp C | pH | DO mg/L |
| JACKSON | 7/6/2009 | 1 | 24.66 | 8.39 | 9.03 |
| JACKSON | | 2 | 23.82 | 8.32 | 7.52 |
| JACKSON | 8/17/2009 | 1 | 22.68 | 8.9 | 9.14 |
| JACKSON | | 2 | 21.5 | 8.8 | 6.13 |
| JACKSON | 9/28/2009 | 0.5 | 14.85 | 8.56 | 8.69 |
| JACKSON | | 1 | 14.79 | 8.55 | 8.65 |
| JACKSON | | 1.5 | 14.72 | 8.55 | 8.68 |
| JACKSON | | 2 | 14.66 | 8.54 | 8.51 |
| JACKSON | 7/29/2010 | 0.5 | 27.34 | **9.34** | 11.94 |
| JACKSON | | 1 | 25.34 | **9.32** | 10.83 |
| JACKSON | | 1.5 | 25.16 | **9.32** | 10.44 |
| JACKSON | | 2 | 24.7 | **9.22** | 8.44 |
| JACKSON | 7/16/2012 | 0.5 | 26.34 | 8.86 | 7.31 |
| JACKSON | | 1 | 25.63 | 8.84 | 7.32 |
| JACKSON | | 1.5 | 25.21 | 8.79 | 7.05 |
| JACKSON | | 2 | 24.76 | 8.68 | 6.54 |

**Data Table for Jumbo Reservoir:**

| Table 6. Assessment of Attainment of Chronic or 30-day Standards for Jumbo Upper | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **# of samples** | **Aquatic Life** | **Water Supply** | **Recreation** | **Agriculture** | **Ambient*** | **Exceeding Standard?** |
| Selenium (ug/L) | **2** | **4.6** | **50** | | **20** | **2.04** | **No** |
| *Ambient (statistic) = the 85th percentile | | | | | | | |

# SPSS Subtask 2.2 -

# Water Quality Analysis

# Appendix D

# Detailed Compilation of Water Quality Review Data

| Parameter[1] | Water Quality Standard (WQS)[3] | Designated Uses [2] | Water Quality Criteria[2] Associated with Use | Ambient Water Quality[4,5] | Meets WQS (Y/N) | Meets Criteria (Y/N) |
|---|---|---|---|---|---|---|
| ***Segment COSPMS01b*** - Mainstem of South Platte River from a point immediately below the confluence with St. Vrain Creek to the Weld/Morgan county line | | | | | | |
| Arsenic* | **340 µg/L (acute, dissolved)** **0.02 µg/L (chronic, tot. rec. †)** | Agriculture | 100 µg/L (30-day avg., tot. rec.) | **50th-ile of arsenic data = 1.1 ug/L (based on 24 samples)** | **NO – Water Supply chronic** | Y |
| | | Aquatic Life Warm 2 | 340 µg/L (acute, dissolved) 150 µg/L (chronic, dissolved) | | | Y |
| | | Water Supply | 0.02 – 10 µg/L (30-day avg., tot. rec.)†† | | | **NO** |
| | | Recreation | 100 µg/L (chronic, tot. rec.) | | | Y |
| *E. Coli** | **126 cfu/100 mL (2-month geometric mean)** | Agriculture | *(no criteria)* | **Seasonal geometric mean = 256.2 cfu/100 ml** | **NO - Recreation** | *(none)* |
| | | Aquatic Life Warm 2 | *(no criteria)* | | | *(none)* |
| | | Water Supply | 630 *E. coli*/100 mL | | | Y |
| | | Recreation | 126 *E. coli*/100 mL | | | **NO** |
| Manganese* | **Table Value Equations = @ hardness ≥ 400 mg/L 4,738 µg/L (acute, dissolved) 2,618 µg/L (chronic, dissolved)** **50 µg/L (30-day avg., tot. rec.) OR existing quality as of 1/1/2000, whichever is less restrictive** | Agriculture | 200 µg/L (30-day avg., tot. rec.) | **85th-ile of dissolved manganese data = 108.64 ug/L (based on 39 samples)** **(existing quality in 2000 = 35.85 ug/L; therefore WQS = 50 ug/L applies)** | **NO – Water Supply chronic** | Y |
| | | Aquatic Life Warm 2 | Table Value Standards = 4,738 µg/L (acute, dissolved) 2,618 µg/L (chronic, dissolved) @ hardness ≥ 400 mg/L | | | Y |
| | | Water Supply | 50 µg/L (30-day avg., dissolved) | | | **NO** |
| | | Recreation | *(no criteria)* | | | *(none)* |
| Sulfate*** | **250 µg/L (30-day avg., tot. rec.) OR existing quality as of 1/1/2000, whichever is less restrictive** | Water Supply | 250 µg/L (30-day avg., tot. rec.) | **50th percentile = 320 µg/L for segment (existing quality in 2000 = 329.5 µg/L; therefore WQS = 329.5 µg/L)** | Yes, but barely | Y (barely) |
| ***Segment COSPLS01*** - Mainstem of South Platte River from the Weld/Morgan county line to the Colorado/Nebraska border | | | | | | |
| Manganese* | **Table Value Equations @ hardness ≥ 400 mg/L = 4,738 µg/L (acute, dissolved) 2,618 µg/L (chronic, dissolved)** **50 µg/L (30-day avg., tot. rec.) OR existing quality as of 1/1/2000, whichever is less restrictive** | Agriculture | 200 µg/L (30-day avg., tot. rec.) | **85th-ile of manganese data = 69 ug/L (based on 39 samples)** **(existing quality in 2000 = 25 ug/L; therefore WQS = 50 ug/L applies)** | **NO – Water Supply chronic** | Y |
| | | Aquatic Life Warm 2 | Table Value Standards = @ hardness ≥ 400 mg/L 4,738 µg/L (acute, dissolved) 2,618 µg/L (chronic, dissolved) @ hardness ≥ 400 mg/L | | | Y |
| | | Water Supply | 50 µg/L (30-day avg., dissolved) | | | **NO** |
| | | Recreation | *(no criteria)* | | | *(none)* |
| Selenium* | **18.4 µg/L (acute, dissolved) 4.6 µg/L (chronic, dissolved)** | Agriculture | 20 µg/L (30-day avg., tot. rec.) | **85th-ile of selenium data = 4.09 ug/L** | Yes, but barely | Y |
| | | Aquatic Life Warm 2 | 18.4 µg/L (acute, dissolved) 4.6 µg/L (chronic, dissolved) | | | Y (barely) |
| | | Water Supply | 50 µg/L (30-day avg., tot. rec.) | | | Y |
| | | Recreation | *(no criteria)* | | | *(none)* |
| Uranium* | *(no water quality standard assigned in Regulation 38; Water Quality Control Division used water quality criteria from Regulation 31 for 303(d) assessment))* | Agriculture | *(no criteria)* | **85th-ile of uranium data = 43.35 ug/L (based on 12 samples)** | *(none)* | *(none)* |
| | | Aquatic Life Warm 2 | Table Value Standards = 11,070 µg/L (acute, dissolved) 6,915 µg/L (chronic, dissolved) | | | Y |
| | | Water Supply | 16.8 – 30 µg/L (30-day avg., tot. rec.)†† | | | **NO** |
| | | Recreation | *(no criteria)* | | | *(none)* |
| Sulfate** | **250 µg/L (30-day avg., tot. rec.) OR existing quality as of 1/1/2000, whichever is less restrictive** | Agriculture | *(no criteria)* | **50th percentile = 744 µg/L for segment (existing quality in 2000 = 411 µg/L; therefore WQS = 411 µg/L)** | **NO – Water Supply chronic** | *(none)* |
| | | Aquatic Life Warm 2 | *(no criteria)* | | | *(none)* |
| | | Water Supply | 250 µg/L (30-day avg., tot. rec.) | | | **NO** |
| | | Recreation | *(no criteria)* | | | *(none)* |
| ***Segment COSPLS03*** - Jackson Reservoir portion only | | | | | | |
| pH* | **6.5 – 9.0 s.u. (instantaneous minimum and maximum, respectively)** | Agriculture | *(no criteria)* | **85th percentile = 9.03 s.u. (based on 5 sampling days)** | **NO- Aquatic Life & Water Supply** | *(none)* |
| | | Aquatic Life Warm 1 | 6.5 – 9.0 (instantaneous, min – max) | | | **NO** |
| | | Water Supply | 5.0 – 9.0 (instantaneous, min – max) | | | **NO** |
| | | Recreation E | *(no criteria)* | | | *(none)* |
| ***Segment COSPLS03*** – North Sterling Reservoir only | | | | | | |
| Dissolved Oxygen* | **5.0 mg/L (minimum)** (see Reg. 31, Table I, Footnote 9 for exclusions) | Agriculture | 3.0 mg/L | **Dissolved oxygen measurements ranged from 1.08 mg/L to 12.22 mg/L** | **NO- All uses** | **NO** |
| | | Aquatic Life Warm 1 | 5.0 mg/L (minimum) | | | **NO** |
| | | Water Supply | 3.0 mg/L | | | **NO** |
| | | Recreation E | 3.0 mg/L | | | **NO** |
| Selenium* | **18.4 µg/L (acute, dissolved) 4.6 µg/L (chronic, dissolved)** | Agriculture | 20 µg/L (30-day avg., tot. rec.) | **85th-ile of selenium data = 5.725 ug/L (based on 6 samples, 2009-2012)** | **NO – Chronic Aquatic Life** | Y |
| | | Aquatic Life Warm 1 | 18.4 µg/L (acute, dissolved) 4.6 µg/L (chronic, dissolved) | | | **NO** |
| | | Water Supply | 50 µg/L (30-day avg., tot. rec.) | | | Y |
| | | Recreation E | *(no criteria)* | | | *(none)* |

Footnotes:

[1] Identified as a key parameter, based on inclusion on: Water Quality Control Commission, 2016 Colorado Section 303(d) List of Impaired Waters and Monitoring and Evaluation List (amended 10/11/16, effective 11/20/16), Regulation #93, 5 CCR 1002-93.

[2] Water Quality Control Commission, Basic Standards and Methodologies for Surface Water, (amended 1/9/17, effective 3/1/17), Regulation #31, 5 CCR 1002-31. **(Note: WQS are generally chosen as the most stringent of these values. Criteria may be used for water quality comparisons for a specific use.)**

[3] Water Quality Control Commission, Classifications and Numeric Standards for South Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin (amended 1/9/17 and 4/10/17, effective 6/30/17), Appendix 38-1 Stream Classifications and Water Quality Standards Tables, Regulation #31, 5 CCR 1002-31

[4] Water Quality Control Division Proponent's Prehearing Statement for 2015 Regulation 93 Rulemaking Hearing, Exhibit 1-38, South Platte River Basin, Rationales for Segments and Parameters Proposed for Inclusion in Regulation No. 93 Water Quality-Limited Segments Requiring Total Maximum Daily Loads (2016 303(d) List), October 6, 2015.

[5] The Water Quality Control Division uses the 50$^{th}$ percentile of ambient data to determine compliance with dissolved standards, and the 85$^{th}$ percentile to determine compliance with total recoverable standards. For assessment of *E.coli* , the Division uses a geometric mean.

Symbols:

* The Water Quality Control Commission has determined these parameters are not meeting the water quality standards.
** The Water Quality Control Commission has determined that there is reason to suspect water quality problems for these parameters.
*** Although the Water Quality Control Commission determined that this parameter was in compliance with the water quality standards, the parameter is included for analysis, as it may impact treatment costs.

† tot. rec. = total recoverable

**††** The first number in the range is a strictly health-based value. The second number in the range is a maximum contaminant level, established under the federal Safe Drinking Water Act that has been determined to be an acceptable level of this chemical in public water supplies, taking treatability and laboratory detection limits into account. Control requirements, such as discharge permit effluent limitations, shall be established using the first number in the range as the ambient water quality target, provided that no effluent limitation shall require an "end-of-pipe" discharge level more restrictive than the second number in the range.

Other relevant water quality data conclusions from reference (4) above:

**COSPMS01b:**

- Sulfate 50$^{th}$ percentile = 320 µg/L for segment. Ambient quality in 2000 was 329.5 µg/L. The sulfate water quality standard is 250 µg/L OR existing quality as of 1/1/2000, whichever is less restrictive. Therefore, the Division determined this segment was in attainment of the less restrictive standard (though just barely). **This is a parameter that should be also considered for Segment COSPLSMS01b, as it may impact treatment costs, and is included in the table above.**
- The Division found the segment was in attainment of acute water quality standards for aquatic life, water supply, and agriculture for aluminum, ammonia, arsenic, nitrate + nitrite, cadmium, copper, lead, manganese, nickel, selenium, silver, uranium, and zinc.
- The Division found the segment was in attainment of chronic water quality standards for aquatic life, water supply, recreation, and agriculture for pH, dissolved oxygen, aluminum, cadmium, copper, iron, lead, molybdenum, nickel, selenium, silver, sulfate, uranium, zinc, and ammonia.

**COSPLS01:**

- The Division found the segment was in attainment of acute water quality standards for aquatic life, water supply, and agriculture for aluminum, ammonia, arsenic, nitrate + nitrite, cadmium, copper, lead, manganese, nickel, selenium, silver, uranium, and zinc. **However, the segment was retained on the 303(d) list in 2016 for selenium by the Water Quality Control Commission.**
- The Division found the segment was in attainment of chronic water quality standards for aquatic life, water supply, recreation, and agriculture for pH, dissolved oxygen, aluminum, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver, zinc, and ammonia.

# APPENDIX H – STORAGE ALTERNATIVE FORMULATION AND EVALUATION TM

NOTE: SOME OF THE INFORMATION IN THIS TM WAS CHANGED DURING PREPARATION OF THE FINAL REPORT

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TECHNICAL MEMORANDUM

| | | | |
|---|---|---|---|
| To: | Joe Frank, Andy Moore | From: | Chip Paulson, Samantha Mauzy, Mary Presecan |
| | Lower South Platte Water Conservancy District, Colorado Water Conservation Board | | Stantec and LRE |
| Subject: | **Storage Alternative Formulation and Evaluation** | Date: | October 24, 2017 |

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## INTRODUCTION

This Technical Memorandum presents the methods and results of the South Platte Storage Study (SPSS) storage alternative formulation and evaluation. It describes:

- the screening of storage options from the full inventory of options;
- the process of constructing surface storage and groundwater storage conceptual alternatives;
- the components comprising those conceptual alternatives;
- specific storage options linked to the conceptual alternatives;
- the modeling analysis used to estimate water supply available from each alternative; and
- the evaluation and comparison of alternatives based on cost, technical, environmental, and social factors.

## SCREENING OF STORAGE OPTIONS

This section describes the process used to screen storage options and eliminate those options with fatal flaws or that did not meet minimum criteria related to SPSS project goals. The objective of this process was not to identify the best storage options, but to eliminate clearly inferior options that would not meet SPSS objectives.

The storage option screening process was conducted collaboratively in a workshop attended by members of the South Platte and Metro Basin Roundtables and the Stantec consultant team. Subsequent refinements were made by the consultant team with concurrence of the SPSS Review Committee.

### Screening of Surface Reservoir Options

The following process was used to filter and screen options for traditional surface reservoir storage.

*Step 1: Full Inventory of Potential Storage Options.* The starting point for the screening analysis was the full inventory of surface and groundwater storage options listed in the TM “South Platte Storage Opportunities Literature Review.” This inventory was “scrubbed” to remove options that were duplicated, out of the study area, too far from the South Platte River to be practical, and for which no information was available. This resulted in a total of 73 potential storage options in the SPSS study area.

*Step 2: Initial Screening – Phase 1.* The 73 potential storage options were screened based on the following criteria:

- Sites that could not be filled practically from the mainstem of the South Platte River below Greeley were determined to not meet the SPSS objectives and were screened out. The SPSS hydrologic analysis and Point Flow Model did not extend upstream of Greeley so information on available flow at potential diversion points upstream of Greeley was not developed for this analysis.
- Sites with a storage capacity of less than 500 ac-ft were determined to be too small to meet the SPSS goals and were screened out.
- Sites that were clearly not the best fit solution among sites in very similar locations that would provide the same function were screened out.

This step in the screening process reduced the list of potential storage sites from 73 to 43.

*Step 3: Initial Screening – Phase 2.* In the screening workshop with Basin Roundtable members and the study team, refinements to the screening process were discussed and applied. These consisted of the following additional criteria:

- The minimum storage capacity assumed to be feasible for the SPSS study was set at 5,000 ac-ft for new reservoirs; smaller reservoir enlargements or rehabilitations were retained. This screened out 16 sites, and left 27 remaining.
- Each remaining site was discussed, and knowledge of the workshop attendees was used to eliminate sites that were known to be infeasible, clearly inferior to other similar options, or not available for use in a future SPSS project because they are owned by specific organizations that intend to develop them for their own purposes.

At the completion of this screening step, 22 traditional surface reservoir sites remained to be considered for incorporation into SPSS storage alternatives. These are shown in Figure 1.

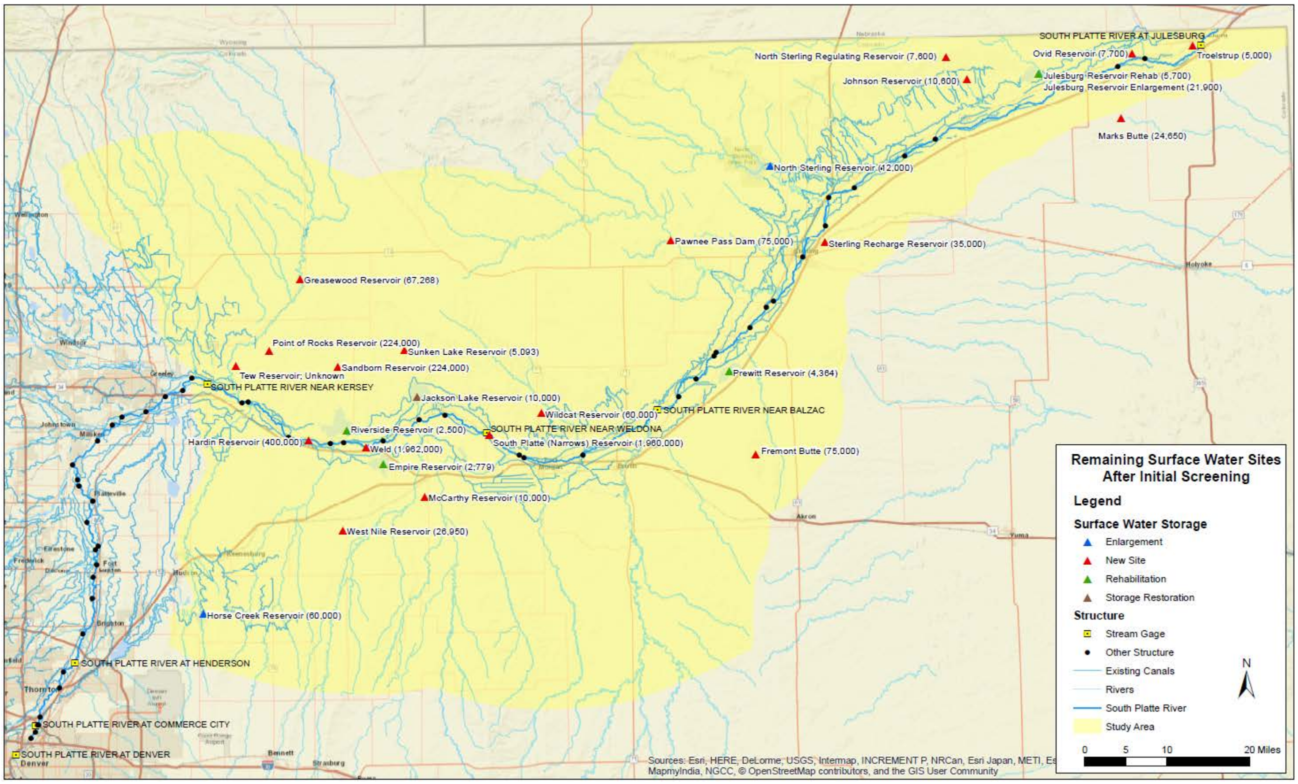



**Figure 1. Surface Water Storage Sites Remaining After Screening**

## Screening of Aquifer Storage Options

*Step 1: Full Inventory of Potential Storage Options.* Twenty-two aquifer storage sites were identified in the SPSS study area in the Literature Review TM. The study team recommended screening out ASR sites in the Denver Metro area south of the SPSS study area boundary; this reduced the list to 12 aquifer storage sites.

*Step 2: Initial Screening.* Based on input from the study team and the Review Committee, storage options relying on shallow alluvial aquifers and aquifers used in augmentation programs were screened out. Storage in the shallow alluvial aquifer along the South Platte River or major tributaries was eliminated due to challenges with maintaining dominion and control of recharged water and current problems with high groundwater levels in some areas. The SPSS project was assumed to require capability for long-term carry-over storage and these aquifer types would be less suitable for that type of operation than others. Aquifer storage and recovery in the Denver Basin was also screened out due to assumed high cost of treating, injecting and extracting large volumes of water over short periods of time.

As a result of this screening process, 7 designated groundwater basins south of the South Platte River remained. These are shown in Figure 2.

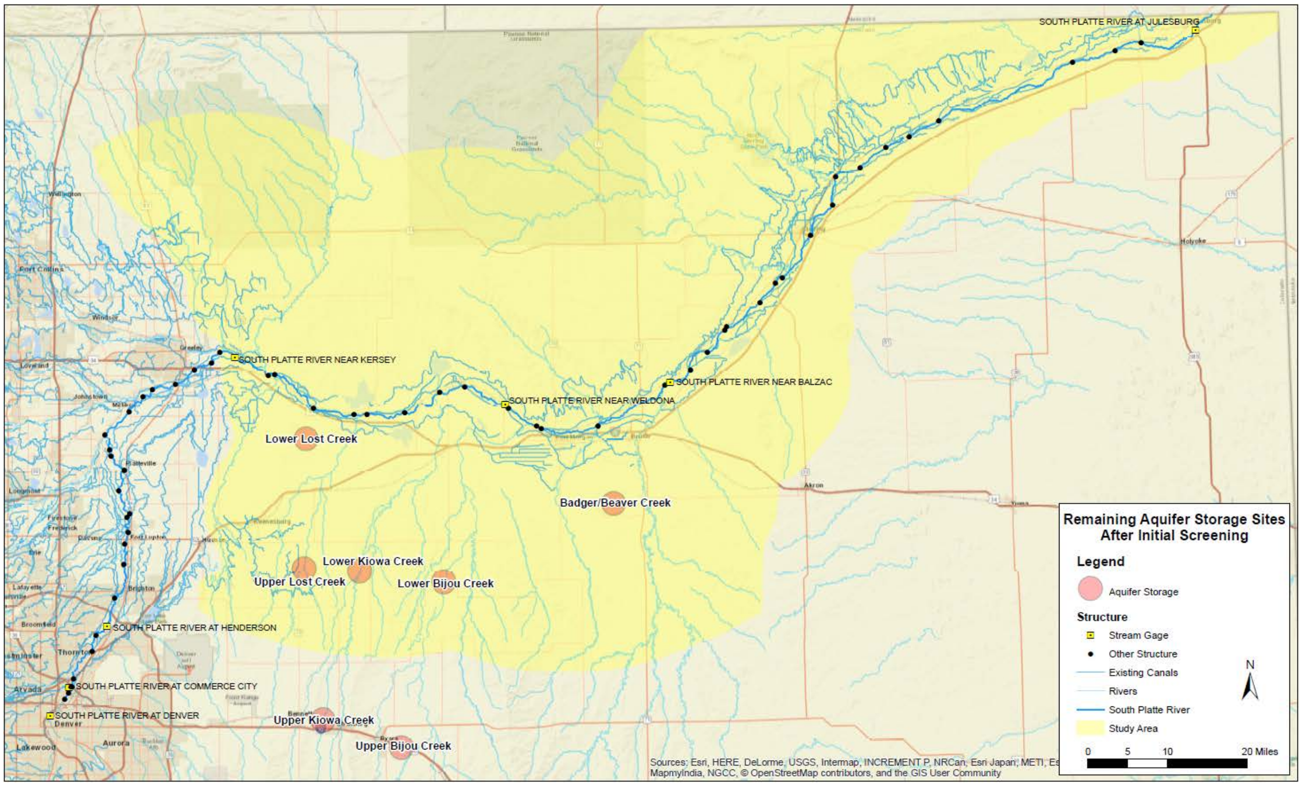


**Figure 2. Aquifer Storage Sites Remaining After Screening**

## Screening of Gravel Pit Storage Options

*Step 1: Full Inventory of Potential Storage Options.* The Literature Review TM identified 55 sites with gravel mining permits in the SPSS study area.

*Step 2: Initial Screening.* The study team recommended screening out sites far from the South Platte River mainstem based on the impracticality of delivering water long distances to small gravel pit reservoirs. This reduced the number of gravel pits to 28.

Figure 3 shows the currently identified locations of potential gravel lake storage considered for the SPSS. For purposes of this study, gravel pits were not evaluated on an individual basis due to their small size, but could be combined on a reach-by-reach basis into storage concepts. Storage could be developed in open-water gravel lakes or in unmined sites with high porosity and slurry walls. No site-specific gravel pit analyses were performed for this study.

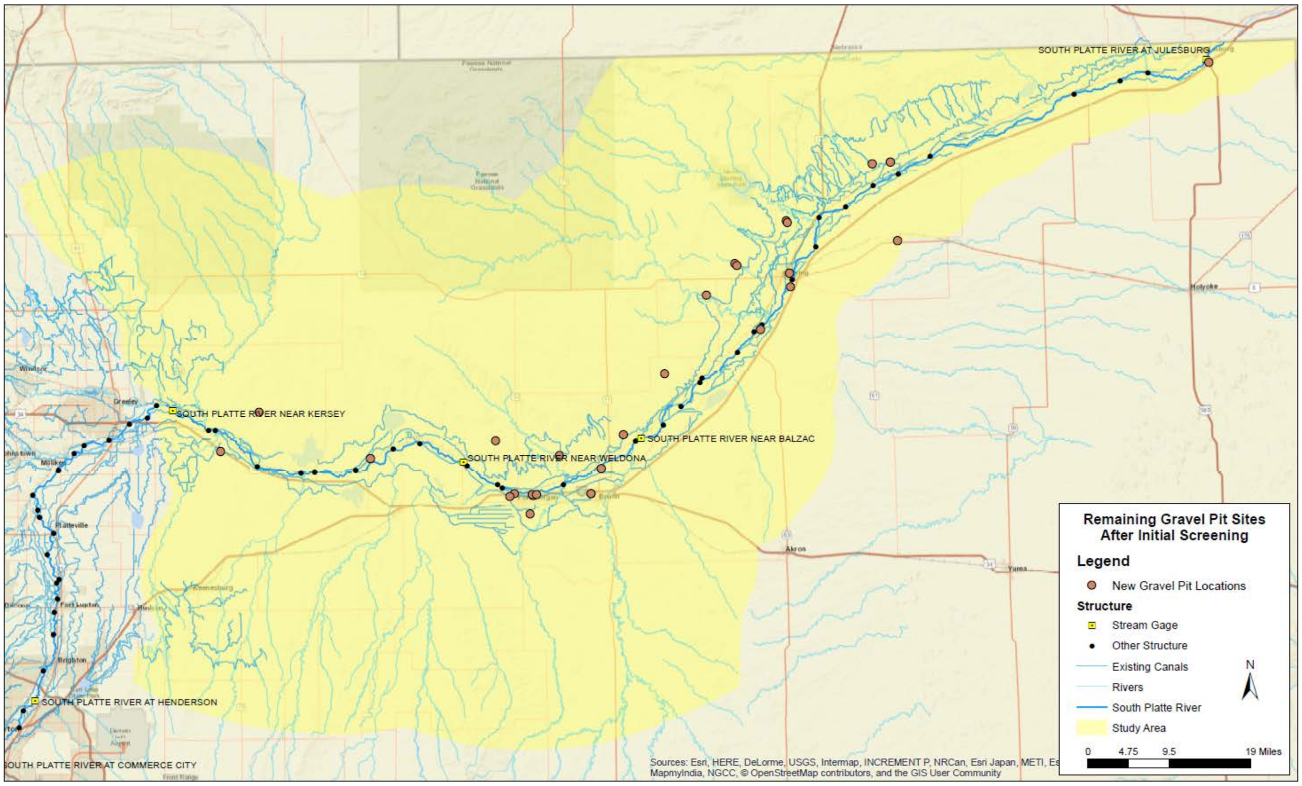



**Figure 3. Gravel Pit Sites Remaining After Screening**

## STORAGE SOLUTION CONCEPTS

### Selection of Storage Concepts

Conceptual storage solutions are generalized approaches to developing additional storage of South Platte River water in the SPSS study area below Greeley. Storage concepts were organized based on the reach of the lower South Platte River in which a storage project would be located, the reach from which water would be diverted, and whether storage would be achieved in a surface reservoir or groundwater basin. Each concept was required to have at least one actual storage site identified in the inventory of storage options described in the “South Platte Storage Opportunities Literature Review” TM.

The following storage concepts were developed for the SPSS.

1. Mainstem Storage – surface reservoir on the mainstem of the South Platte River

2. Upper Basin Storage – surface storage with a reservoir and river diversion between Greeley and the South Platte River near Weldona streamgage

3. Mid Basin Storage North – surface storage with a reservoir and river diversion on the north side of the river between the South Platte River near Weldona streamgage and the South Platte River near Balzac streamgage

4. Mid Basin Storage South – surface storage with a reservoir and river diversion on the south side of the river between the South Platte River near Weldona streamgage and the South Platte River near Balzac streamgage

5. Lower Basin Storage – surface storage with a reservoir and river diversion downstream of the South Platte River near Balzac streamgage

6. Existing Reservoir Improvements – enlargements or rehabilitations of existing reservoirs anywhere in the study area

7. Designated Groundwater Storage Basin West – groundwater aquifer storage and recovery in a designated groundwater basin in the western portion of the study area

8. Designated Groundwater Storage Basin East – groundwater aquifer storage and recovery in a designated groundwater basin in the eastern portion of the study area

**Definition of Components Associated with Storage Concepts**

In order to analyze the relative benefits of the identified storage concepts, the common components necessary to implement the concepts were defined at a conceptual level. These components are described below.

*Storage Components*

The storage component for each concept consists of the “bucket” in which water would be stored. Table 1 lists the specific surface and groundwater storage options (“buckets”) remaining after the previously described screening process that could be associated with each storage concept.

**Table 1. Specific Storage Options Linked to Generalized Storage Solution Concepts**

| Storage Solution Concepts | Potential Storage Sites and Maximum Capacities |
|---|---|
| Mainstem Storage | South Platte (Narrows) Reservoir Site (973,000 ac-ft)<br>Hardin Reservoir Site (400,000 ac-ft) |
| Upper Basin Storage | Sandborn Reservoir Site (224,000 ac-ft)<br>Point of Rocks Reservoir Site (224,000 ac-ft)<br>Sunken Lake Reservoir Site (5,093 ac-ft)<br>Greasewood Reservoir Site (67,268 ac-ft)<br>Jackson Lake Reservoir Rehabilitation (10,000 ac-ft) |
| Mid Basin Storage North | Wildcat Reservoir Site (60,000 ac-ft)<br>Pawnee Pass Reservoir Site (75,000 ac-ft) |

| Storage Solution Concepts | Potential Storage Sites and Maximum Capacities |
|---|---|
| Mid Basin Storage South | Beaver Creek Reservoir Site (95,000 ac-ft)<br>Fremont Butte Reservoir Site (75,000 ac-ft)<br>West Nile Reservoir Site (26,950 ac-ft)<br>McCarthy Reservoir Site (10,000 ac-ft) |
| Lower Basin Storage | Julesburg Reservoir Enlargement/Rehabilitation (27,600 ac-ft)<br>Ovid Reservoir Site (7,700 ac-ft)<br>Troelstrup Reservoir Site (5,000 ac-ft)<br>North Sterling Reservoir Enlargement (12,000 ac-ft)<br>North Sterling Regulation Reservoir (7,600 ac-ft)<br>Johnson Reservoir (10,600 ac-ft) |
| Existing Reservoir Improvements | Julesburg Reservoir Enlargement/Rehabilitation (27,600 ac-ft)<br>North Sterling Reservoir Enlargement (12,000 ac-ft)<br>Prewitt Reservoir Rehabilitation (4,364 ac-ft)<br>Riverside Reservoir Rehabilitation (2,500 ac-ft)<br>Jackson Lake Reservoir Rehabilitation (10,000 ac-ft) |
| Designated Groundwater Basin Storage West | Upper Lost Creek Aquifer (1,260,000 ac-ft)<br>Lower Lost Creek Aquifer (157,000 ac-ft)<br>Upper Kiowa Creek Aquifer (234,000 ac-ft)<br>Lower Kiowa Creek Aquifer (806,000 ac-ft)<br>Upper Bijou Creek Aquifer (466,000 ac-ft)<br>Lower Bijou Creek Aquifer (1,067,000 ac-ft) |
| Designated Groundwater Basin Storage East | Beaver/Badger Aquifer (311,000 ac-ft) |

*River Diversion and Intake Components*

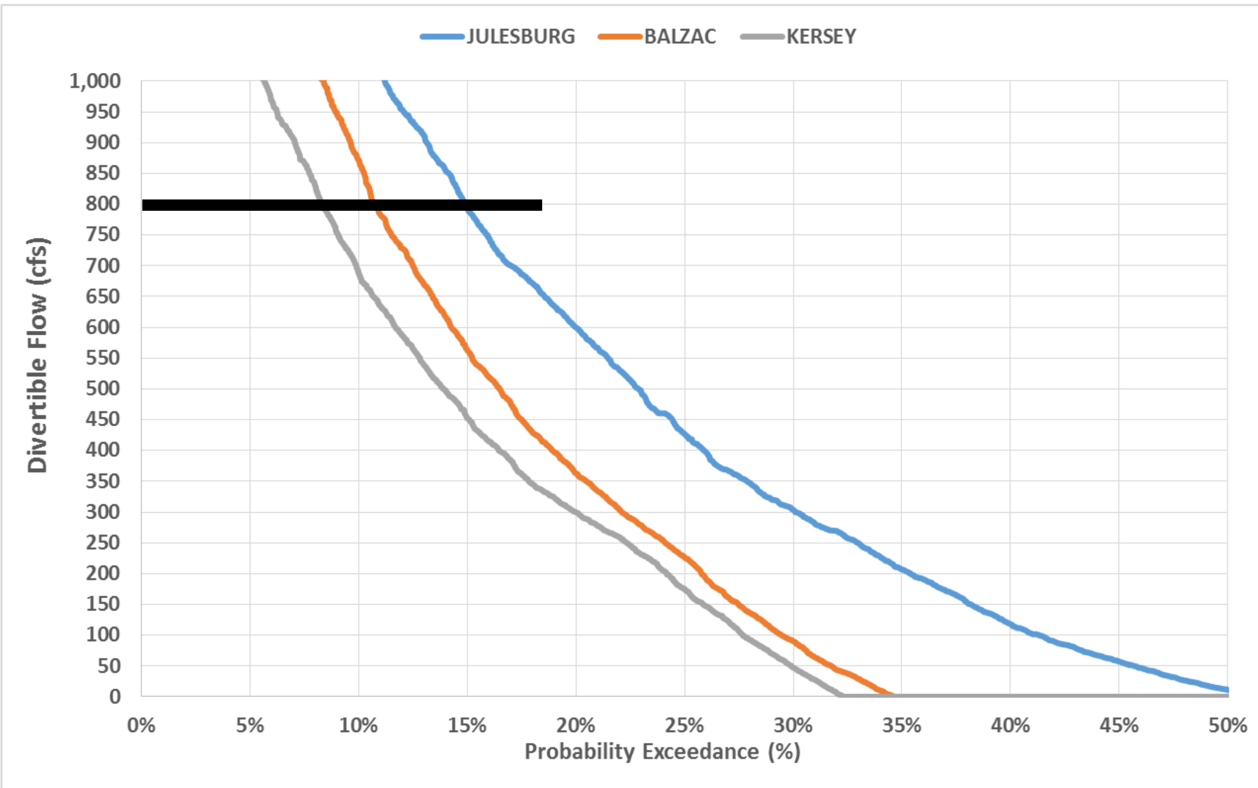
With the exception of the Mainstem Storage concept, all concepts require diversion of water from the South Platte River and conveyance to an off-channel storage facility. For any off-channel storage option, the water supply yield would be constrained by the capacity of the diversion and conveyance facilities used to fill the reservoir. An estimate of a reasonable assumption for filling capacity was developed in two steps.

1. Historical records were reviewed for the largest existing diversions on the South Platte below Denver to get an indication of the effective capacity of current facilities. The maximum recorded diversion to Burlington Ditch was 635 cfs and the maximum recorded diversion to the North Sterling Canal was 764 cfs. Based on this, a tentative inlet capacity of 800 cfs was selected.

2. The 800 cfs capacity value was compared to the flow frequency data generated for future available flow in the hydrologic analysis described in the TM “South Platte River Hydrologic Analysis.” Figure 4 plots the probability that a given diversion capacity would be equaled or exceeded by the storable flow in the South Platte at three of the streamgage locations. This plot shows that with a diversion and conveyance capacity of 800 cfs, available storable flow would be exceeded on only 8 percent of the days in the 20-year Point Flow Model simulation

period at the Kersey streamgage, and on 15 percent of the days at the Julesburg stream gage. A diversion of this size would capture all the available water on most days and would only bypass storable flow on the days of highest runoff in a year. It was assumed to be a reasonable compromise between cost and capacity for this analysis.

**Figure 4. Exceedance Probability of Future South Platte Storable Flow**




Two “bookend” alternatives were considered for SPSS concepts:

(1) Shared Infrastructure: use existing diversion structures and irrigation canals to the maximum extent possible.
(2) Independent Infrastructure: construct new dedicated diversion structure, pump station and pipeline to convey water to the reservoir.

A cursory evaluation was performed of the potential to use existing irrigation structures to convey SPSS water to new or enlarged existing storage facilities. Information was collected for selected irrigation ditches from the Colorado Decision Support System HydroBase dataset, South Platte Decision Support System Task 5 Memoranda, and historical diversion data.

To assess the Shared Infrastructure alternative, the potential for using excess capacity in existing irrigation canals was investigated. Data for the capacity of existing canals was tabulated for selected conveyance structures that could be paired with SPSS storage options. Table 2 summarizes the pertinent data for this analysis, and shows that for all but one canal the estimated physical capacity is less than 800 cfs. The decreed capacity of the selected ditches is generally much larger than the physical capacity. The SPSS Review Committee noted that the irrigation canals would generally be running close to full when the maximum SPSS deliveries would be available from the river, so little or no excess capacity would be available for SPSS project water. For these reasons, the Shared Infrastructure option was not analyzed for specific storage concepts. Nonetheless, if specific storage options are being formulated in the future, use of existing conveyance infrastructure should be reviewed as a potential way to minimize costs and maximize use of existing resources.

**Table 2. Capacities of Existing Irrigation Canals That Could Fill SPSS Storage Options**

| Reservoir | Existing Irrigation System for Filling from South Platte River | Estimated Physical Capacity (cfs) |
|---|---|---|
| Sandborn | Greeley No. 2 Canal aka New Cache la Poudre Company Ditch | 650 |
| Riverside | Riverside Intake Canal | 1,000 |
| Wildcat | Riverside Canal | 370 |
| Beaver Creek | None | - |
| Morgan Beaver | None | - |
| Julesburg | Harmony Ditch No. 1 | 450 |
| Ovid | Peterson Ditch | 150 |
| Troelstrup | Peterson Ditch | 150 |
| Jackson Lake | Riverside Canal | 370 |
| | Jackson Lake inlet | 400 |
| Prewitt | Lower Platte and Beaver Ditch | 228 |
| | Prewitt Intake Canal | 695 |
| North Sterling | North Sterling Canal | 600 |

As a result, for the SPSS analysis inlet structure components were assumed to consist of:

- A new 800 cfs diversion structure on the South Platte River at a location close to the storage option
- Two new 96-inch pipelines from the diversion structure to the reservoir or aquifer recharge area

- A new pump station at the diversion structure sized to lift 400 cfs to the reservoir or aquifer recharge area. Gravel pit storage could be used to effectively reduce the size of conveyance facilities needed to fill reservoirs or aquifer storage. This strategy could affect all concepts similarly; for this preliminary analysis it was assumed that a 10,000 ac-ft gravel pit complex at the diversion point could allow the capacity of the intake conveyance facilities to be sized at 50 percent of the river diversion capacity.

*Outlet Components*

As described in the SPSS Water Demands TM, for purposes of the SPSS analysis, it was assumed that any storage project could be operated to meet demands in three ways: (1) make releases to the South Platte and exchange up to Kersey to meet demands in the Northern Front Range area; (2) make releases to the South Platte to meet demands downstream of the discharge point; and (3) make releases to a new pipeline to Brighton to meet demands in the Denver Metro/Northern Front Range area. To make these releases each storage concept included:

- Release of water back to the South Platte in the same pipeline used to fill the reservoir (bi-directional pipeline), with an unconstrained capacity.
- 100 mgd pipeline to Brighton. A capacity of 100 mgd was selected because it is similar to the ultimate capacity of the Prairie Waters pipeline that delivers water from the Brighton area to Aurora, some of which is ultimately used in the South Denver Metro region.
- A 20,000 ac-ft gravel pit complex near Kersey to serve as the exchange-to point for the exchange alternative.

## STORAGE CONCEPT WATER SUPPLY ANALYSIS METHODS

In order to simulate operation of each storage concept to estimate the water supply yield it could produce, a MODSIM operations model was constructed for the Lower South Platte River. This section describes the methods used to create the MODSIM model and perform that analysis.

### Hydrology

The MODSIM operations model used the daily estimate of available water under future river conditions for the period 1996-2015 from the Point Flow Model (see SPSS Hydrologic Analysis TM). The estimates of future available water account for effects of Identified Projects and Processes from the Colorado Water Plan and decreed but unexercised exchanges that would not have been reflected in the historical data in the Point Flow Model.

### Demands

Demands were applied to each storage concept to evaluate its performance. The same demands were applied to each concept, regardless of where it was located in the SPSS study area. This provided a standard basis of comparison for all the storage concepts.

Development of demands for the SPSS project was described in the SPSS Water Demands TM. Demands were a combination of agricultural and municipal demands based on the SWSI 2010 water supply gap analysis for the lower South Platte Basin in 2050, assuming 60 percent implementation of IPPs. For purposes of the modeling analysis, demands were aggregated at the four primary streamgages in the SPSS study area. These are summarized in Table 3 and Figure 6. Weekly (or quarter-monthly) demand patterns were derived from typical municipal and agricultural water use records. The weekly demand pattern used in the storage concept modeling is shown in Figure 5.


**Figure 5. Weekly Demand Pattern**

**Table 3. Summary of SPSS Water Demands**

| Reach | Agricultural Demand Based on Future Shortage (ac-ft/yr) | M&I Demand Based on Future Shortage (ac-ft/yr) | Total Demand (ac-ft/yr) |
|---|---|---|---|
| Upstream of Denver Gage | 1,400 | 105,400 | 106,800 |
| Denver Gage to Kersey Gage | 210,200 | 111,300 | 321,500 |
| Kersey Gage to Balzac Gage | 46,600 | 9,500 | 56,100 |
| Balzac Gage to Julesburg Gage | 11,400 | 7,100 | 18,500 |
| **Basin Total** | **269,600** | **233,300** | **502,900** |

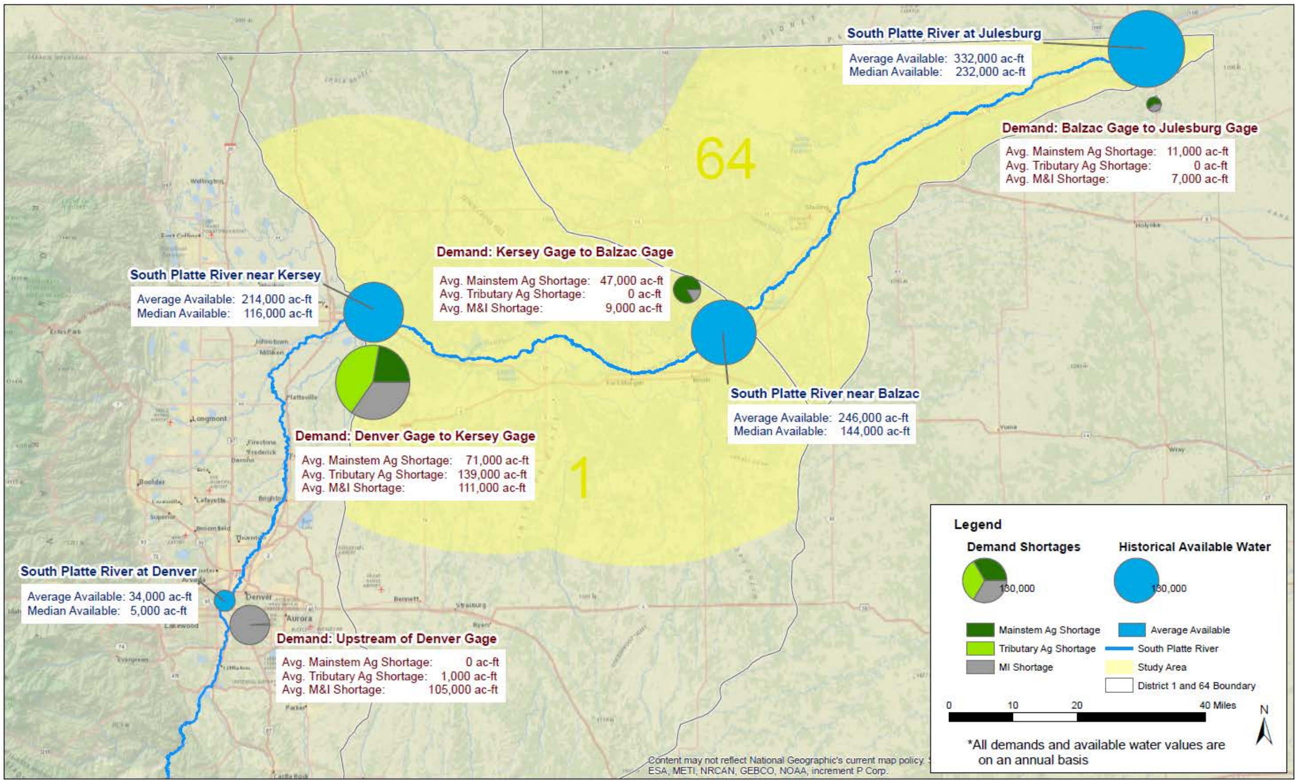



**Figure 6. Summary of Available Water and Demands at Key Locations in SPSS Study Area**

All storage concepts were simulated to concurrently meet the three demand scenarios according to the following logic.

1. Priority 1: Exchange to Kersey. Water was exchanged to Kersey to meet the M&I and agricultural demands aggregated at the Kersey gage. Demands at the Kersey gage represent M&I and agricultural shortages for areas primarily east and north of this point. It is recognized that infrastructure would be required to deliver water from Kersey to M&I or agricultural customers upstream of this point. That infrastructure has not been conceptualized and has not been included in the SPSS costs described in this report. This demand was given the highest priority in the modeling because it makes use of available exchange potential to move as much water as possible upstream to the largest number of potential users with a minimum of new infrastructure.
2. Priority 2: Release to River. Water was released back to the South Platte River to meet downstream agricultural and municipal demands. This would include use of the SPSS water to meet augmentation commitments.
3. Priority 3: Pipe to Brighton. Water delivered by pipeline to the Brighton area could meet demands for municipal customers upstream of the Denver gage and municipal and agricultural customers upstream of the Kersey gage. The pipeline would overcome the constraints of exchange potential and maximize the use of the SPSS water in the basin. This was given the lowest priority among the demand scenarios because it would have the highest capital and operating costs. The Pipe to Brighton option was not applied to the

Lower Basin Storage Concept because it was considered to be unrealistic to construct a pipeline from near Julesburg to the Denver Metro area.

In summary, it was assumed that the Kersey demand could be met through a combination of exchange and pipeline deliveries, the Denver demand could be met through pipeline deliveries alone, and the Balzac and Julesburg demands could be met by direct releases to the South Platte.

**Storage Options**

Representative storage options were selected for use in each of the storage concepts. This allowed realistic elevation-area-capacity data and evaporation data to be used in the simulations. The study team performed a best-fit evaluation to select a representative storage option for each storage concept. The best-fit option was selected based on data in the Site Evaluation Framework (described in a later section of this TM) including physical, environmental and social attributes of the candidate reservoir and groundwater sites in each region of the SPSS study area. Table 4 lists the representative storage options selected for simulating each storage concept, and the rationale used in the selection process. The locations of these representative storage options are shown in Figure 7. Appendix A contains maps of the representative storage options used for each storage concept, and the location of conceptual inlet-outlet facilities (intake pipelines, use of existing irrigation canals, or both).

**Table 4. Representative Storage Sites Used for Simulation of Storage Concepts**

| Storage Solution Concepts | Representative Storage Sites | Rationale for Selection of Representative Storage Site |
|---|---|---|
| Mainstem Storage | South Platte (Narrows) Reservoir | Narrows has more capacity than Hardin. Hardin has more surface area, and therefore more evaporation. Hardin has more bald eagle habitat. Narrows was already selected as a preferred site because it went through a federal (USBR) environmental review process in the 1980s. |
| Upper Basin Storage | Sandborn Reservoir | Eliminated Greasewood because it is much further from the mainstem and would be hard to fill with diversion from the SPSS study area. Point of Rocks and Sandborn could be filled from an extension of Greeley No. 2 Canal. Remaining sites are similar in all but two categories – Sandborn has more State land in the reservoir area, and Point of Rocks has more oil and gas wells. |
| Mid Basin Storage North | Wildcat Reservoir | Wildcat is the largest of the potential sites. |
| Mid Basin Storage South | Beaver Creek Reservoir | Beaver Creek is closer to the mainstem than Fremont Butte. |
| Lower Basin Storage | Julesburg Enlargement/Rehabilitation, Ovid Reservoir, Troelstrup Reservoir | Logical combination of small reservoirs as close to the state line as possible. |

| Storage Solution Concepts | Representative Storage Sites | Rationale for Selection of Representative Storage Site |
|---|---|---|
| Existing Reservoir Improvements | Julesburg, North Sterling, Prewitt, Jackson Lake, Riverside | Use all existing reservoirs with potential for enlargement or rehabilitation. |
| Designated Groundwater Basin Storage West | Lower Lost Creek Aquifer | Rely on Colorado Geological Survey (CGS) ranking of aquifer storage sites from a previously published report. Upper Lost Creek is best from the standpoint of avoiding conflicts with other infrastructure and for recovery of stored water, but it is further from the mainstem in the study area so would be more difficult to fill. Lost Creek basins are farthest west of the designated basins. |
| Designated Groundwater Basin Storage East | Beaver/Badger Aquifer | Badger/Beaver Basin is farthest east and scored high in the CGS evaluation. |

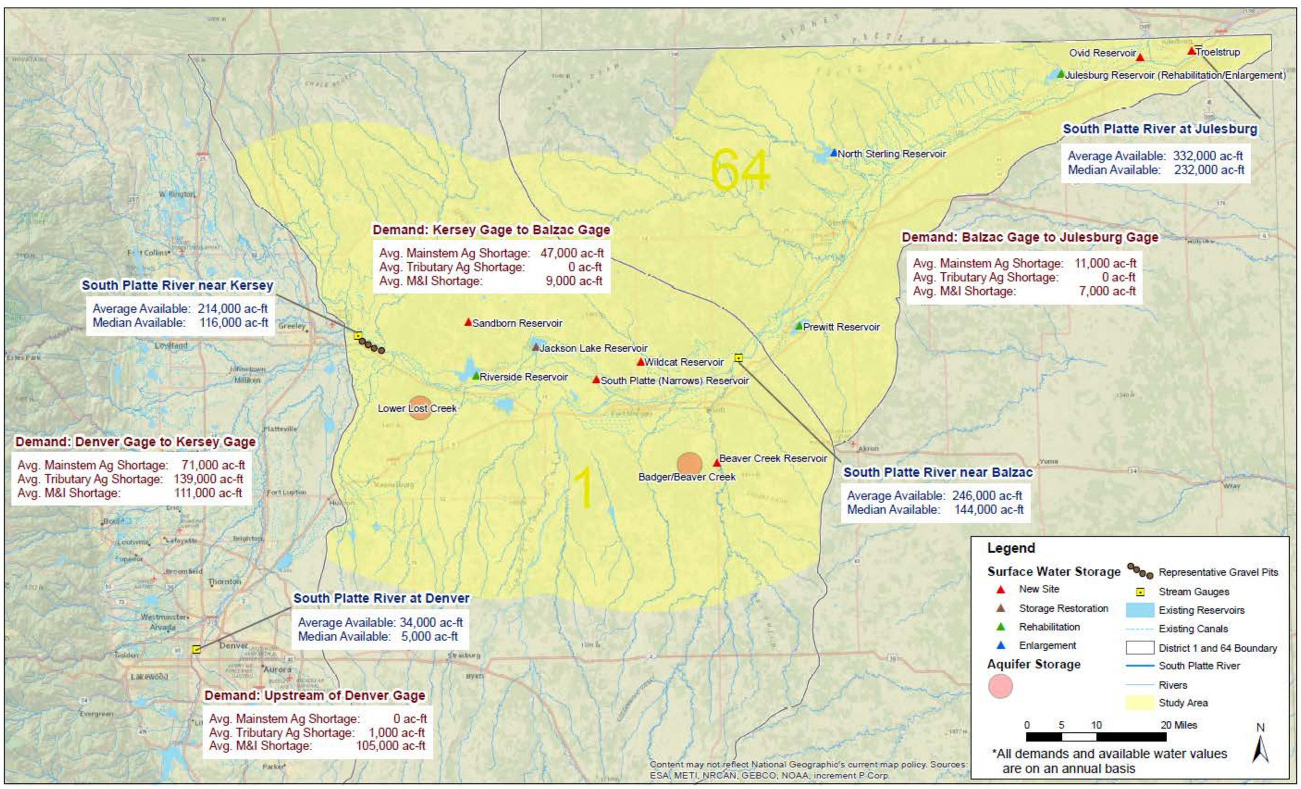



**Figure 7. Representative Storage Options Used to Model Storage Concepts**

## System Losses

Losses in pipelines and pump stations were set at 5 percent of the flow conveyed.

Net evaporation at all the reservoir sites was set at 34 inches/year, based on a typical value for the lower South Platte Basin.

### Groundwater Storage Options

To simplify the initial comparison of options, all groundwater storage options were assumed to be operated in an aquifer storage and recovery mode in which recharge would occur in surface infiltration basins and recovery would occur through a gallery of extraction wells. A more detailed description of the aquifer storage options and assumptions for analysis and cost estimating is presented in a separate technical memorandum.

The primary assumptions used to simulate groundwater storage options were developed based on review of available documentation for hydrogeologic characteristics of the designated basins and professional judgment, and are listed in Table 5. Year-to-year carryover storage was allowed as it would be in a surface reservoir. Deliveries from the river were assumed to occur from new river diversions and dedicated pipelines without any regulating storage (e.g., gravel lakes), similar to operation of the surface storage options. The river diversion rates are much higher than aquifer infiltration rates could reasonably allow, and so some intermediate storage is assumed to be included in the aquifer storage concepts near the point of river diversion.

**Table 5. Aquifer Storage Modeling Assumptions**

| Characteristic | Lower Lost Creek Basin | Badger/Beaver Basin |
|---|---|---|
| Storage Capacity (ac-ft) | 157,000 | 311,000 |
| Storage per Acre (ac-ft/ac) | 5.7 | 4.4 |
| Maximum Inflow (ac-ft/month) | 24,000 | 24,000 |
| Maximum Outflow (ac-ft/month) | 12,000 | 12,000 |
| Dominion and Control / Residence Time | Challenging | Challenging |
| Multi-year Storage | Challenging | Challenging |
| Infiltration Rate (ft/day) | 1.0 | 1.0 |
| Extraction Well Capacity (gpm) | 500 | 500 |
| Approximate Well Count | 190 | 190 |
| Losses in Aquifer (% of inflow) | 10 | 10 |

### Reservoir Operations

Reservoir storage could be operated in many different ways depending on the needs of the owners. Conceptually, water from storage could be:

- used as a base supply with a constant amount taken every year;
- used as a supplemental dry year supply with water withdrawn only in drought periods;
- used as a primary supply with water taken whenever it is available; or
- used as a mitigation supply to augment diversions from other sources.

Because SPSS reservoir ownership is unknown and the demands the reservoir could be operated to meet are unknown, a standard operating approach was adopted for each storage concept such that the performance of the concepts could be compared against the same set of conditions. Two operating approaches were considered.

1. Firm Yield Analysis. Firm yield is the maximum yield that can be delivered in every year, for all years of the simulation. In this approach the firm yield for each concept was determined by varying the total demand on a trial-and-error basis until the maximum demand that could be met in every year was determined. Total system demands in Table 3 were scaled up or down keeping the same geographic and temporal distribution.

2. As-Available Analysis. This approach estimated the yield that can be delivered if the water is taken from the river into storage whenever it is available and delivered from storage to a demand center whenever there is demand. It assumes SPSS water is the primary supply for the user and would be taken whenever it is available.

Results from simulations of storage concepts using both approaches to reservoir operations were investigated to assure that the selection of a particular operating assumption would not bias the study recommendations.

## STORAGE CONCEPT WATER SUPPLY ANALYSIS RESULTS

### Basic Firm Yield Analysis

The firm yield for each of the storage concepts was estimated for the maximum capacity of the representative storage options. Results are shown in Table 6. As an example of the firm yield simulations, Figure 8 shows a plot of daily model results for the Upper Basin – Sandborn Reservoir simulation. The figure shows the demand met on a daily basis by a 224,000 ac-ft reservoir diverting from the Upper Basin. The firm yield is met on almost every day of the simulation; the shortages are due to the tolerance in the iterative routine used to estimate firm yield in the MODSIM model. The plot shows the reservoir emptying during the critical drought in the model period. Similar plots for the other storage concepts are included in Appendix B.

**Table 6. Storage Concept Firm Yield for Maximum Capacity of Representative Storage Sites**

| Storage Concept | Representative Storage Site(s) | Reservoir Capacity (ac-ft) | Firm Yield (ac-ft/yr) |
|---|---|---|---|
| Mainstem Storage | South Platte (Narrows) | 973,000 | 62,000 |
| Upper Basin Storage | Sandborn | 224,000 | 22,000 |
| Mid Basin Storage North | Wildcat | 60,000 | 9,000 |
| Mid Basin Storage South | Beaver Creek | 95,000 | 11,000 |
| Lower Basin Storage | Julesburg, Ovid, Troelstrup | 40,300 | 24,000 |
| Existing Reservoir Improvements | Riverside, Jackson, Prewitt, Julesburg, North Sterling | 56,464 | 17,000 |
| Designated Groundwater Basin Storage West | Lower Lost Creek Aquifer | 157,000 | 20,000 |
| Designated Groundwater Basin Storage East | Beaver/Badger Aquifer | 311,000 | 36,000 |

The firm yield analysis supports the following findings.

- In general, concepts located further downstream in the basin have greater yield for similar storage capacities. This is due to the increase in available water in the downstream direction on the South Platte River.

- Average annual available water under future conditions varies from about 160,000 ac-ft/yr at Greeley to about 290,000 ac-ft/yr at Julesburg. Firm yields are much less than these values even for the large storage options due to the significant year-to-year variability in streamflow. Substantially more storage would be required to significantly increase firm yields from the alternatives.

- Storage concepts that incorporate more than one reservoir option tend to provide greater firm yield than single reservoir options. This is due to the ability of multiple diversion and inlet structures to capture more available water than a single inlet structure. While specific alternatives would have to be studied, in general this highlights the benefits of developing multiple off-channel storage projects as part of an overall SPSS strategy.

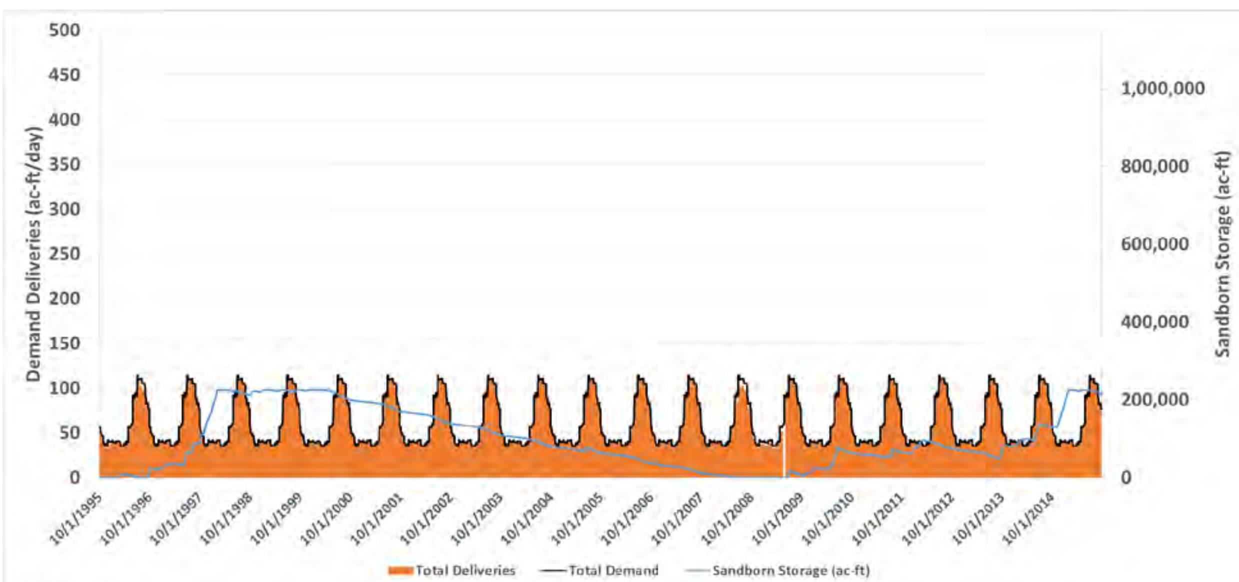


**Figure 8. Demand Met and Storage Contents for Sandborn Reservoir Firm Yield Analysis**

Figure 9 plots the demand locations receiving deliveries of firm yield for each of the storage concepts. Recall that the Kersey demand is met through a combination of exchange and pipeline deliveries, the Denver demand is met through pipeline deliveries alone, and the Balzac and Julesburg demands are met by direct releases to the South Platte. Kersey demands receive the majority of the firm yield for most concepts. Exchanges have the highest priority in the model when attempting to satisfy demands, so those are exercised first and remaining water is released to the river or piped to Brighton. For concepts with some or all of the storage in the lower basin (Lower Basin Storage, Existing Reservoir Improvements), direct releases are the primary mechanism for meeting demands because of the constraints of limited exchange potential and the assumption that a pipeline to Brighton was not feasible for storage options near Julesburg. Different reservoir operation assumptions would give different results for distribution of demands being met; for this analysis, the total firm yield is the most important parameter for comparing storage concepts.

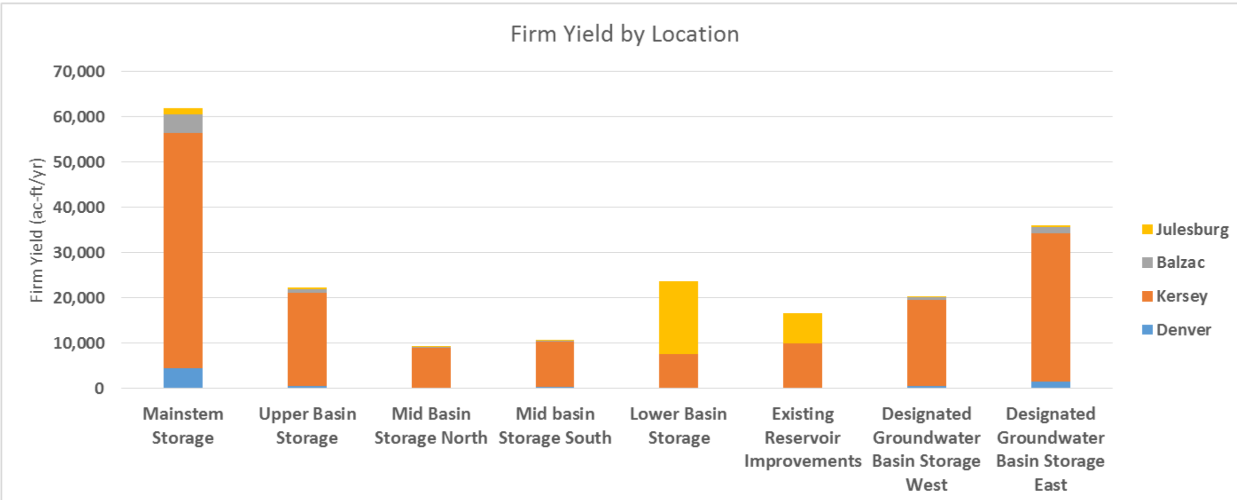



**Figure 9. Distribution of Firm Yield to Demand Points for Storage Concepts with Maximum Capacity of Representative Storage Site**

## Firm Yield Sensitivity Analyses

In the firm yield sensitivity analysis, selected alternative sizes of storage capacity for certain storage concepts were investigated to assess the effect of capacity on firm yield.

*Mainstem Storage Concept.* Table 7 and Figure 10 compare firm yield at the South Platte (Narrows) Dam site for reservoir capacities of 973,000 ac-ft (the maximum capacity), 500,000 ac-ft and 250,000 ac-ft. Results show firm yield is strongly correlated to reservoir capacity. Although the storage efficiency (storage-to-yield ratio) is better for the smaller reservoir, in general bigger is better for the mainstem dam sizes investigated.

**Table 7. Mainstem Storage Concept Sensitivity Analysis Results**

| Reservoir Capacity (ac-ft) | Firm Yield (ac-ft/yr) | Storage:Yield Ratio |
|---|---|---|
| 973,000 | 61,700 | 16:1 |
| 500,000 | 38,000 | 13:1 |
| 250,000 | 20,300 | 12:1 |

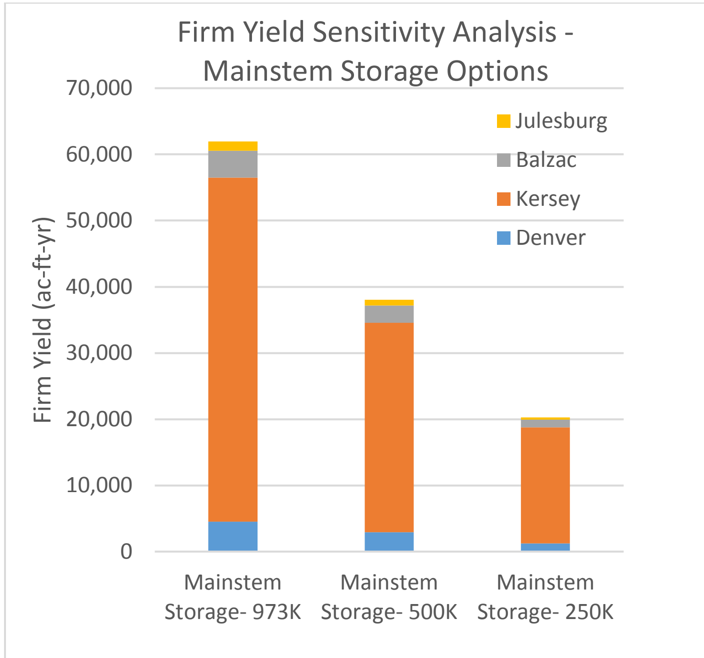



**Figure 10. Mainstem Storage Concept Sensitivity Analysis Results**

*Mid Basin Storage Concept.* A larger storage capacity than the two identified Mid Basin sites was simulated to estimate potential benefits from additional storage in this region. A 150,000 ac-ft capacity was simulated at the Wildcat Reservoir location. Results are shown in Table 8. A larger storage capacity provides a significant increase in firm yield in this region because firm yield is not supply limited even with off-channel storage options. Because of the high variability in annual flow the storage:yield ratio is better for smaller reservoir sizes.

**Table 8. Mid Basin Concept Sensitivity Analysis**

| Storage Site | Capacity (ac-ft) | Firm Yield (ac-ft/yr) | Storage:Yield Ratio |
|---|---|---|---|
| Wildcat | 60,000 | 9,300 | 6:1 |
| Beaver Creek | 95,000 | 10,700 | 9:1 |
| Wildcat | 150,000 | 17,200 | 9:1 |

*Aquifer Storage vs Surface Storage*. To compare relative benefits of surface storage and aquifer storage, the Upper Basin Storage Concept using Sandborn Reservoir was simulated with a capacity of 150,000 ac-ft, which is similar to the Lost Basin ASR capacity of 157,000 ac-ft. Results are shown in Table 9. The ASR concept gives a higher firm yield and better storage:yield ratio for essentially the same storage capacity. This is likely due primarily to the elimination of evaporation losses in the aquifer storage concept (although the simulation does include some groundwater losses).

**Table 9. Surface Storage vs Aquifer Storage Comparison in Upper Basin**

| Storage Option | Capacity (ac-ft) | Firm Yield (ac-ft/yr) | Storage:Yield Ratio |
|---|---|---|---|
| Upper Basin Surface Storage | 224,000 | 22,200 | 10:1 |
| Upper Basin Surface Storage | 150,000 | 16,200 | 9:1 |
| Upper Basin Aquifer Storage | 157,000 | 20,100 | 8:1 |

*Combination of Upper Basin + Lower Basin Concepts*. Benefits of combining an Upper Basin project with a Lower Basin project were investigated by simulating a combination of Lost Creek ASR in the Upper Basin with the three surface reservoirs in the Lower Basin Storage concept. Results are shown in Table 10 and Figure 11. The benefits are significant; firm yield of this combination is exceeded only by the large Mainstem Dam concept. While the firm yield of the combined concepts is less than the sum of the individual concepts operating alone (because they both attempt to store some of the same water), the combined firm yield is significantly greater than the firm yield of either one of the individual concepts. This shows the benefits of storage distributed in multiple sites throughout the basin.

**Table 10. Firm Yield for Combined Upper and Lower Basin Storage Concepts**

| Storage Concept | Storage Options Simulated | Total Capacity (ac-ft) | Firm Yield (ac-ft/yr) | Storage:Yield Ratio |
|---|---|---|---|---|
| Lower Basin Storage Alone | Julesburg Enlargement/ Rehabilitation, Ovid, Troelstrup | 40,300 | 23,500 | 2:1 |
| Upper Basin Storage Alone | Lower Lost Creek ASR | 157,000 | 20,100 | 8:1 |
| Combined Upper and Lower Basin Storage | All of above | 197,300 | 39,200 | 5:1 |

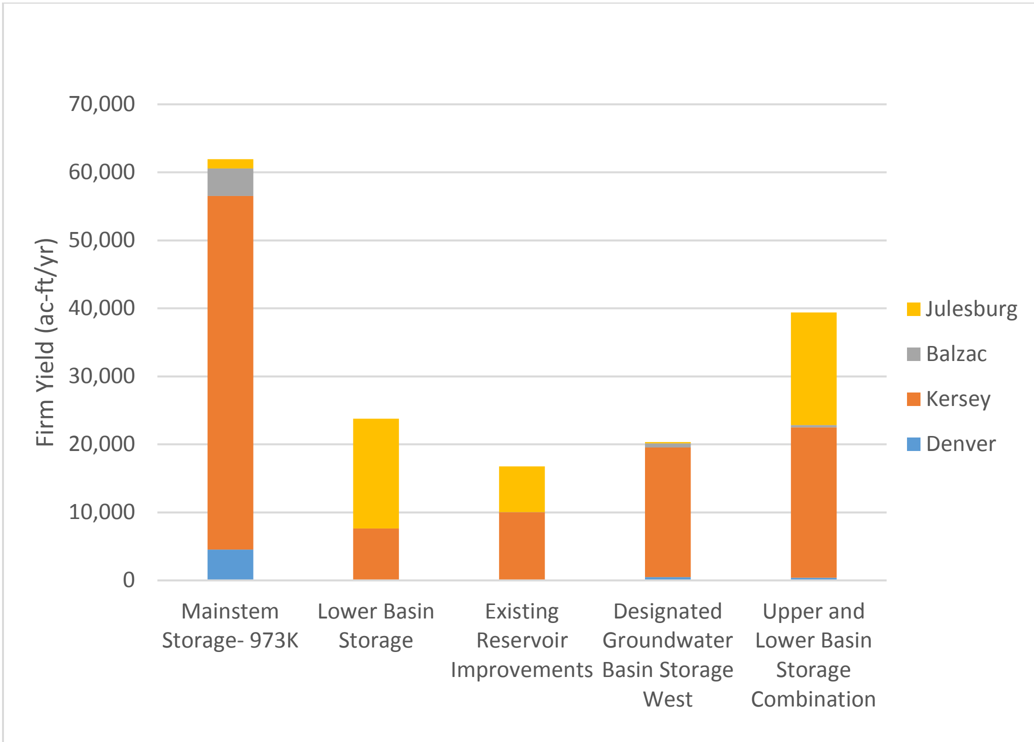



**Figure 11. Comparison of Firm Yield for Combined Upper and Lower Basin Storage Concept with Other Concepts**

## As-Available Analysis of Storage Concepts

As noted previously, actual operations of any of the SPSS storage concepts are unknown because the ownership is unknown. Reservoir owners could choose to operate their storage in something other than a firm yield approach. To test the sensitivity of the comparison of storage concepts to operating assumptions, two other operational scenarios were simulated that assumed the storage would be operated to meet as much demand as possible whenever that demand occurred. These scenarios varied only in the amount of demand applied to the storage reservoirs.

- Scenario 1 – Demand on the reservoir was set to the total demand estimated for the future South Platte Basin gap at the four demand centers as described in the previous “Demands” section (annual demand = 502,882 AFY).
- Scenario 2 – Scaled-back demand to force reservoirs to hold more water in storage during wet periods (annual demand = 97,000 AFY).

Modeling results are summarized in Table 11 for the maximum potential capacities at each of the representative storage sites for the SPSS storage concepts. The average annual deliveries under this kind of operating assumption are much higher than the firm yields shown in Table 6. However, when full gap demands were simulated, the applied demand was very large relative to the supply and the storage capacity so on most days the model moved all the available water from the river to storage and then immediately out of storage to meet the demand. This is shown for one of the storage concepts (Upper Basin Storage) in Figure 12 as an example. Essentially the demand being met was supply limited, as water was diverted from the river whenever it was available, leaving limited water to store in the reservoirs. Very high demands are met on a few days but during large parts of the simulation no deliveries are made; that is, reliability is very low. For the Upper Basin Storage simulation in Figure 12, the reliability (percentage of days the full applied demand is completely satisfied) is only 1 percent. For the Mainstem Storage concept the reliability is higher – 9 percent – because the storage volume is larger and there are no constraints in diversion and intake capacities. Figure 12 also shows that the storage is rarely used because demands are so high water is moved directly from the river to the demand centers. The simulation of this type of operation does not highlight the value of storage, but does demonstrate that there is a large amount of available water in the river to meet high demands on a very infrequent basis.

**Table 11. Yield of Storage Concepts Based on As-Available Operations**

| Solution Name | Representative Storage Site(s) | Reservoir Capacity (AF) | Full Gap Demand (502,882 AFY) - Average Annual Delivery (AF/Y) | Scaled Demand (97,000 AFY) - Average Annual Delivery (AF/Y) |
|---|---|---|---|---|
| Mainstem Storage | Narrows | 973,000 | 118,000 | 81,000 |
| Upper Basin Storage | Sandborn | 224,000 | 74,000 | 48,000 |
| Mid Basin Storage North | Wildcat | 60,000 | 82,000 | 43,000 |
| Mid basin Storage South | Beaver Creek | 95,000 | 85,000 | 46,000 |
| Lower Basin Storage | Julesburg, Ovid, Troelstrup | 40,300 | 129,000 | 48,000 |
| Existing Reservoir Improvements | Riverside, Jackson, Prewitt, Julesburg, North Sterling | 56,464 | 143,000 | 59,000 |
| Designated Groundwater Basin Storage West | Lost Creek Aquifer | 157,000 | 70,000 | 43,000 |
| Designated Groundwater Basin Storage East | Beaver/Badger Aquifer | 311,000 | 80,000 | 51,000 |

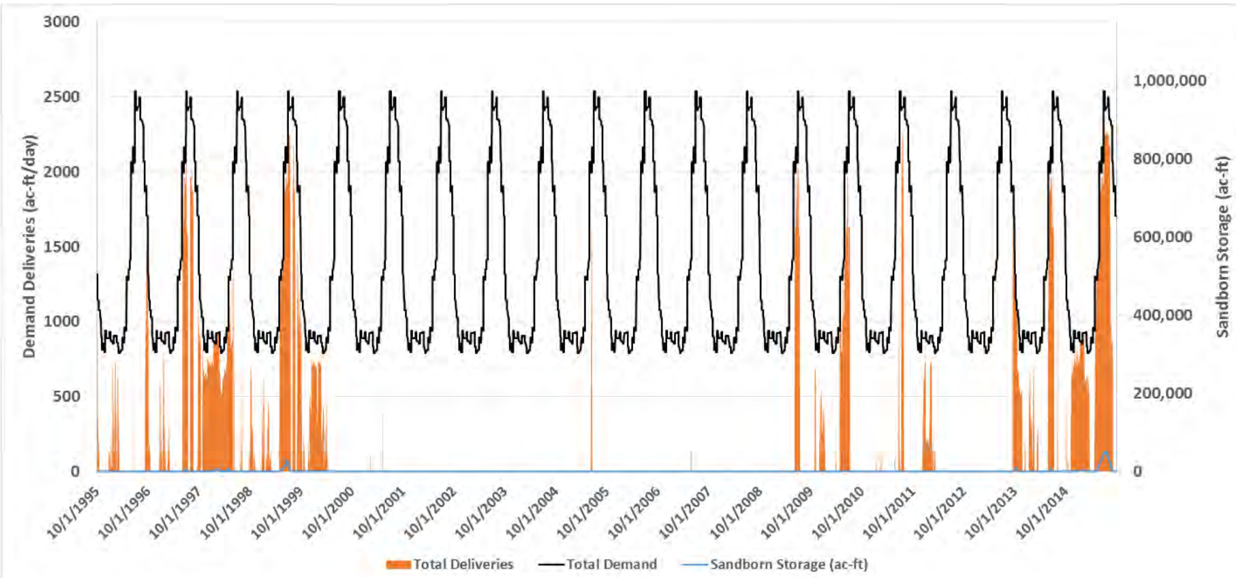



**Figure 12. Simulation of Sandborn Reservoir with Full Gap Demand Applied in As-Available Operation Mode**

Simulation of the scaled-back demands is summarized for each concept in Table 11, and is displayed for the Upper Basin (Sandborn) concept in Figure 13. The scaled-back demands are 97,000 ac-ft/yr compared to over 502,000 ac-ft/yr for the full gap demands. Average annual deliveries are less than for the full gap scenario (because less water is demanded) and the benefits of storage are more evident. In addition, Figure 13 shows that the reliability for this condition is approaching 50 percent, which is much better than when the full gap demands are applied.

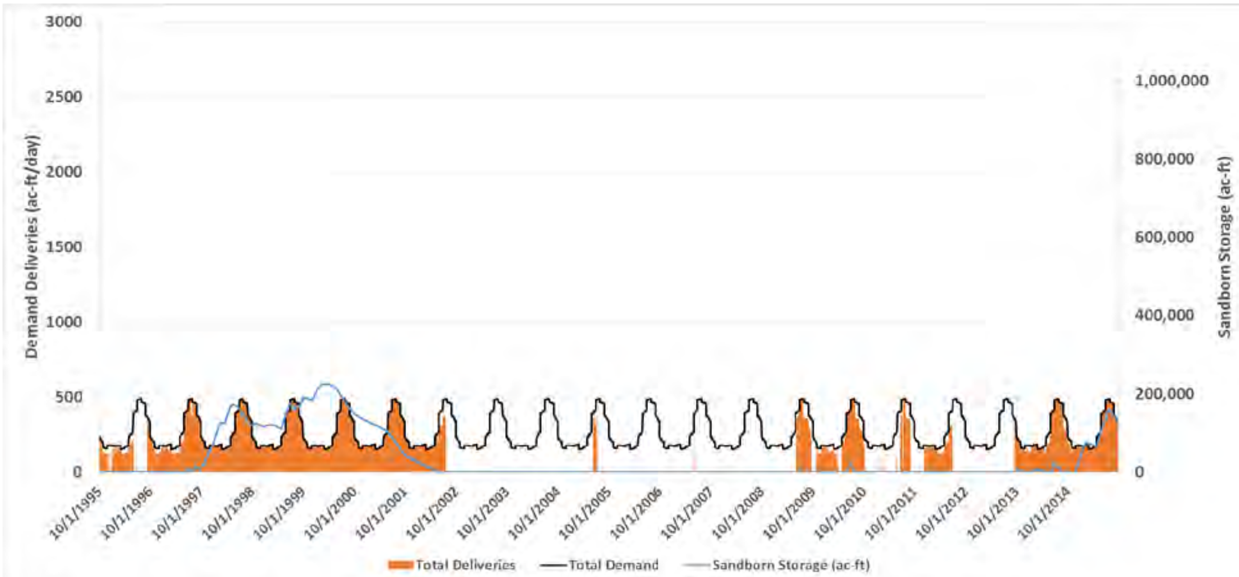



**Figure 13. Simulation of Sandborn Reservoir with Scaled-Back Demand Applied in As-Available Operation Mode**

A preliminary version of the SPSS MODSIM model was used to run a sensitivity analysis of different reservoir sizes for each of the concepts with the Full Gap Demands applied. Results showed very little difference in the average yield that could be provided even with very different storage capacities, because under this condition with very large demands the system is supply limited, not storage limited.

**Summary of Storage Concept Simulations**

The key findings of the storage concept analysis are as follows.

- The Firm Yield results are the most useful for this analysis and have an easier message to convey. Thus the firm yield results will be used to draw conclusions. The results of the As-Available analysis generally point to the same findings.
- Not surprisingly, the large mainstem reservoir has the best performance. Smaller mainstem reservoirs have significantly less firm yield and are comparable to other off-channel options.
- Aquifer storage projects perform better than surface storage projects of the same size diverting from the same reach of the South Platte. Lower evaporation losses offset assumed losses to the groundwater basin from ASR.
- Storage options lower in the basin tend to be more efficient (better storage:yield ratio) because there is more water available. This is biased by the fact that the lower basin concepts simulated in this study have multiple storage buckets and hence multiple inlets, so there is more diversion capacity, but the additional water is still an important factor in performance of storage options.
- A combination of upper basin and lower basin storage concepts rivals the large mainstem dam for firm yield benefits.

- Combinations of storage options can provide significantly more benefit than individual options, but the increase is not linear – i.e., the total yield from two storage options is less than the sum of the yield from the options operating alone.
- No feasible storage concepts or reasonable combinations of concepts are capable of putting all the available flow in the lower South Platte River to beneficial use. Therefore as a general principle, more storage will always be “better” in this region in terms of maximizing available supply for basin water users.
- Because nearly all concepts require off-channel storage and diversion from the South Platte River, intake capacity constraints can be important and there are benefits to having multiple off-channel storage projects to minimize these effects.

## CHARACTERIZATION OF STORAGE OPTIONS – SITE EVALUATION FRAMEWORK

The previous section discussed the ability of storage concepts to provide water supply benefits in the South Platte Basin. Individual SPSS storage options were then evaluated and compared based on technical, cost, and environmental and permitting factors. This section describes the data compiled for each storage option.

The surface and groundwater storage options in the SPSS study area were characterized based on a variety of technical and environmental and permitting parameters. Data for all storage options remaining after the initial screening process were collected. The sources available for candidate reservoir sites were described in the South Platte Storage Opportunities Literature Review TM.

Data were compiled in a Site Evaluation Framework (SEF) database. Database attributes (parameters, data types) and qualifiers (values, ratings) for the SEF are defined in Appendix C.

Where possible, data were collected from previous studies and reports. The SPSS study team used the best available maps, aerial photography and other resources to fill in the database attributes for each storage option. Professional judgment was used where necessary. For each storage option the descriptive data were based on the maximum storage capacity reported for that site.

Database entries for each storage option are shown in Appendix D.

The information in the SEF was used to select the representative storage sites for modeling each storage concept as described previously. Representative sites were the sites that provided the best balance of technical feasibility and size while avoiding difficult environmental and social impacts to the extent possible. While the representative sites were selected as the “best fit” among the potential sites in each portion of the SPSS study area (see Table 4), further study could determine that other sites are as good or better. The data in the SEF can provide the starting point for future studies if desired.

## COST ESTIMATES

A summary of cost estimates for components included in the SPSS storage scenarios is provided in this section. A separate technical memorandum provides details on the derivation of the cost estimates.

### Surface Storage Costs

Surface reservoir construction costs are summarized in Table 12. These cost estimates include capital construction, land acquisition, permitting, and design. The reservoirs with the lowest unit cost are the most cost-effective in terms of storage provided per dollar spent. For new surface reservoirs, unit cost is generally inversely correlated with capacity such that the largest reservoirs have the lowest unit cost. This is shown in Figure 14. Enlarged or rehabilitated existing reservoirs have more variable unit costs because the type of work required to achieve the additional storage varies considerably from site to site.

**Table 12. Summary of Surface Reservoir Costs**

| Dam Type/Name | Storage Capacity (ac-ft) | Estimated 2017 Cost ($ million) | Unit Cost ($/ac-ft) |
|---|---|---|---|
| New Site | | | |
| Sandborn Reservoir | 224,000 | $128 | $570 |
| West Nile Reservoir | 26,950 | 57 | $2,100 |
| McCarthy Reservoir | 10,000 | 25 | $2,500 |
| South Platte (Narrows) Reservoir | 1,960,000 | $125 | $64 |
| Wildcat Reservoir | 60,000 | $74 | $1,200 |
| Pawnee Pass Dam | 75,000 | $249 | $3,300 |
| Fremont Butte | 76,000 | $71 | $940 |
| North Sterling Regulating Reservoir | 7,600 | $35 | $4,600 |
| Johnson Reservoir | 10,600 | $21 | $2,000 |
| Ovid Reservoir | 7,700 | $21 | $2,700 |
| Troelstrup | 5,000 | $16 | $3,100 |
| Beaver Creek | 95,000 | $61 | $640 |
| Enlargement | | | |
| North Sterling Reservoir Enlargement | 12,000 | $22 | $1,800 |
| Julesburg Reservoir Enlargement | 21,900 | $44 | $2,000 |
| Rehabilitation | | | |
| Empire Reservoir Rehab | 2,779 | $14 | $5,000 |
| Prewitt Reservoir Rehab | 4,364 | $5.5 | $1,300 |
| Julesburg Reservoir Rehab | 5,700 | $31 | $5,400 |
| Jackson Lake Reservoir Rehab | 10,000 | $1.8 | $190 |
| Riverside Reservoir Rehab | 2,500 | $13 | $5,000 |

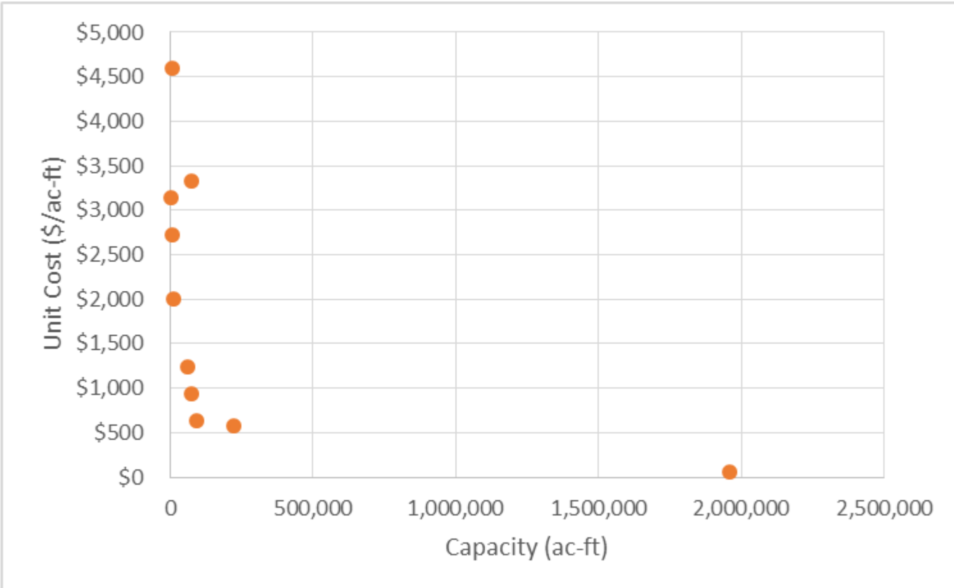



**Figure 14. Unit Cost of Surface Storage vs Capacity for New Reservoirs**

**Aquifer Storage Costs**

Aquifer storage costs were based on conceptual designs for infiltration basin recharge and recovery within an alluvial aquifer. Conceptual designs include components required to recharge and recovery of water at a site, but not the conveyance to and from the site.

Aquifer storage and recovery concept costs are more correlated to recharge and recovery rates than total storage volumes. Because of this, Table 13 presents the same total cost estimate for Lower Lost Creek Basin and Badger/Beaver Basin. These costs were developed on a unit basis so future cost estimates can be scaled to different recharge and recovery scenarios.

**Table 13. Aquifer Storage and Recovery Costs**

| Storage Concept | Storage Capacity (ac-ft) | Recharge Rate (ac-ft per month) | Recovery Rate (ac-ft per month) | Estimated 2017 Cost ($ million) | Unit Cost ($/ac-ft) |
|---|---|---|---|---|---|
| Lower Lost Creek Aquifer | 157,000 | 24,000 | 12,000 | $163 | $1,038 |
| Beaver/Badger Aquifer | 311,00 | 24,000 | 12,000 | $163 | $524 |

The aquifer storage cost estimates were based on SPSS delivery and demand scenarios with 10,000 ac-ft of gravel pit regulating storage near the river diversion. Aquifer storage concepts were modeled with a capacity of 24,000 ac-ft per month of inflow/recharge and 12,000 ac-ft per month of outflow/recovery. It is possible that these scenarios would not represent reasonable rates of alluvial aquifer recharge and recovery for all alluvial ASR sites, but these rates were used to provide a similar cost comparison to surface water storage options. It was also assumed that land availability and hydrogeologic conditions would not constrain site construction or operations for recharge or recovery.

**Conveyance Costs**

As described previously, storage concepts require combinations of river diversions, facilities to convey water from the river to the reservoir, and facilities to convey water from the reservoir to demand centers. Derivation of these costs is described in the Cost Estimating TM. For purposes of the SPSS conceptual costs it was assumed that new diversion and conveyance facilities would be required for SPSS projects; use of existing diversion structures or irrigation canals to fill reservoirs could reduce actual costs upon further analysis. Summaries of SPSS cost estimating assumptions and data are provided below.

At the conceptual level, all diversion structures were assumed to be sized for 800 cfs at a cost of $3.6 million regardless of their location.

For purposes of conceptual cost estimating it was assumed that a maximum flow rate of 400 cfs would be pumped and piped from the diversion structure to the storage reservoir in a bi-directional pipeline, which would then be used to release water back to the river when the reservoir is operated to meet downstream demands. This assumes a 10,000 ac-ft gravel pit storage complex at the diversion structure to balance peak flows.

Table 14 summarizes key parameters and costs for conceptual intake conveyance systems for each storage concept. Conveyance facility and cost requirements should be considered conservative, but allow for equal comparison of concepts. These costs represent construction cost only, and do not include costs for permitting, design, land acquisition, easement and right-of-way acquisition, or environmental impact mitigation.

**Table 14. Cost Estimates for Intake Conveyance Systems for Storage Concepts**

| Alternative | Pipeline Cost | Pump Station Cost | Dam and Diversion Structure Cost | Gravel Pit Storage Cost | Contingency | Total Conveyance Cost |
|---|---|---|---|---|---|---|
| Upper Basin Storage- Sandborn Reservoir | $43,750,000 | $50,360,000 | $3,600,000 | $15,000,000 | $56,355,000 | $169,065,000 |
| Mid Basin Storage North- Wildcat Reservoir | $26,110,000 | $49,950,000 | $3,600,000 | $15,000,000 | $47,330,000 | $141,990,000 |
| Mid Basin Storage South- Beaver Creek Reservoir | $140,690,000 | $113,010,000 | $3,600,000 | $15,000,000 | $136,150,000 | $408,450,000 |
| Lower Basin Storage- Trilakes Northeast (Julesburg, Ovid, and Troelstrup) | $9,010,000 | $16,750,000 | $5,600,000 | $30,000,000 | $30,680,000 | $92,040,000 |
| Existing Reservoir Improvements (Julesburg, North Sterling, Prewitt, Jackson, and Riverside) | $34,970,000 | $59,270,000 | $8,400,000 | $45,000,000 | $73,820,000 | $221,460,000 |
| Groundwater Basin Storage West- Lost Creek Aquifer | $62,550,000 | $78,210,000 | $3,600,000 | $15,000,000 | $79,680,000 | $239,040,000 |
| Groundwater Basin Storage East- Beaver Badger Aquifer | $70,790,000 | $138,150,000 | $3,600,000 | $15,000,000 | $113,770,000 | $341,310,000 |

Deliveries to demand centers would require infrastructure as follows.

- Exchange to Kersey: A 20,000 ac-ft gravel pit reservoir was included with all concepts so facilitate exchanges and improve efficiencies of deliveries to customers in the northern Front Range area. The cost of the gravel pit and ancillary facilities was estimated to be $30 million.

- Release to River: No separate facilities are needed. For this evaluation it was assumed the intake pipeline would be a bi-direction pipeline that could be used to both fill the reservoir from the South Platte River and also release water to the South Platte River to meet downstream demands.

- Pipe to Brighton: The 100 mgd pipeline to Brighton was assumed to be a 60-inch pipeline for all alternatives. Pipeline length and pumping station cost varied for each alternative.

Table 15 summarizes the capital cost estimates for these conveyance requirements. These values do not include costs for permitting, design, land acquisition, easement and right-of-way acquisition, or environmental impact mitigation.

**Table 15. Conveyance Costs for Pipeline to Brighton Component of Storage Concepts**

| Alternative | Length (mi) | Pipeline Cost | Pump Station Cost | Contingency | Total Cost |
|---|---|---|---|---|---|
| Mainstem Storage – Pipe from South Platte (Narrows) Reservoir | 62 | $138,170,000 | $85,130,000 | $111,650,000 | $334,950,000 |
| Upper Basin Storage – Pipe from Sandborn Reservoir | 52 | $114,640,000 | $69,850,000 | $92,245,000 | $276,735,000 |
| Mid Basin Storage North – Pipe from Wildcat Reservoir | 71 | $157,560,000 | $100,780,000 | $129,170,000 | $387,510,000 |
| Mid Basin Storage South – Pipe from Beaver Creek Reservoir | 72 | $158,920,000 | $102,530,000 | $130,725,000 | $392,175,000 |
| Lower Basin Storage- Trilakes Northeast – Pipe from Julesburg Reservoir | 164 | $364,640,000 | $209,100,000 | $286,870,000 | $860,610,000 |
| Existing Reservoir Improvements – Pipe from Riverside Reservoir | 52 | $114,640,000 | $69,850,000 | $92,245,000 | $276,735,000 |
| Groundwater Basin Storage West – Pipe from Lost Creek Aquifer | 32 | $69,860,000 | $47,950,000 | $58,905,000 | $176,715,000 |
| Groundwater Basin Storage East – Pipe from Badger / Beaver Aquifer | 64 | $141,400,000 | $91,250,000 | $116,325,000 | $348,975,000 |

## Summary of Costs by Storage Concept

Table 16 summarizes capital costs for SPSS storage concepts. These costs are based on the largest feasible storage capacity for the surface reservoir or ASR project. No cost optimization was performed for this analysis.

**Table 16. Summary of Storage Concept Costs for Maximum Representative Storage Site**

| Storage Concept (Representative Site) | Storage Capacity (ac-ft) | Storage Cost ($M) | Intake System Cost ($M) (Diversion, Gravel Pits, Pipes, Pump) | Delivery System Cost ($M) (Pipe to Brighton, Kersey Gravel Pits) | Total Storage Concept Cost ($M) | Firm Yield (AFY) | Total Unit Cost ($/AFY) |
|---|---|---|---|---|---|---|---|
| Mainstem Dam (Narrows) | 973,000 | $125 | - | $335 | $460 | 62,000 | $7,400 |
| Upper Basin Storage (Sandborn) | 224,000 | $128 | $168 | $277 | $573 | 22,000 | $26,000 |
| Mid Basin Storage North (Wildcat) | 60,000 | $74 | $141 | $388 | $602 | 9,000 | $66,900 |
| Mid Basin Storage South (Beaver) | 95,000 | $61 | $407 | $392 | $860 | 11,000 | $78,200 |
| Existing Reservoirs | 40,300 | $121 | $221 | $277 | $619 | 17,000 | $36,400 |
| Lower Basin Storage | 56,464 | $58 | $92 | $781 | $932 | 24,000 | $38,800 |
| Groundwater Storage West (Lost Creek) | 157,000 | $163 | $354 | $177 | $693 | 20,000 | $34,700 |
| Groundwater Storage East (Badger/Beaver) | 311,000 | $163 | $336 | $349 | $848 | 36,000 | $23,600 |

## COMPARISON OF STORAGE SITES

Criteria and data from the SEF were used to compare storage sites using a simple scoring system. The purpose of the scoring system was to provide a means of identifying the more feasible storage options. At this level the comparison of sites is not a precise assessment, and results should be used only to identify overall trends or large differences between options.

Appendix C lists numerical values assigned to each of the qualifiers for the attributes. Assigning values to the qualifiers allowed for calculation of a triple bottom line evaluation score for each option. Due to the limited level of analysis conducted at this stage, most attributes were quantified using values 1 for good performance and 0 for poor performance. In some cases intermediate values of 0.5 were assigned. For attributes with a negative impact, negative values were used.

Evaluation of alternatives using a triple bottom line scoring system with multiple criteria requires assumptions for the weight of the criteria. For this analysis three weighting scenarios were tested:

- Equal Weights; all criteria received an equal weight of 1.
- Technical Weights; all criteria related to technical feasibility of the storage option (e.g., scalability, constructability, ability to use existing infrastructure) were given a weight of 3 and all other criteria were given a weight of 1.

- Environmental Weights; all criteria related to environmental parameters (e.g., wetlands, habitat impacts, permittability) were given a weight of 3 and all other criteria were given a weight of 1.

Table 17 summarizes the results of the triple bottom line site evaluation process for the three criteria weighting scenarios. The table shows the numerical score for the storage options. In addition, the average of the scores was computed across the 3 weighting scenarios for each storage option to assess how the sites performed across all weightings. This is shown in Table 18. Figure 15 shows the range of scores for each of the weighting scenarios as well as the maximum possible score for each scenario.

Result of the multi-criteria comparison of sites can be summarized as follows:

- Sites that tend to rise to the top of the scoring process tend to do so regardless of the weights assigned to the criteria. Similarly, sites that tend to fall to the bottom of the scoring process tend to do so regardless of the weights assigned to the criteria. This is helpful in that the relative scoring of most sites is fairly independent of the weight assigned to the criteria in the SEF.

- As expected, aquifer storage options and enlargements and rehabilitations of existing reservoirs tend to score higher than new reservoirs.

- Also as expected, the on-channel storage options (Narrows Reservoir and Hardin Reservoir) score poorly relative to most other options.

- Of the new off-channel reservoir options, the sites with the most promise appear to be Wildcat, Point of Rocks, Beaver Creek, Johnson, North Sterling Regulating, and Sandborn.

- Scores are clustered over a relatively narrow range compared to the maximum possible score for each weighting scenario, and no storage options had a score close to the maximum possible score. Differences among storage options are small, and at this level of analysis the triple bottom line scoring process should not be used to eliminate options.

At this level of analysis, the storage option scoring process is very approximate and is based on conceptual information and considerable professional judgment. Significant information about individual sites was unknown at this stage. Refinement of site specific data could change scores of options significantly. In addition, sites were scored without regard for how they could be used in a specific solution that could be formulated by a specific water user. When considering how storage sites would be incorporated into a particular alternative and integrated into the operations of a particular water user, results for the scoring process could vary considerably from this generic approach.

**Table 17. Summary of Storage Site Evaluation Scores for Different Criteria Weighting Scenarios**

| Name | Category | Site Score-Equal Weighting | Site Score-Feasibility Weighting | Site Score-Environmental Weighting |
|---|---|---|---|---|
| Range of Possible Scores (Min / Max) | | 0 / 20.5 | 0 / 43.5 | 0 / 37.5 |
| Badger/Beaver Creek | Aquifer | 9.5 | 24.5 | 13.5 |
| Beaver Creek Reservoir | New Site | 8.5 | 18.5 | 12.5 |
| Fremont Butte | New Site | 7.5 | 18.5 | 7.5 |
| Greasewood Reservoir | New Site | 6.5 | 16.5 | 6.5 |
| Hardin Reservoir | New Site | 6 | 20 | 0 |
| Jackson Lake Reservoir | Rehabilitation | 9.5 | 25.5 | 10.5 |
| Johnson Reservoir | New Site | 7 | 21 | 7 |
| Julesburg Reservoir (Enlrg) | Enlargement | 8 | 25 | 8 |
| Julesburg Reservoir (Rehab) | Rehabilitation | 10.5 | 27.5 | 15.5 |
| Lower Bijou Creek | Aquifer | 10.5 | 28.5 | 13.5 |
| Lower Kiowa Creek | Aquifer | 10 | 26 | 12 |
| Lower Lost Creek | Aquifer | 11.5 | 28.5 | 17.5 |
| McCarthy Reservoir | New Site | 6 | 16 | 6 |
| North Sterling Reg Res | New Site | 7 | 21 | 7 |
| North Sterling Reservoir | Enlargement | 7 | 22 | 6 |
| Ovid Reservoir | New Site | 6.5 | 21.5 | 4.5 |
| Pawnee Pass Dam | New Site | 7 | 19 | 6 |
| Point of Rocks Reservoir | New Site | 8.5 | 21.5 | 10.5 |
| Prewitt Reservoir | Rehabilitation | 9 | 26 | 8 |
| Riverside Reservoir | Rehabilitation | 10 | 25 | 13 |
| Sandborn Reservoir | New Site | 7 | 19 | 7 |
| South Platte (Narrows) Res | New Site | 7.5 | 22.5 | 3.5 |
| Sunken Lake Reservoirs | New Site | 6.5 | 18.5 | 5.5 |
| Troelstrup | New Site | 6.5 | 21.5 | 4.5 |
| Upper Bijou Creek | Aquifer | 8.5 | 20.5 | 11.5 |
| Upper Kiowa Creek | Aquifer | 8.5 | 20.5 | 11.5 |
| Upper Lost Creek | Aquifer | 10 | 26 | 14 |
| West Nile Reservoir | New Site | 5.5 | 14.5 | 5.5 |
| Wildcat Reservoir | New Site | 9 | 26 | 8 |

Note: Green shading indicates approximately top 20% of scores; red shading indicates approximately bottom 20% of scores.

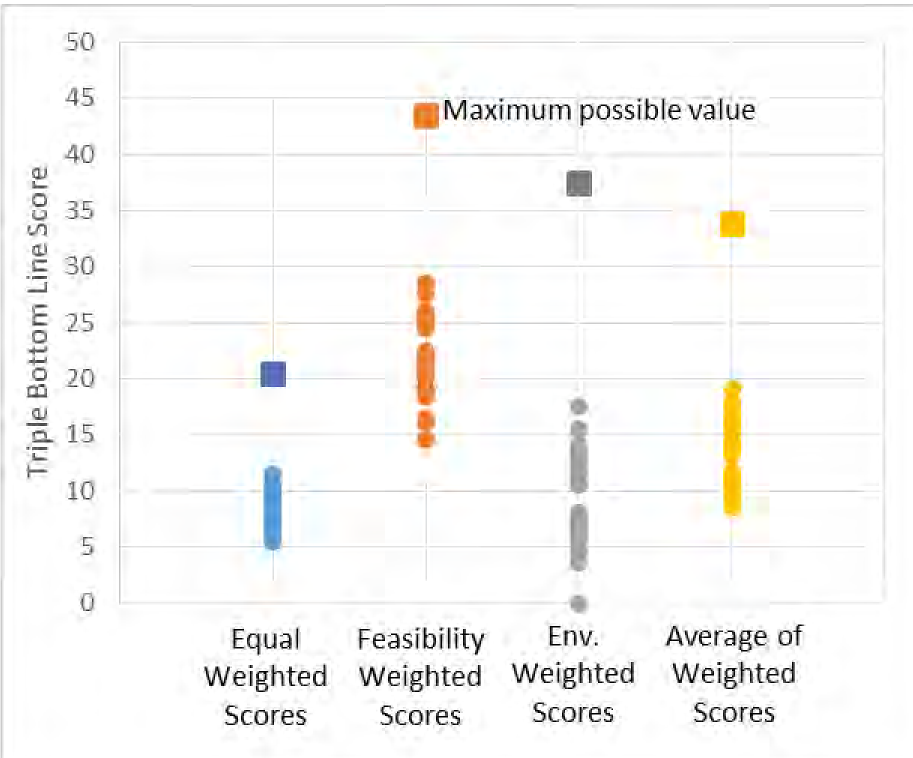



**Figure 15. Range of Storage Site Scores for Different Weighting Scenarios**

**Table 18. Average of Scores Across Three Weighting Scenarios for Reservoir Storage Options**

| Storage Options Sorted by Average Score | Average of Scores for 3 Weighting Scenarios |
|---|---|
| Lower Lost Creek | 19.2 |
| Julesburg Reservoir (Rehabilitation) | 17.8 |
| Lower Bijou Creek | 17.5 |
| Upper Lost Creek | 16.7 |
| Lower Kiowa Creek | 16.0 |
| Riverside Reservoir | 16.0 |
| Badger/Beaver Creek | 15.8 |
| Jackson Lake Reservoir | 15.2 |
| Prewitt Reservoir | 14.3 |
| Wildcat Reservoir | 14.3 |
| Julesburg Reservoir (Enlargement) | 13.7 |
| Point of Rocks Reservoir | 13.5 |
| Upper Bijou Creek | 13.5 |
| Upper Kiowa Creek | 13.5 |

| Storage Options Sorted by Average Score | Average of Scores for 3 Weighting Scenarios |
|---|---|
| Beaver Creek Reservoir | 13.2 |
| Johnson Reservoir | 11.7 |
| North Sterling Regulating Reservoir | 11.7 |
| North Sterling Reservoir | 11.7 |
| Fremont Butte | 11.2 |
| South Platte (Narrows) Reservoir | 11.2 |
| Sandborn Reservoir | 11.0 |
| Ovid Reservoir | 10.8 |
| Troelstrup | 10.8 |
| Pawnee Pass Dam | 10.7 |
| Sunken Lake Reservoir | 10.2 |
| Greasewood Reservoir | 9.8 |
| McCarthy Reservoir | 9.3 |
| Hardin Reservoir | 8.7 |
| West Nile Reservoir | 8.5 |

Note: Orange indicates aquifer storage, green indicates existing reservoir modification, blue indicates off-channel surface reservoir, and white indicates on-channel surface reservoir.

When comparing storage sites, attributes of size, cost and triple bottom line scoring are all important. Table 19 compares these features for each of the storage sites. In this table the storage cost includes the cost of conveying water from the South Platte River to the storage site. The inlet cost includes a new diversion structure and a new, dedicated pipeline and pump station system from the river to the storage site. In some cases existing irrigation canals could be used to convey a portion of the project water to a location fairly near the site, potentially reducing the storage+inlet cost.

**Table 19. Comparison of Storage Site Capacity, Cost and Triple Bottom Line Score**

| Dam Type/Name | Storage Capacity (ac-ft) | Storage + Inlet System | | | Triple Bottom Line Score |
|---|---|---|---|---|---|
| | | Dam or ASR Cost ($ million) | Inlet Cost(1) ($ million) | Total Unit Cost(2) ($/ac-ft) | |
| New Surface Storage | | | | | |
| Sandborn Reservoir | 224,000 | $128 | $168 | $296 | 11.0 |
| West Nile Reservoir | 26,950 | 57 | $168 | $225 | 8.5 |
| McCarthy Reservoir | 10,000 | 25 | $150 | $175 | 9.3 |
| South Platte (Narrows) Reservoir | 1,960,000 | $125 | $0 | $125 | 11.2 |
| Wildcat Reservoir | 60,000 | $74 | $141 | $215 | 14.3 |
| Pawnee Pass Dam | 75,000 | $249 | $200 | $449 | 10.7 |
| Fremont Butte | 76,000 | $71 | $273 | $344 | 11.2 |
| North Sterling Regulating Reservoir | 7,600 | $35 | $168 | $203 | 11.7 |

| Dam Type/Name | Storage Capacity (ac-ft) | Storage + Inlet System | | | Triple Bottom Line Score |
|---|---|---|---|---|---|
| | | Dam or ASR Cost ($ million) | Inlet Cost(1) ($ million) | Total Unit Cost(2) ($/ac-ft) | |
| Johnson Reservoir | 10,600 | $21 | $89 | $110 | 11.7 |
| Ovid Reservoir | 7,700 | $21 | $35 | $56 | 10.8 |
| Troelstrup | 5,000 | $16 | $35 | $51 | 10.8 |
| Beaver Creek | 95,000 | $61 | $200 | $261 | 13.2 |
| Enlargement of Surface Storage | | | | | |
| North Sterling Reservoir Enlargement | 12,000 | $22 | 60 | $82 | 11.7 |
| Julesburg Reservoir Enlargement | 21,900 | $44 | $40 | $84 | 13.7 |
| Rehabilitation of Surface Storage | | | | | |
| Empire Reservoir Rehab | 2,779 | 14 | 40 | $54 | NA |
| Prewitt Reservoir Rehab | 4,364 | 5.5 | 40 | $46 | 14.3 |
| Julesburg Reservoir Rehab | 5,700 | $31 | $40 | $71 | 17.8 |
| Jackson Lake Reservoir Rehab | 10,000 | $2 | $40 | $42 | 15.2 |
| Riverside Reservoir Rehab | 2,500 | 12.5 | 35 | $48 | 16.0 |
| Aquifer Storage | | | | | |
| Lower Lost Creek Basin | 157,000 | 163 | 354 | $517 | 19.2 |
| Badger/Beaver Basin | 311,000 | 163 | 336 | $499 | 15.8 |

Notes:
(1) Inlet cost assumes new diversion, pipeline and pump station(s) from South Platte River to storage site.
(2) Storage sites that could be filled in part using existing irrigation canals, thus reducing cost, are shown in bold.

## COMPARISON OF STORAGE CONCEPTS

In addition to data for individual storage sites, the SEF for the SPSS contains many attributes that apply to the overall solutions and storage concepts. These attributes are listed and described in Appendix C. Many of the storage concept attributes are based on the specific criteria listed in HB-1256 for evaluating SPSS alternatives. Others were developed by the study team to assist in comparing the storage concepts on a relative basis.

Table 20 shows the attribute values for the eight SPSS storage concepts considered in this study. It also lists the cumulative scores for each storage concept when numerical values are assigned to the attribute qualifiers (e.g., 1.0, 0.5, 0) as shown in Appendix C. For many of the attributes, particularly those associated with the HB-1256 criteria, the storage concepts have very similar performance. They were formulated to meet demands in a variety of locations in the basin and thus have similar capabilities of providing water supply benefits listed in HB-1256. The storage concepts relying on reservoirs lower in the South Platte basin (e.g., Lower Basin Storage, Existing Storage) have lower scores due to the relatively greater difficulty in providing water supply and flood management benefits for large portions of the basin when storage is located downstream.

It is noted that this comparison is based on the storage concepts and representative storage sites simulated in the MODSIM model. For the SPSS analysis it was necessary to select a limited number of concepts for analysis. Many variations of these concepts would be feasible, including use of different storage options, increased storage, and different operating assumptions. Variations in these storage concept definitions could result in substantial differences in scores exceeding the variability in the scores in Table 20. Furthermore, none of the concepts or individual site designs were optimized at this level because ownership of storage projects is not known. Results in this table should be used only for a high-level comparison of storage concepts. The fact that the comparison yields fairly similar scores for all of the storage concepts suggests that any of them could be candidates for further study in the future under the right circumstances. However, concepts with more storage higher in the basin offer a greater potential for benefits and could be more attractive to a broader variety of potential participants.

## Table 20. Site Evaluation Framework Attribute Values for Storage Concepts

| Attribute | Description | Mainstem Dam | Upper Basin Storage | Mid Basin Storage - North | Mid Basin Storage - South | Lower Basin Storage | Existing Storage | Aquifer Storage West | Aquifer Storage East | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Water Supply Gap Solution | The storage solution could capture water to meet demands in the basin. | High | Medium | Low | Medium | Medium | Medium | Medium | Medium | Based on firm yield |
| Reduce TransBasin Diversions | The storage solution could yield additional supplies from in-basin sources, reducing the need for future transbasin diversions. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Any in-basin yield substitutes for transbasin diversions |
| Multiple Users Supply | The storage solution could supply water to various municipal, industrial, environmental, and agricultural water users in the basin. | High | High | High | High | Low | Medium | High | Medium | Upstream is good. Far downstream with no pipeline is bad. |
| Augmentation Plan Operation Enhancement | The storage solution could be used to optimize the operation of existing or future augmentation plans. | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Any storage concept can release to river so all those above Lower Basin could be operated for augmentation |
| Aquifer Recharge Operations | The storage solution is an aquifer recharge facility, directly delivers water to aquifer recharge facilities, or facilitates conjunctive use. | Medium | Medium | Medium | Medium | Low | Medium | High | High | Lower Basin would be below aquifer recharge facilities |

| Attribute | Description | Mainstem Dam | Upper Basin Storage | Mid Basin Storage - North | Mid Basin Storage - South | Lower Basin Storage | Existing Storage | Aquifer Storage West | Aquifer Storage East | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| ATM Partnership | A storage solution would have available storage for temporary leased water to be stored to help the ATM operations and partnerships. | High | High | High | High | High | High | High | High | All could do this |
| Exchange Potential Enhancement | The storage solution adds storage capacity for interim storage or "leap-frogging" exchanges, or could add streamflows that would increase exchange potential in the river. | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes for all except Lower Basin |
| Recreation Benefit | The storage solution would increase recreational opportunities. | Positive | Positive | Positive | Positive | Positive | Neutral | Neutral | Neutral | Positive for new surface sites; neutral for GW and existing storage sites |
| Enhance Streamflow | The storage solution could deliver water to downstream users via natural channels, enhancing stream flow. | Medium | High | High | High | Medium | Medium | High | High | All could release to South Platte; some could release to tribs |
| Compact Compliance | The storage solution could increase low flows at the state line and reduce frequency of compact calls. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | All would do this |
| Increase Ag Production | The storage solution could help meet the agricultural demand gap in the basin. | Low | Low | Low | Low | High | Low | Low | Low | |

| Attribute | Description | Mainstem Dam | Upper Basin Storage | Mid Basin Storage - North | Mid Basin Storage - South | Lower Basin Storage | Existing Storage | Aquifer Storage West | Aquifer Storage East | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Reduce Buy&Dry | The storage solution could yield additional M&I supplies from in-basin sources, reducing the pressure to buy Ag water rights. | High | Medium | Low | Medium | Medium | Medium | Medium | Medium | Based on firm yield |
| Delivery Water Quality | The storage solution would deliver raw water requiring advance treatment to achieve primary and/or secondary drinking water standards. | Low | Low | Low | Low | Low | Low | Low | Low | All water in SPSS study area would need advanced treatment for potable use |
| Permitting Feasibility | The potential permitting feasibility of site and solution. | Low | Medium | Medium | Medium | Medium | High | High | High | On channel is worst; existing dams and GW are best |
| Water Rights | Measure of the perceived ease in obtaining the water rights/decrees required to operate the solution. | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Set all to medium. All will have some issues. |
| Combined Permitting | Captures the potential increase in permitting complexity for the solutions compared to storage sites alone. | Same | Same | Same | More | More | More | Same | More | Used "More" for concepts requiring longer pipelines to Brighton |
| Estimated Permit Timeline | The probability that permits would be secured quickly. | Low | Medium | Medium | Medium | Medium | High | Medium | Medium | Mainstem dam is longest. Modifications to existing reservoirs is shortest. |

| Attribute | Description | Mainstem Dam | Upper Basin Storage | Mid Basin Storage - North | Mid Basin Storage - South | Lower Basin Storage | Existing Storage | Aquifer Storage West | Aquifer Storage East | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| Combined Impact | Captures the potential increase in environmental impacts for the solutions compared to individual sites alone. | More | More | More | More | More | More | More | More | All require facilities outside the storage footprint |
| River Reach | River reach where the solution is predominantly located. | Kersey-Balzac | Kersey-Balzac | Kersey-Balzac | Kersey-Balzac | Balzac-Julesburg | Balzac-Julesburg | Kersey-Balzac | Balzac-Julesburg | |
| Meet Demands | Ability of a solution to meet demands, either upstream or downstream | US and DS | US and DS | US and DS | US and DS | US and DS | US and DS | US and DS | US and DS | All concepts were formulated to meet demands throughout Basin |
| | | | | | | | | | | |
| **Total Score (Unweighted)** | | **11.5** | **12** | **11** | **11** | **8** | **10** | **12** | **10.5** | |

The ability of the simulated storage concepts to put Colorado's South Platte River water to beneficial use is summarized in Table 21. This analysis used future hydrology, and shows that while a significant amount of water that would otherwise leave the State could contribute to in-state beneficial uses, considerably more storage would be required to use all the State's available South Platte water resources.

**Table 21. Water Leaving the State Under Future Hydrology for Simulated Storage Concepts**

| Storage Concept | Average Annual Water Leaving State (ac-ft) | Percentage of Available Water Contributing to Beneficial Use (1) |
|---|---|---|
| No Storage | 343,000 | - |
| Mainstem Storage | 169,000 | 51% |
| Upper Basin Storage | 279,000 | 19% |
| Mid Basin Storage North | 272,000 | 21% |
| Mid Basin Storage South | 269,000 | 22% |
| Lower Basin Storage | 193,000 | 44% |
| Existing Reservoir Improvements | 173,000 | 50% |
| Designated Groundwater Basin Storage West | 280,000 | 18% |
| Designated Groundwater Basin Storage East | 271,000 | 21% |

Notes:
(1) Includes evaporation losses and other losses which would not be beneficial uses

## SUMMARY OF FINDINGS AND CONCLUSIONS

A preliminary summary of high-level findings and conclusions is presented here. These will be refined and finalized after discussion with the SPSS Review Committee and other stakeholders.

- Not surprisingly, a large mainstem reservoir has the best performance in terms of putting the state's water to beneficial use. However, permitting obstacles may be insurmountable.

- Many off-channel storage options are feasible and can be combined in a wide variety of water supply concepts.

- Aquifer storage projects perform better than surface storage projects of the same size diverting from the same reach of the South Platte. Lower evaporation losses offset assumed losses to the groundwater basin from ASR.

- Storage options lower in the basin tend to be more efficient (better storage:yield ratio) because there is more water available. However they are further from the main demand centers.

- Combinations of storage options can provide significantly more benefit than individual options. A combination of upper basin and lower basin storage concepts rivals the large mainstem dam option for firm yield benefits.

- No feasible storage concepts or reasonable combinations of concepts are capable of putting all the available flow in the lower South Platte River to beneficial use. Therefore as a general principle, more storage will always be “better” in this region in terms of maximizing available supply for basin water users.

- Because nearly all concepts require off-channel storage and diversion from the South Platte River, intake capacity constraints can be important and there are benefits to having multiple off-channel storage projects to minimize the effects of these constraints.

- Aquifer storage options and enlargements and rehabilitations of existing reservoirs tend to score higher than new reservoirs in the multi-criteria ranking process.

- Triple bottom line scores for the storage sites analyzed in this study were fairly similar at this level of analysis without specific information on how the sites would be used in a water supply strategy; thus the triple bottom line scoring process should not be used to eliminate options at this time.

- Any of the storage concepts could be candidates for further study in the future under the right circumstances. However, concepts with more storage higher in the basin generally offer a greater potential for benefits and could be more attractive to a broader variety of potential participants.

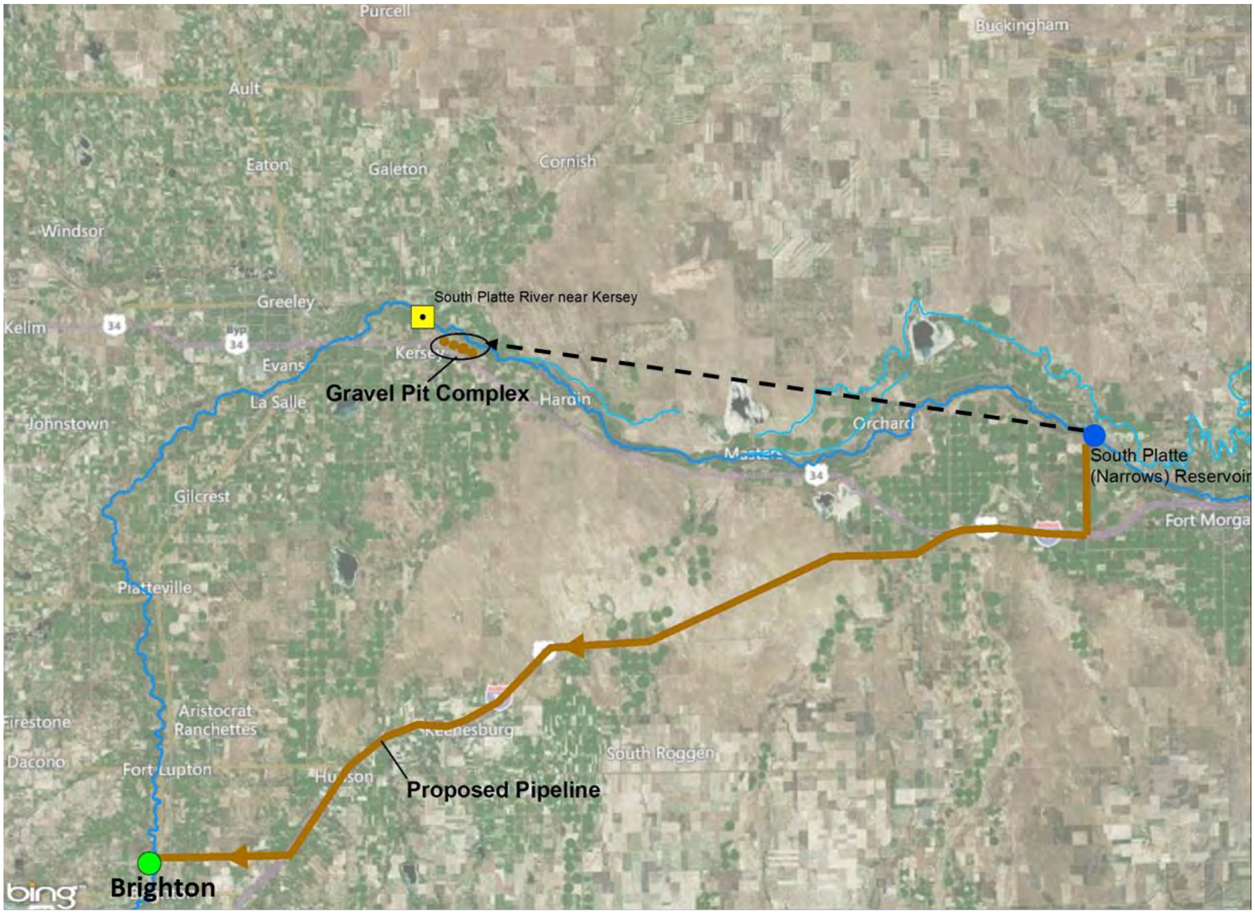
# APPENDIX A

# MAPS OF REPRESENTATIVE STORAGE OPTIONS FOR STORAGE CONCEPTS

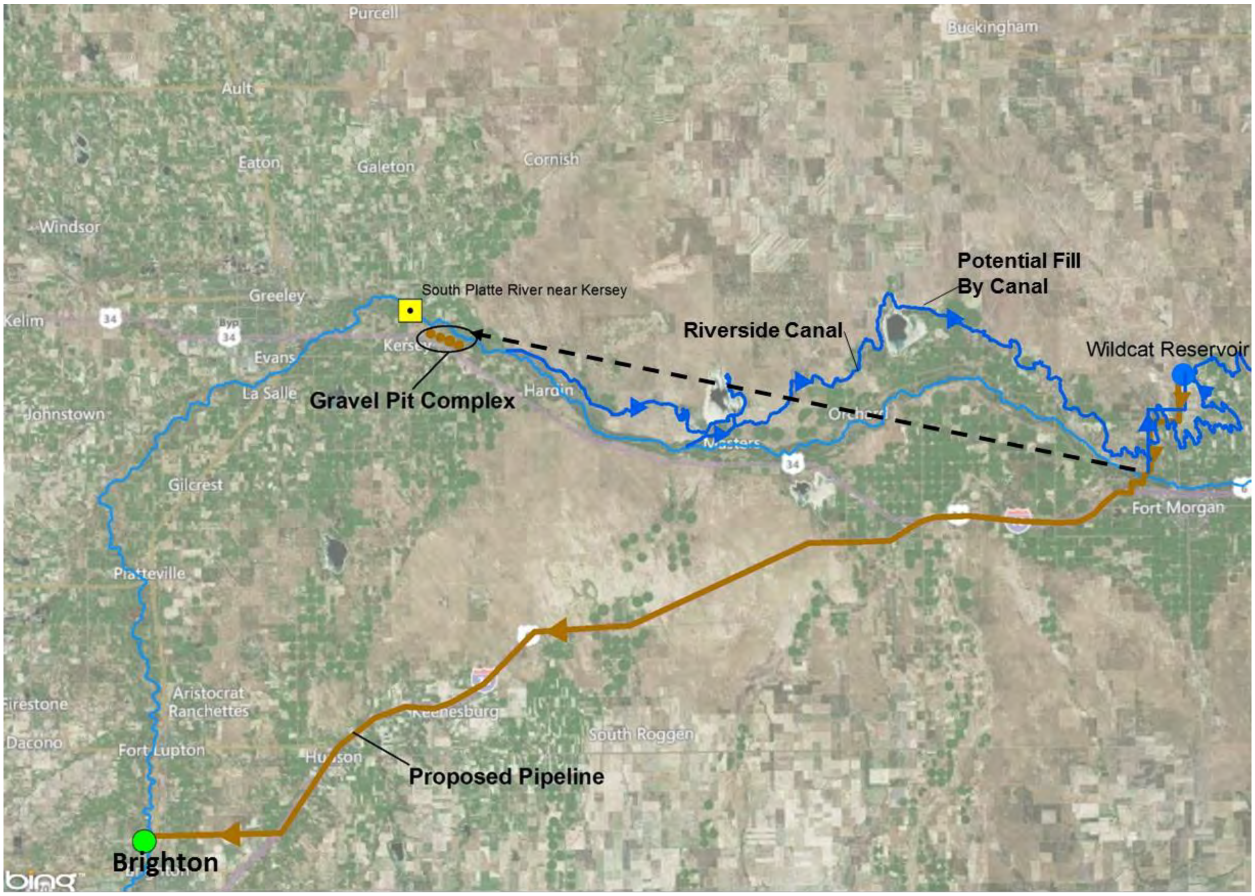
## APPENDIX A – MAPS OF REPRESENTATIVE STORAGE OPTIONS FOR STORAGE CONCEPTS

### Upper Basin Storage – Sandborn Reservoir

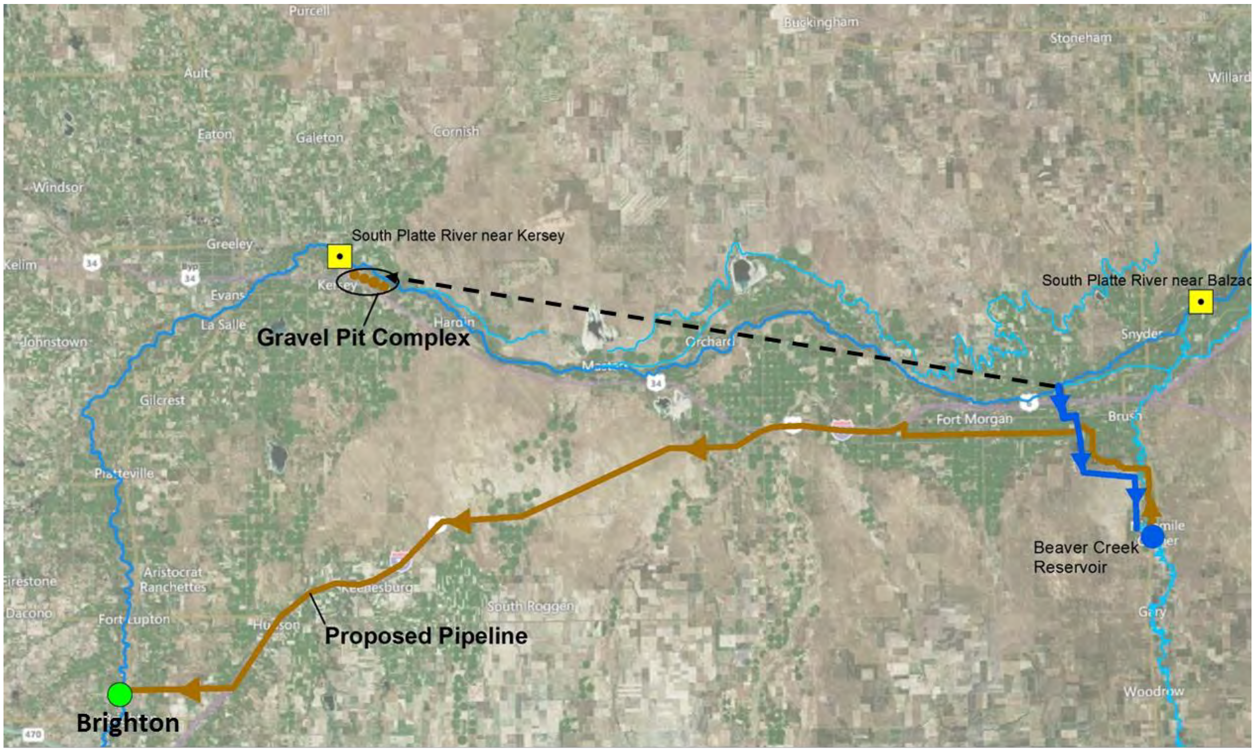
## Mainstem Storage – South Platte (Narrows) Reservoir



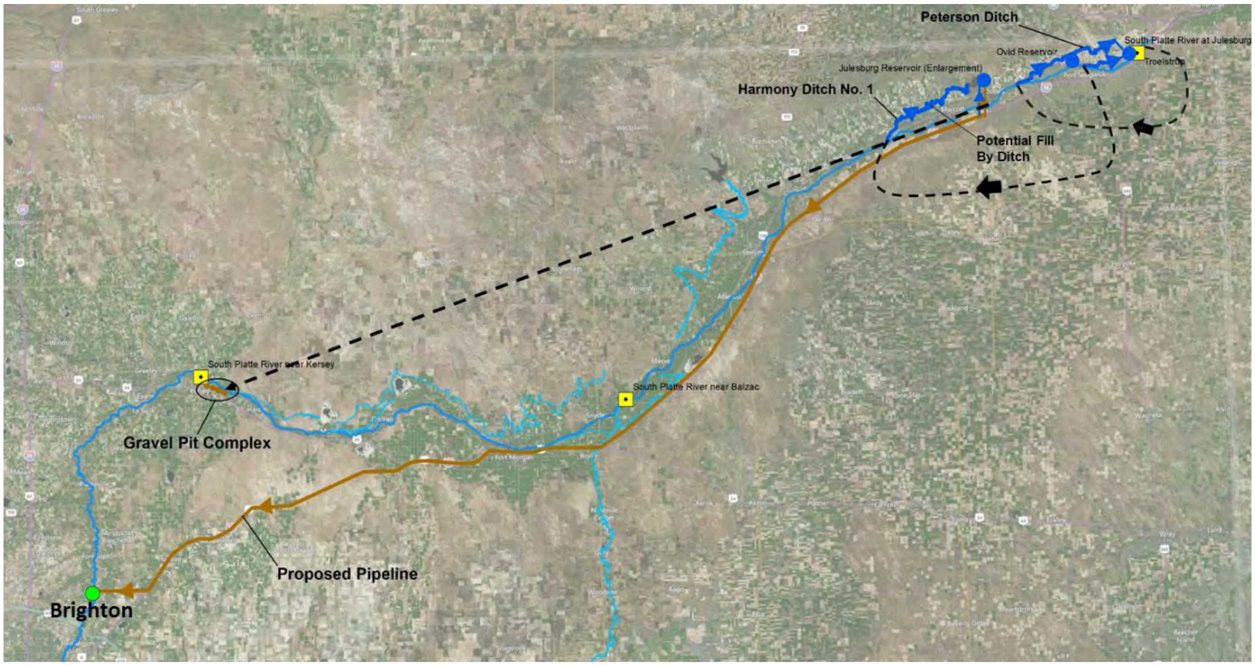
**Mid Basin Storage North – Wildcat Reservoir**



## Mid Basin Storage South – Beaver Creek Reservoir

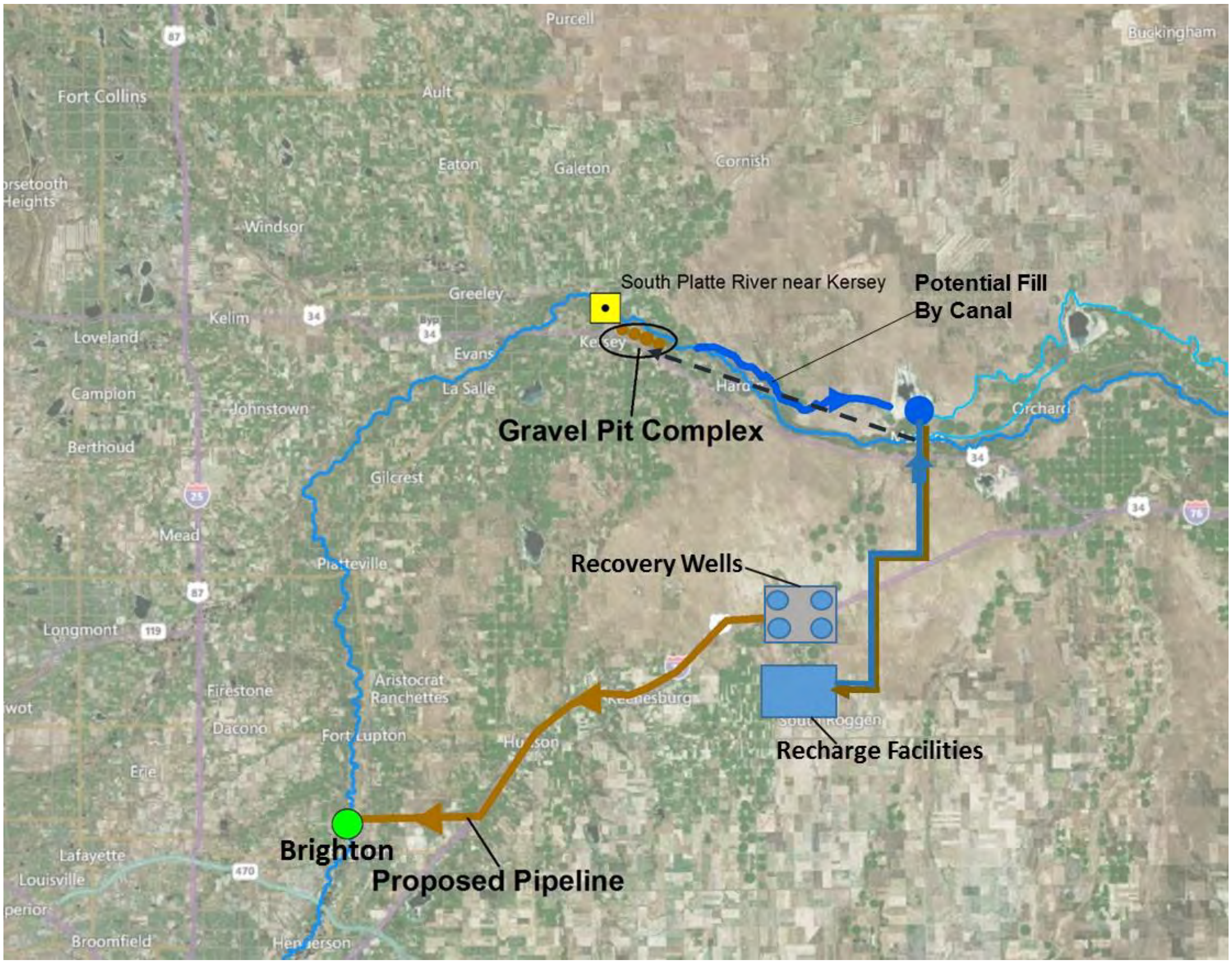


## Lower Basin Storage – Julesburg, Ovid, Troelstrup

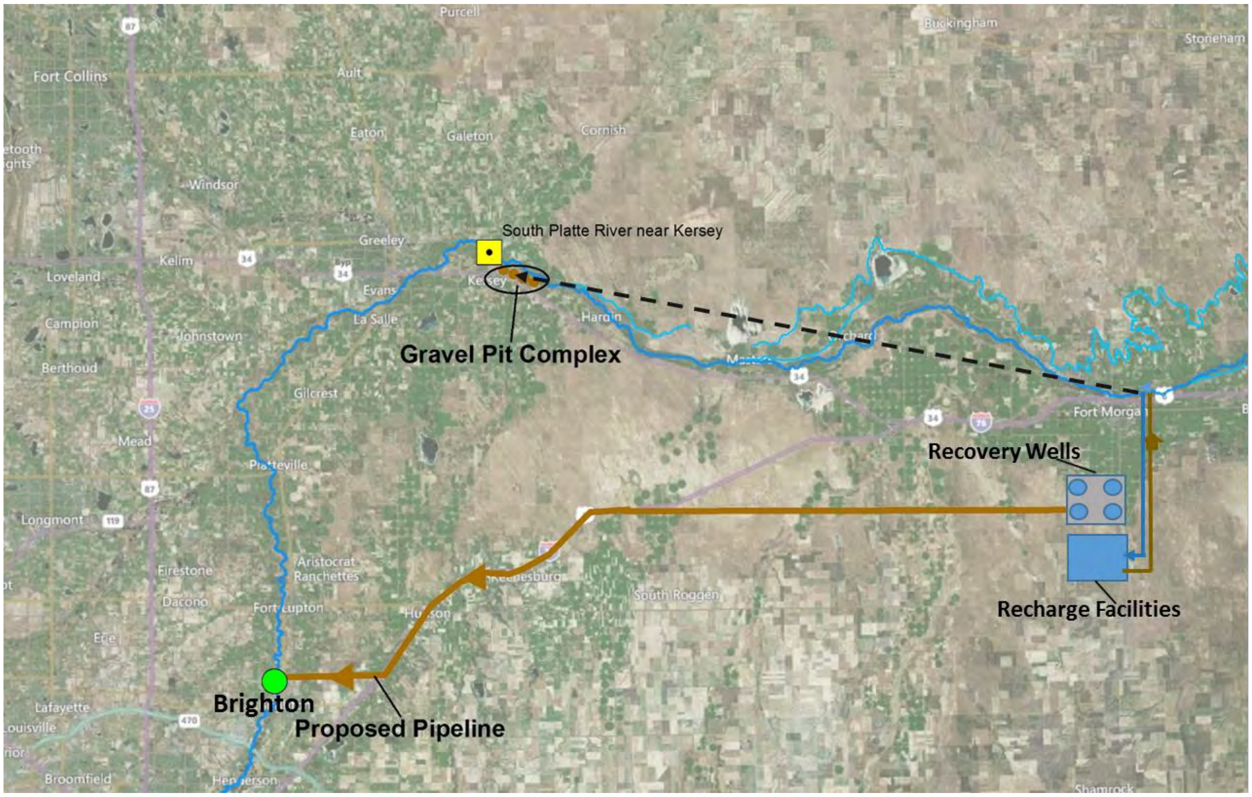


## Existing Reservoir Improvements – Julesburg, North Sterling, Prewitt, Jackson Lake, Riverside

## Designated Groundwater Storage Basin West - Lost Creek Basin



**Designated Basin Groundwater Storage East – Badger/Beaver Basin**

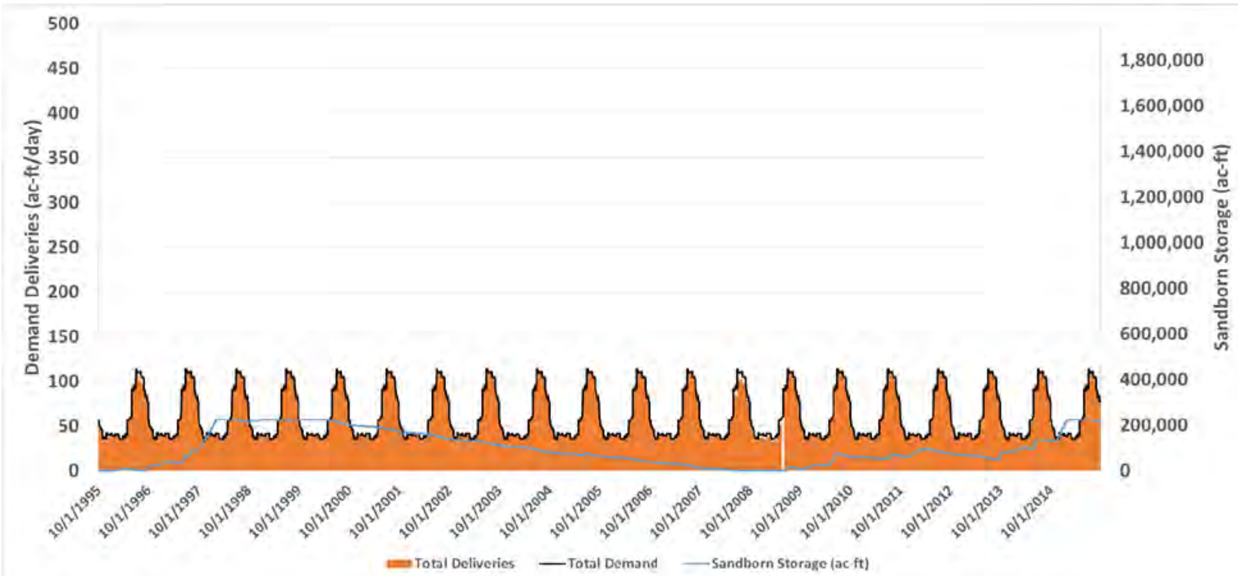


# APPENDIX B

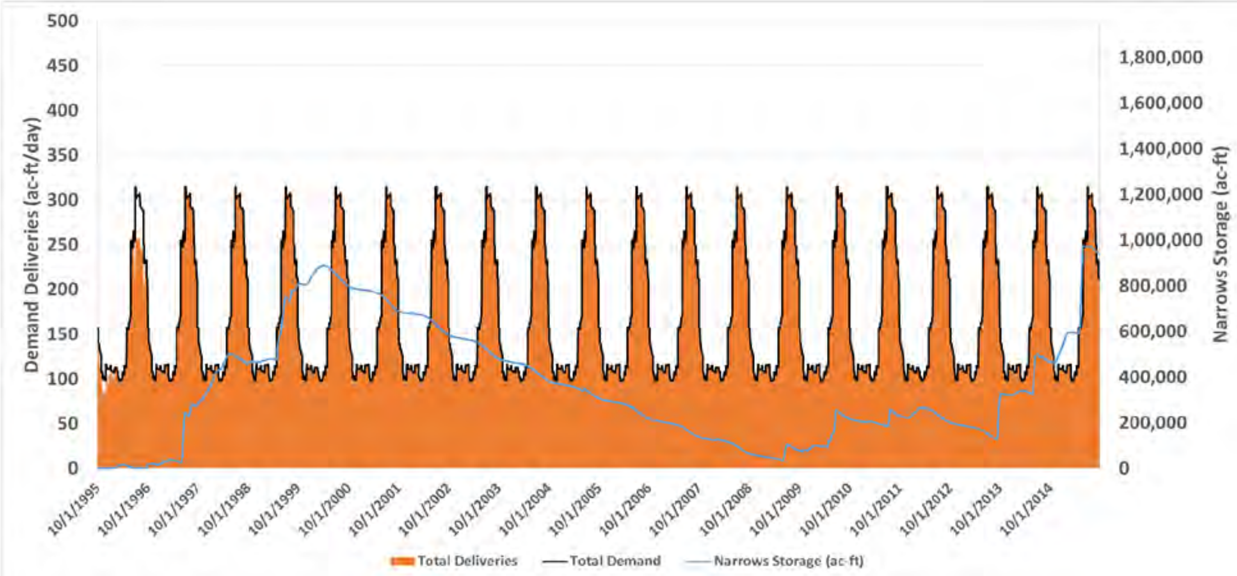
# DEMAND MET AND STORAGE CONTENTS PLOTS FOR STORAGE CONCEPTS

**APPENDIX B – DEMAND MET AND STORAGE CONTENTS PLOTS FOR STORAGE CONCEPTS**

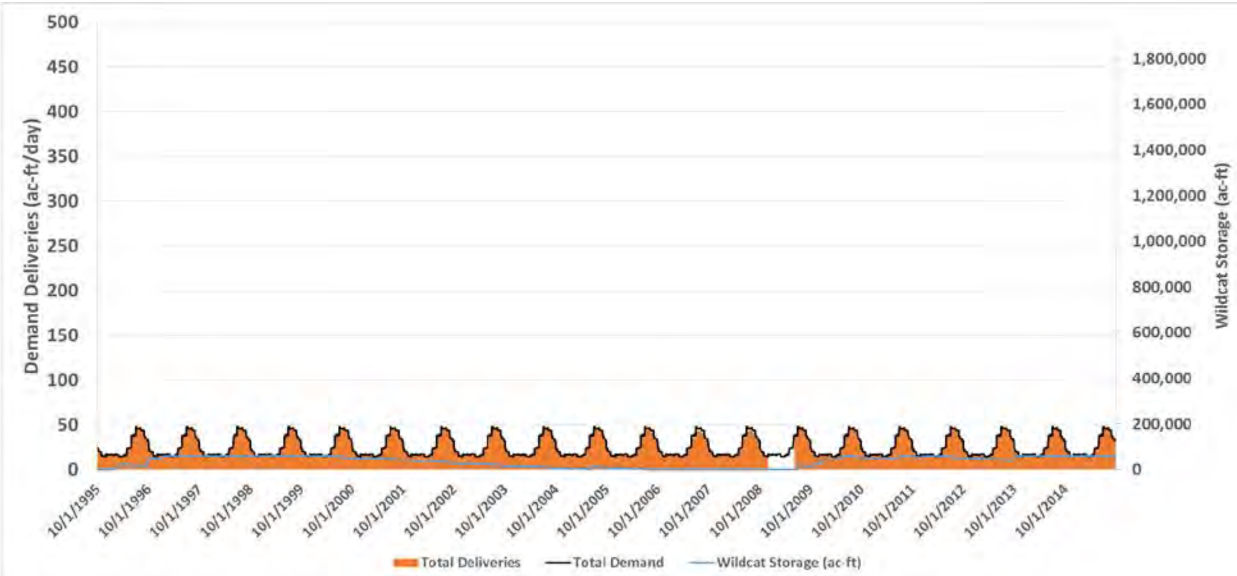
**Upper Basin Storage – With Sandborn Reservoir as representative storage site**



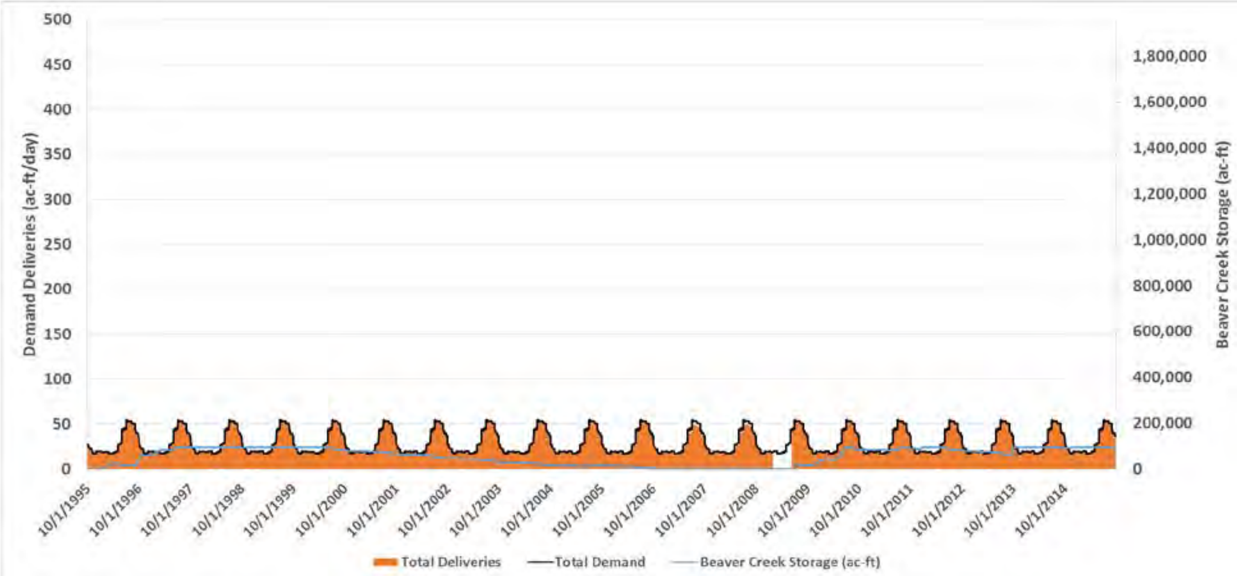
## Mainstem Storage – With South Platte (Narrows) Reservoir as representative storage site



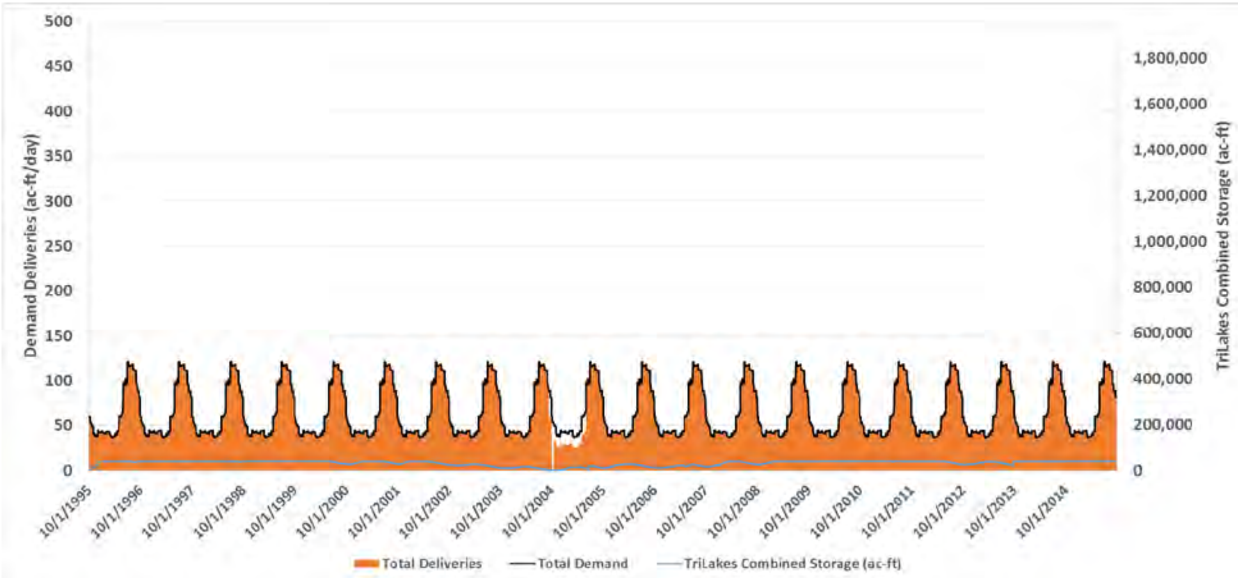
**Mid Basin Storage North – With Wildcat Reservoir as representative storage site**



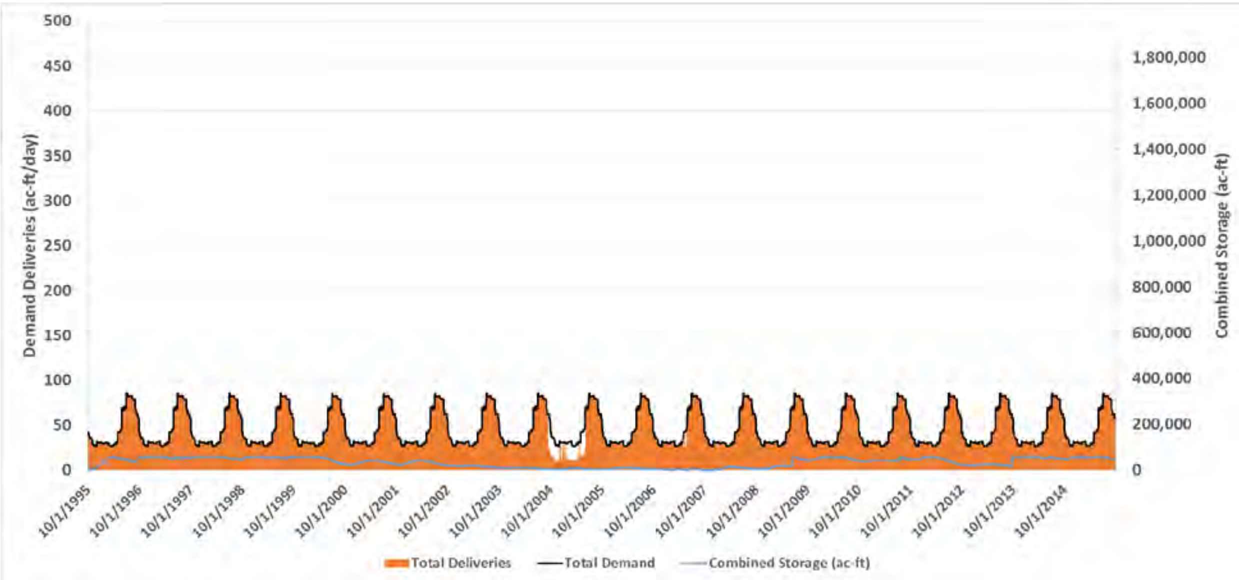
**Mid Basin Storage South – With Beaver Creek Reservoir as representative storage site**



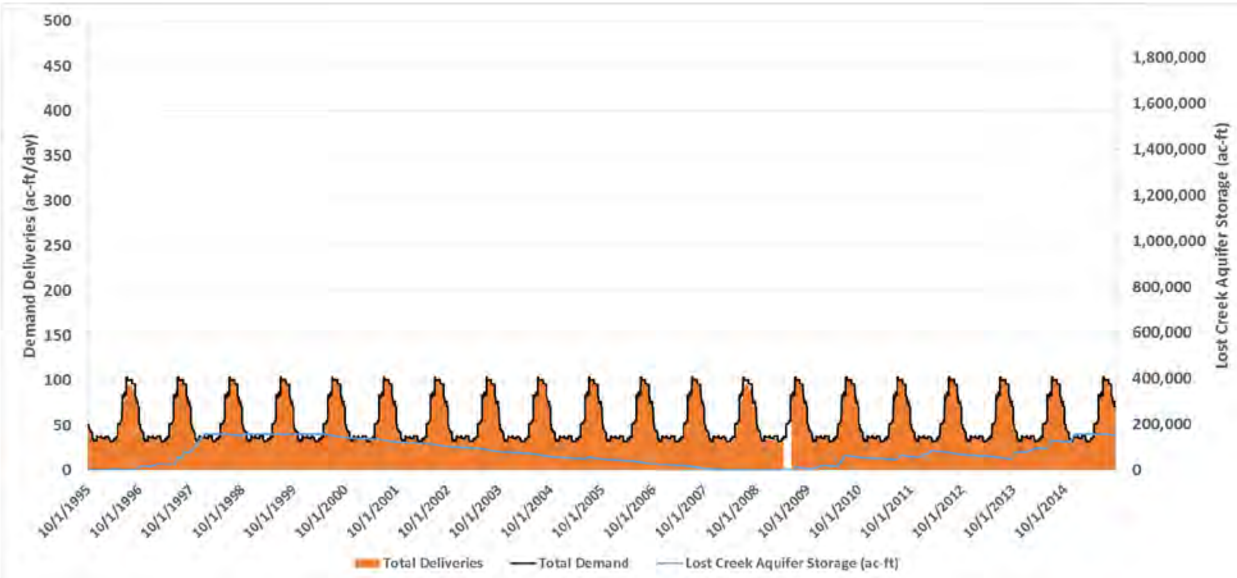
**Lower Basin Storage – With TriLakes Northeast (Julesburg, Ovid, Toelstrup) as representative storage sites**



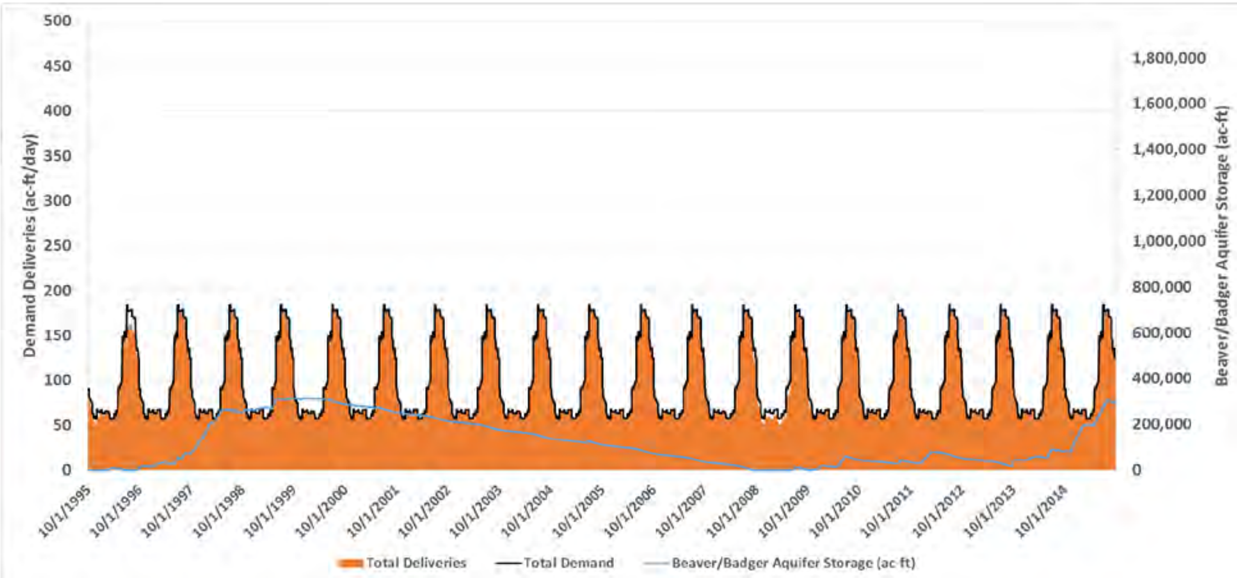
**Existing Reservoir Improvements – With Julesburg, North Sterling, Prewitt, Jackson Lake, Riverside as representative storage sites**



## Designated Groundwater Storage Basin West – With Lost Creek Basin as representative storage site



**Designated Basin Groundwater Storage East – With Badger/Beaver Basin as representative storage site**



# APPENDIX C

# SITE EVALUATION FRAMEWORK ATTRIBUTES AND QUALIFIERS

## APPENDIX C – SITE EVALUATION FRAMEWORK ATTRIBUTES AND QUALIFIERS

| Attribute Name | HB 1256 Connection | Attribute Definition | Applies To | Evaluation Type | Qualifier | Qualifier Score | Qualifier Definition |
|---|---|---|---|---|---|---|---|
| MigratoryBirdHabitat | Enhancing migratory bird habitats | The storage site adds surface water areas that could be used for migratory birds. | Storage Site | Qualitative | Yes | 1 | Storage site has surface water area that improves habitat for migratory birds. |
| | | | | | No | 0 | Storage site does not improve habitat for migratory birds. |
| FloodControlRank | Flood control | The storage site could store flows that would otherwise cause flooding. The potential to reduce flood damages is based on project type, size, and area infrastructure. | Storage Site | Quantitative | High | 1 | On-stream reservoir on the mainstem greater than 50,000 ac-ft, and upstream of urban/municipal areas. |
| | | | | | Medium | 0.5 | On-stream reservoir on a tributary greater than 50,000 ac-ft, and upstream of urban/municipal areas. |
| | | | | | Low | 0 | Less than 50,000 ac-ft, or off-stream reservoir/aquifer recharge, or downstream of all urban/municipal areas. |
| WaterSupplyGapSoln | An increased ability to address Colorado's predicted future water supply-demand gap | The storage solution could capture water to meet demands in the basin. It is estimated based on the average annual yield for the historical period. | Storage Solution | Quantitative | High | 1 | Solution's annual average yield is more than 50,000 acre-feet. |
| | | | | | Medium | 0.5 | Solution's annual average yield is between 10,000 and 50,000 acre-feet. |
| | | | | | Low | 0 | Solution's annual average yield is less than 10,000 acre-feet. |
| ReduceTransBasinDiversions | Reducing present and future needs to import water from one basin to another water basin through a transbasin diversion | The storage solution could yield additional supplies from in-basin sources, reducing the need for future transbasin diversions beyond those identified in regional or state plans. | Storage Solution | Qualitative | Yes | 1 | Storage solution would reduce the need for future transbasin diversions beyond those identified in regional or state plans. |
| | | | | | No | 0 | Storage solution would not reduce the need for transbasin diversions. |
| MultipleUsersSupply | Increased municipal, industrial, environmental, and agricultural water supply | The storage solution could supply water to various municipal, industrial, environmental, and agricultural water users in the basin. | Storage Solution | Qualitative | High | 1 | Storage solution easily supplies water to many municipal, industrial, environmental, and agricultural water users. |
| | | | | | Medium | 0.5 | Storage solution supplies water to a few municipal, industrial, environmental, and agricultural water users, or can supply many users with more difficulty. |
| | | | | | Low | 0 | Storage solution supplies water to only one water user. |
| AugPlanOperationEnhancement | not applicable | The storage solution could be used to optimize the operation of existing or future augmentation plans. | Storage Solution | Qualitative | Yes | 1 | Operation of this storage solution would enhance the operation of existing and future augmentation plans. |
| | | | | | Maybe | 0.5 | There is potential for this storage solution to enhance operation of existing and future augmentation plans. |

| Attribute Name | HB 1256 Connection | Attribute Definition | Applies To | Evaluation Type | Qualifier | Qualifier Score | Qualifier Definition |
|---|---|---|---|---|---|---|---|
| | | | | | No | 0 | There is limited to no opportunity for this storage solution to enhance operation of existing and future augmentation plans. |
| AquiferRechargeOperations | Providing storage water rights that allow for aquifer recharge | The storage solution is an aquifer recharge facility, directly delivers water to aquifer recharge facilities, or facilitates conjunctive use. | Storage Solution | Qualitative | High | 1 | Storage solution includes an aquifer recharge facility. |
| | | | | | Medium | 0.5 | Storage solution could deliver water to an aquifer recharge facility. |
| | | | | | Low | 0 | Storage solution would not benefit aquifer recharge. |
| ATMPartnership | Providing the ability to use alternative agricultural transfer methods in conjunction with water storage | A storage solution would have available storage for temporary leased water to be stored to help the ATM operations and partnerships. ATM partnership potential is based on average available storage. | Storage Solution | Quantitative | High | 1 | For a reservoir sized to capture the available flows, on average, site has 10,000 ac-ft of available storage. |
| | | | | | Low | 0 | For a reservoir sized to capture the available flows, on average, site has less than 10,000 ac-ft of available storage. |
| ExchPotentialEnhancement | Enhancing exchange potential | The storage solution adds storage capacity for interim storage or "leap-frogging" exchanges, or could add streamflows that would increase exchange potential in the river. | Storage Solution | Qualitative | Yes | 1 | The storage solution would add interim storage or add streamflows to facilitate or increase exchange potential. |
| | | | | | No | 0 | The storage solution would not add interim storage and would not add streamflows to facilitate or increase exchange potential. |
| RecreationBenefit | Recreational benefits | The storage solution would increase recreational opportunities. | Storage Solution | Qualitative | Positive | 1 | Construction of this storage solution would increase recreational opportunities compared to pre-construction condition. |
| | | | | | Neutral | 0 | Construction of this storage solution would not change recreational opportunities compared to pre-construction condition. |
| | | | | | Negative | -1 | Construction of this storage solution would decrease recreational opportunities compared to pre-construction condition. |
| EnhanceStreamflow | Improving instream flow | The storage solution could deliver water to downstream users via natural channels during dry periods, enhancing stream flow. | Storage Solution | Qualitative | High | 1 | Solution could deliver water to downstream users via South Platte River and natural channels during dry periods, thereby enhancing streamflows. |
| | | | | | Medium | 0.5 | Solution could deliver water to downstream users via South Platte River, thereby enhancing streamflows |
| | | | | | Low | 0 | Solution could not deliver water to downstream users via natural channels during dry periods, little to no opportunity for streamflow enhancement |

| Attribute Name | HB 1256 Connection | Attribute Definition | Applies To | Evaluation Type | Qualifier | Qualifier Score | Qualifier Definition |
|---|---|---|---|---|---|---|---|
| CompactCompliance | Improving water compact compliance | The storage solution could increase low flows at the state line and reduce frequency of compact calls. Note that the storage solution would not be operated to meet compact requirements, but return flows from additional supplies could increase flows at the stateline. | Storage Solution | Qualitative | Yes | 1 | Would decrease frequency of compact calls. |
| | | | | | No | 0 | Would not decrease frequency of compact calls. |
| IncreaseAgProduction | Increased agricultural production | The storage solution could capture water to meet the agricultural demand gap in the basin. It is estimated based on the average annual yield for the historical period. | Storage Solution | Quantitative | High | 1 | Project would provide water greater than the agricultural demand (gap) in its demand reach, and could supply agricultural water to other demand reaches. |
| | | | | | Medium | 0.5 | Project would provide water equal to or greater than the agricultural demand (gap) in its demand reach. |
| | | | | | Low | 0 | Project would provide less water than the projected agricultural demand (gap) in its demand reach. |
| ReduceBuyDry | Reducing reliance on the practice of buying agricultural water and drying up the agricultural land served by the water | The storage solution could yield additional supplies from in-basin sources, reducing the pressure to buy water rights and dry the land. This attribute captures the ability of the site to provide additional water to M&I demands. | Storage Solution | Quantitative | High | 1 | Annual average delivery to M&I users would be more than 50,000 acre-feet. |
| | | | | | Medium | 0.5 | Annual average delivery to M&I users would be between 10,000 and 50,000 acre-feet. |
| | | | | | Low | 0 | Annual average delivery to M&I users would be less than 10,000 acre-feet. |
| WildlifeHabitatImpact | Improving wildlife habitats | The storage site could impact wildlife habitats. The potential degree of impact is based on aerial imagery review. | Storage Site | Qualitative | Positive | 1 | Construction will positively impact wildlife habitat compared to pre-construction condition. |
| | | | | | Neutral | 0 | Construction will not change the wildlife habitat conditions at the site compared to pre-construction conditions. |
| | | | | | Negative | -1 | Construction will negatively impact wildlife habitat at the site compared to pre-construction conditions. |
| CriticalHabitat_ESA | Enhancing compliance with endangered species habitat regulations | A Designated Critical Habitat (DCH) of a species would be present at the storage site. DCH is an area of habitat believed to be essential to a federal species. The attribute is based on a comparison of site(s) to the DCH as mapped by US Fish & Wildlife. | Storage Site | Qualitative | Yes | -1 | The site would be located within Designated Critical Habitat. |
| | | | | | No | 0 | The site would be not located within Designated Critical Habitat. |
| NWI | not applicable | Wetlands would be present at the site, and is based on the National Wetlands Inventory (NWI) data set. | Storage Site | Qualitative | High | -1 | There would be more than 100 acres of wetlands at the site. |
| | | | | | Medium | -0.5 | There would be more than 10 acre but less than 100 acres of wetlands at the site. |

| Attribute Name | HB 1256 Connection | Attribute Definition | Applies To | Evaluation Type | Qualifier | Qualifier Score | Qualifier Definition |
|---|---|---|---|---|---|---|---|
| | | | | | Low | 0 | There would be less than 10 acre wetlands present at the site. |
| WildlifeSpeciesImpact | Enhancing compliance with endangered species habitat regulations. | The storage site could impact wildlife. The potential degree of impact is based on aerial imagery review, CO county lists, and USFWS IPaC Planning System's list of T&E species. | Storage Site | Qualitative | Positive | 1 | Construction will positively impact wildlife species compared to pre-construction condition. |
| | | | | | Neutral | 0 | Construction will not impact wildlife species at the site compared to pre-construction conditions. |
| | | | | | Negative | -1 | Construction will negatively impact wildlife species at the site compared to pre-construction conditions. |
| EvapPotential | not applicable | The storage site could lose water to evaporation. It is assumed that surface water storage sites will have similar evaporation rates while aquifer storage sites will have minimal evaporation loss. | Storage Site | Qualitative | High | 0 | Surface water storage would have high potential for evaporation loss. |
| | | | | | Low | 1 | Aquifer storage would have low potential to evaporation loss. |
| SourceWaterQual | not applicable | The existing or source water supply would have parameters on 303(d) or M&E list. | Storage Site | Qualitative | Yes | 0 | Existing or source water for the project site has parameters on the 303(d) list. |
| | | | | | No | 1 | The state has not determined that the existing or source water quality does not meet standards. |
| | | | | | Unknown | 0.5 | Existing or source water for the project site has parameters on the M&E list. |
| DeliveryWaterQual | not applicable | The storage solution would deliver raw water at various quality levels. Water quality is based on whether advance treatment (Ultrafiltration or reverse osmosis) is needed to achieve primary and/or secondary drinking water standards. | Storage Solution | Qualitative | High | 1 | No advanced treatment would be needed after water is withdrawn to meet primary and/or secondary drinking water standards. |
| | | | | | Low | 0 | Advanced treatment would be needed after water is withdrawn to achieve primary and/or secondary drinking water standards. |
| Scalability | not applicable | The storage solution could be enlarged by constructing it in phases, triggered by need thresholds or change in future conditions. In general, large Infrastructure projects like dams are less scalable than pump stations. Typical of aquifer storage with facilities that can be enlarged by adding pumps or parallel pipelines. | Storage Site | Qualitative | High | 1 | Infrastructure could be added to the project that would increase the storage capacity or yield. |
| | | | | | Medium | 0.5 | There are alternatives for enlargement and yield increase, with potential high cost (e.g., engineering and retrofitting). |
| | | | | | Low | 0 | Options to enlarge the storage and yield of the project have not been identified. |
| FederalNexus | not applicable | A federal nexus exists if a project requires a federal permit or federal funding would be used for the project. | Storage Site | Qualitative | Yes | 0 | Would have a federal nexus. |
| | | | | | No | 1 | Would not have a federal nexus. |
| | | | | | Maybe | 0.5 | There is potential for a federal nexus. |
| PermittingFeasibility | not applicable | The potential permitting feasibility of site and solution. | Storage Solution | Qualitative | High | 1 | High probability that the storage solution could be permitted. |
| | | | | | Medium | 0.5 | Some risk have been identified, however the storage solution could reasonable be permitted. |

| Attribute Name | HB 1256 Connection | Attribute Definition | Applies To | Evaluation Type | Qualifier | Qualifier Score | Qualifier Definition |
|---|---|---|---|---|---|---|---|
| | | | | | Low | 0 | It is unlikely that the storage solution could be permitted effectively. |
| WaterRights | not applicable | Measure of the perceived ease in obtaining the water rights/decrees required to operate the storage solution. | Storage Solution | Qualitative | High | 1 | The water rights necessary to operate the storage solution would be fairly straight forward. |
| | | | | | Medium | 0.5 | There would be some complexity and perceived opposition to the project, but it would be possible to obtain water rights. |
| | | | | | Low | 0 | There would be a high degree of complexity and perceived opposition to this project, and there may be challenges to obtaining the water rights. |
| CombinedPermitting | not applicable | Captures the potential increase in permitting complexity (i.e., cost and time) for the solutions in cases that the permitting of the combined solution result in additional efforts. | Storage Solution | Qualitative | Same | 1 | The permitting of the solution would not be more complex than permitting the individual elements of the solution. |
| | | | | | More | 0 | Permitting complexity would increase when permitting the storage solution. |
| LandOwner | not applicable | Type of land ownership for the storage site. This is important to determine feasibility and cost. [Private, Public, etc.] | Storage Site | Qualitative | Private | 1 | The storage site would be located only in private land. |
| | | | | | Public | 0.5 | The storage site would be fully or partially located in public land. |
| | | | | | Historical | 0 | The storage site would be fully or partially located in a historic denominated site. |
| Partnerships_Consumptive | not applicable | For sites previously identified, this field captures if current site idea owners have expressed willingness to consider partnerships that will result in additional storage for the basin. For new sites, without idea owner, the default will be YES to partnerships. | Storage Site | Qualitative | Yes | 1 | Idea owners have expressed interest to consider partnerships that would result in additional storage for the basin. |
| | | | | | No | 0 | Idea owners have expressed no interest in partnerships. |
| | | | | | Unknown | 0.5 | There is no current information whether or not partnership opportunities would be considered for this site. |
| Partnerships_NonConsumptive | not applicable | Capture idea-owners interest in exploring partnerships to provide non-consumptive benefits. | Storage Site | Qualitative | Yes | 1 | Idea owners have expressed interest to consider partnerships that would result in benefits to non-consumptive uses. |
| | | | | | No | 0 | Idea owners have expressed no interest in partnerships for non-consumptive uses. |
| | | | | | Unknown | 0.5 | There is no current information for this site whether or not partnership opportunities would be considered for this site. |
| EstPermitTimeline | not applicable | The probability that permits would be secured quickly. | Storage Solution | Qualitative | High | 1 | Permitting would be less than five years. |
| | | | | | Medium | 0.5 | Permitting could be 5 years to 15 years. |
| | | | | | Low | 0 | Permitting could be longer than 15 years. |

| Attribute Name | HB 1256 Connection | Attribute Definition | Applies To | Evaluation Type | Qualifier | Qualifier Score | Qualifier Definition |
|---|---|---|---|---|---|---|---|
| MigratoryBirdImpact | not applicable | The potential degree of impact to migratory bird habitat based on aerial imagery review. | Storage Site | Qualitative | Positive | 1 | Construction of this water project will positively impact migratory bird habitat compared to pre-construction condition. |
| | | | | | Neutral | 0 | Construction of this water project will not change the migratory bird habitat conditions at the site. |
| | | | | | Negative | -1 | Construction of this water project will negatively impact migratory bird habitat. |
| SPWRAPPotential | not applicable | If a Federal Nexus exists, does the new water related activity meet all project requirements of the PRRIP and is there potential for the benefit of streamlined permitting by inclusion in SPWRAP? | Storage Site | Qualitative | Yes | 1 | All PRRIP project requirements would be met and there is potential for streamlined permitting by inclusion in SPWRAP. |
| | | | | | No | 0 | PRRIP project requirements would not be met and there is no potential for streamlined permitting by inclusion in SPWRAP. |
| BaldEagleNestsImpacts | not applicable | Bald Eagle nest sites (active and inactive) are recorded (in the CPW dataset) near the site. | Storage Site | Qualitative | High | 0 | Colorado Parks and Wildlife has identified active Bald Eagle nest site(s) near proposed project site. |
| | | | | | Medium | 0.5 | Colorado Parks and Wildlife has identified destroyed, inactive, or roost area for Bald Eagle near the proposed project site. |
| | | | | | Low | 1 | No Bald Eagle nest sites have been identified within or adjacent to the proposed project site. On-site investigation required to confirm. |
| ExistingWaterQuality | not applicable | An existing storage site proposed for enlargement, rehabilitation, or restoration that has parameters on 303(d) or M&E list | Storage Site | Qualitative | Yes | 0 | Existing water for the project site has parameters on the 303(d) list. |
| | | | | | No | 0 | The state has not determined that the existing water quality does not meet standards. |
| | | | | | Unknown | 0.5 | Existing water for the project site has parameters on the M&E list. |
| | | | | | Not Applicable | 0 | Not an existing site. |
| SolutionCompatibility | not applicable | A storage site typically is able to meet demands in its proximity (demand segment), but could meet additional demands farther from the site if incorporated into a conveyance or exchange water supply solution. | Storage Site | Qualitative | Yes | 1 | The site could be incorporated into one or more water supply solutions to meet additional demands outside the site's demand segment. |
| | | | | | No | 0 | The site could not be incorporated into a solution to meet additional demands outside the site's demand segment. |
| CombinedImpact | not applicable | Captures the potential increase in environmental impacts for the solutions in cases that require construction of pipelines and other infrastructure not within the site footprint. | Storage Solution | Qualitative | Same | 1 | The concepts involved in the solution do not add additional environmental impacts outside of individual site footprints. |
| | | | | | More | 0 | The concepts involved in the solution add additional environmental impacts outside of the footprints of the individual sites. |

| Attribute Name | HB 1256 Connection | Attribute Definition | Applies To | Evaluation Type | Qualifier | Qualifier Score | Qualifier Definition |
|---|---|---|---|---|---|---|---|
| SoilType | not applicable | Is the soil type within 1 mile of the site compatible with the desired use (i.e. Hydrologic Soil Group A for aquifer storage or Hydrologic Soil Group B, C, or D for surface water storage) | Storage Site | Qualitative | Yes | 1 | All soil within 1 mile of the site is classified as Hydrologic Soil Group A for Aquifer storage or B, C, or D for surface storage. |
| | | | | | No | 0 | Within 1 mile of the site, there is an occurrence of soil type that is not compatible with the desired use. |
| SiteFillMethod | not applicable | Can the storage site be filled by gravity or will pumping be required? | Storage Site | Qualitative | Pumping | 0 | It is not possible to fill this site by gravity using existing facilities. Pumping is required or construction of new facilities is required. |
| | | | | | Gravity Fill | 1 | It is possible to fill this site solely by the use of gravity through existing facilities. No pumping would be required. |
| Constructability | not applicable | Captures engineering feasibility/constructability. | Storage Site | Qualitative | High | 1 | No documented engineering constructability issues or complications. |
| | | | | | Low | 0 | Potential for engineering constructability issues or complications have been documented. |
| RegionalIntegration | not applicable | Opportunities may exist to operate the site cooperatively with nearby sites, either new or existing. | Storage Site | Qualitative | Yes | 1 | There is potential to operate this site in cooperation with nearby sites. |
| | | | | | No | 0 | There is no opportunity to coordinate with nearby sites or no other sites are near enough for cooperation. |
| RiverReach | not applicable | Which river reach is the solution predominantly in? | Storage Solution | Qualitative | Denver-Kersey | 0 | The solution is predominantly in the reach between South Platte at Denver and South Platte at Kersey gages. |
| | | | | | Kersey-Balzac | 0 | The solution is predominantly in the reach between South Platte at Kersey and South Platte near Balzac gages. |
| | | | | | Balzac-Julesburg | 0 | The solution is predominantly in the reach between South Platte near Balzac and South Platte at Julesburg gages. |
| MeetDemands | not applicable | Describes the ability of a solution to meet demands, either upstream or downstream | Storage Solution | Qualitative | Within | 0 | The solution is able to meet demands within its own reach. |
| | | | | | US or DS | 0.5 | The solution is able to meet demands in upstream reaches or downstream reaches. |
| | | | | | US and DS | 1 | The solution is able to meet demands in both upstream and downstream reaches. |
| | | | | | None | -1 | The solution is not able to meet demands in any reach. |
| OilAndGasWells | not applicable | | Storage Site | Qualitative | None | 1 | No oil and gas wells were identified at or near the site location |

| Attribute Name | HB 1256 Connection | Attribute Definition | Applies To | Evaluation Type | Qualifier | Qualifier Score | Qualifier Definition |
|---|---|---|---|---|---|---|---|
| | | Indicates presence of oil and gas wells at or near the site location upon inspection of satellite imagery | | | Low | 0.5 | Few oil and gas wells were identified at or near the site location |
| | | | | | High | 0 | Many oil and gas wells were identified at or near the site location |
| UseExistInfrastructure | not applicable | Does infrastructure exist that can be used to fill the storage site? | Storage Site | Qualitative | Yes | 1 | Infrastructure exists that could be used to fill the storage site |
| | | | | | No | 0 | Infrastructure does not exist that could be used to fill the storage site |
| EaseToUseExisting | not applicable | If infrastructure exists, how easy will it be to utilize in order to fill the storage site? | Storage Site | Qualitative | Easy | 1 | Existing infrastructure could be used as-is or with minor modifications. |
| | | | | | Medium | 0.5 | Some modifications would be necessary in order to use the existing infrastructure |
| | | | | | Difficult | 0 | Major modifications would be necessary in order to use the existing infrastructure |
| | | | | | N/A | 0 | Infrastructure does not exist. |

# APPENDIX D

# SITE EVALUATION FRAMEWORK ENTRIES

# Sites Evaluation

Site ID: 163

## Badger/Beaver Creek

Category: Aquifer Storage

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 9.5

☐ Site Screened Out

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 311,000 ac-ft

Total Capacity 311,000 ac-ft

Inundated Area: 0 acres

Evaporation Potential: Low

Soil Type Yes

Fill Method: Gravity Fill

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: No

Existing Water Quality: No

Source Water Quality: No

Constructability: High

Scalability: Medium

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat No

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Low

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Neutral

Wildlife Habitat Impact: Neutral

Migratory Bird Impact Neutral

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: Low

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: No

Notes: New Storage = 1,555,910 Acre-ft in unsaturated zone * 0.2 Aquifer Porosity. Alluvial deposits in National Forest Land and Privately Owned Ranch land?. Keep this site- ranked favorably on CGS evaluation.

Site ID: 519

# Beaver Creek Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 8.5

☐ Site Screened Out

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 95,000 ac-ft

Total Capacity 95,000 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type No

Fill Method: Pumping

Land Owner Private

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($) 0

Cost Estimate Year 0

## BENEFITS (Site- Level)

Flood Control Rank: Medium

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

| | |
|---|---|
| National Wetlands Inventory: | High |
| Critical Habitat in Environmentally Sensitive Areas: | No |
| Wildlife Species Impact: | Neutral |
| Wildlife Habitat Impact: | Neutral |
| Migratory Bird Impact | Neutral |
| Bald Eagle Nests Impact: | Low |
| Presence of Oil and Gas Wells: | None |

## PERMITTING

| | |
|---|---|
| Federal Nexus: | Yes |
| SPWRAP Potential: | Yes |

Notes:

Site ID: 517

# Fremont Butte

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 6.5

☐ Site Screened Out

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 76,000 ac-ft

Total Capacity 76,000 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type No

Fill Method: Pumping

Land Owner Private

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Medium

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Low

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: From Workshop #1 conversation. Land owner from GIS shapefile. For soils- site location may not be exact, 1.5 mile buffer used

Site ID: 263

# Greasewood Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 6.5

☐ Site Screened Out — Second Screening- Eliminated in favor of Point of Rocks/ Sandborn. Too far fro

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 67,268 ac-ft

Total Capacity 67,268 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type No

Fill Method: Pumping

Land Owner Private

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Medium

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

| | |
|---|---|
| National Wetlands Inventory: | Low |
| Critical Habitat in Environmentally Sensitive Areas: | No |
| Wildlife Species Impact: | Negative |
| Wildlife Habitat Impact: | Negative |
| Migratory Bird Impact | Negative |
| Bald Eagle Nests Impact: | Low |
| Presence of Oil and Gas Wells: | None |

## PERMITTING

| | |
|---|---|
| Federal Nexus: | Yes |
| SPWRAP Potential: | Yes |

Notes: Land owner from GIS shapefile. For soils- 1.5 mile buffer used

Site ID: 9

# Hardin Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 5

☐ Site Screened Out — Second Screening- Screened out in favor of Narrows. Both sites have same exch

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 400,000 - 671,000 ac-ft

Total Capacity: 400,000 - 671,000 ac-ft

Inundated Area: 16,500 acres

Evaporation Potential: High

Soil Type: No

Fill Method: Gravity Fill

Land Owner: Private

Reservoir Owner: Northern Colorado Water Conservancy Distric

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: Low

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Easy

## COST (Site- Level)

Storage Unit Cost ($/ac-ft): 675

Total Storage Cost ($): 270,000,000

Cost Estimate Year: 1982

## BENEFITS (Site- Level)

Flood Control Rank: High

Migratory Bird Habitat: Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

| | |
|---|---|
| National Wetlands Inventory: | High |
| Critical Habitat in Environmentally Sensitive Areas: | No |
| Wildlife Species Impact: | Negative |
| Wildlife Habitat Impact: | Negative |
| Migratory Bird Impact | Negative |
| Bald Eagle Nests Impact: | High |
| Presence of Oil and Gas Wells: | High |

## PERMITTING

| | |
|---|---|
| Federal Nexus: | Yes |
| SPWRAP Potential: | No |

Notes: See (Dames & Moore, 1982). Difference in capacity due to with and without a flood control pool of 200,000 ac-ft. Cost estimate based on smaller reservoir size. Larger size = $298,000. For soils- 1.5 mile buffer used. NWI: 338 acres (PEM, PFO, and PSS).

Site ID: 89

# Jackson Lake Reservoir

Category: Storage Restoration

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 9.5

☐ Site Screened Out

## FEATURES

Existing Capacity: 25,000 ac-ft

New Capacity 10,000 ac-ft

Total Capacity 35000 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type No

Fill Method: Gravity Fill

Land Owner Public

Reservoir Owner: Jackson Lake Reservoir & Irrigation Company

Consumptive Partnerships: Yes

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Yes

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Easy

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Low

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Neutral

Bald Eagle Nests Impact: Medium

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: Potential partnerships to recapture storage by dredging (front range city, oil/gas industry, or State Parks Dept.) Info updated 2/21/17 based on email communication with Cynthia Lefever (fmrico@outlook.com). Land owner from GIS shapefile. For soils- 1.5 mile buffer used. Fill method from Google Earth view. Inundated area (existing) 2511 acres. NWI:PEM=8 acres

Site ID: 188

# Johnson Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 7

☐ Site Screened Out

## FEATURES

| | | |
|---|---|---|
| Existing Capacity: | 0 | ac-ft |
| New Capacity | 10,600 | ac-ft |
| Total Capacity | 10,600 | ac-ft |
| Inundated Area: | | acres |
| Evaporation Potential: | High | |
| Soil Type | No | |
| Fill Method: | Gravity Fill | |
| Land Owner | Public | |
| Reservoir Owner: | | |
| Consumptive Partnerships: | Unknown | |
| Non-Consumptive Partnerships: | Unknown | |
| Regional Integration: | Yes | |
| Existing Water Quality: | Not Applicable | |
| Source Water Quality: | Yes | |
| Constructability: | High | |
| Scalability: | Low | |
| Use Existing Infrastructure: | Yes | |
| Ease To Use Existing Infrastructure: | Medium | |

## COST (Site- Level)

| | |
|---|---|
| Storage Unit Cost ($/ac-ft): | 1,120 |
| Total Storage Cost ($) | 11,820,000 |
| Cost Estimate Year | 2001 |

## BENEFITS (Site- Level)

| | |
|---|---|
| Flood Control Rank: | Low |
| Migratory Bird Habitat | Yes |
| Solution Compatibility: | No |

## ENVIRONMENTAL

| | |
|---|---|
| National Wetlands Inventory: | Low |
| Critical Habitat in Environmentally Sensitive Areas: | No |
| Wildlife Species Impact: | Negative |
| Wildlife Habitat Impact: | Negative |
| Migratory Bird Impact | Negative |
| Bald Eagle Nests Impact: | Low |
| Presence of Oil and Gas Wells: | None |

## PERMITTING

| | |
|---|---|
| Federal Nexus: | Yes |
| SPWRAP Potential: | Yes |

Notes: Kept as best fit site (3-17-17 Workshop #1). For soils- site location may not be exact, 1.5 mile buffer used.

Site ID: 2

# Julesburg Reservoir (Enlargement)

Category: Enlargement

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 8

☐ Site Screened Out

## FEATURES

Existing Capacity: 22,900 ac-ft

New Capacity 21,900 ac-ft

Total Capacity 44800 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type No

Fill Method: Gravity Fill

Land Owner Private

Reservoir Owner: Julesburg Irrigation District

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Unknown

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Easy

## COST (Site- Level)

Storage Unit Cost ($/ac-ft): 1,150

Total Storage Cost ($) 25,100,000

Cost Estimate Year 2001

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat Yes

Solution Compatibility: No

## ENVIRONMENTAL

| | |
|---|---|
| National Wetlands Inventory: | Medium |
| Critical Habitat in Environmentally Sensitive Areas: | No |
| Wildlife Species Impact: | Negative |
| Wildlife Habitat Impact: | Negative |
| Migratory Bird Impact | Negative |
| Bald Eagle Nests Impact: | Low |
| Presence of Oil and Gas Wells: | None |

## PERMITTING

| | |
|---|---|
| Federal Nexus: | Yes |
| SPWRAP Potential: | Yes |

Notes: Option represented is C3. For soils- 1.5 mile buffer used. NWI - 343 acres.

Site ID: 80

# Julesburg Reservoir (Rehabilitation)

Category: Rehabilitation

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 10.5

☐ Site Screened Out

## FEATURES

Existing Capacity: 22,900 ac-ft

New Capacity 5,700 ac-ft

Total Capacity 28600 ac-ft

Inundated Area: 3,811 acres

Evaporation Potential: High

Soil Type No

Fill Method: Gravity Fill

Land Owner Private

Reservoir Owner: Julesburg Irrigation District

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Unknown

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Easy

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat Yes

Solution Compatibility: No

## ENVIRONMENTAL

National Wetlands Inventory: High

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Neutral

Wildlife Habitat Impact: Neutral

Migratory Bird Impact Neutral

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: For soils- 1.5 mile buffer used. 343 acres- nwi.

Site ID: 162

# Lower Bijou Creek

Category: Aquifer Storage

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 10.5

☐ Site Screened Out — Second Screening- Dropped in favor of Upper/Lower Lost Creek and Badger/Be

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 1,067,000 ac-ft

Total Capacity 1,067,000 ac-ft

Inundated Area: 0 acres

Evaporation Potential: Low

Soil Type Yes

Fill Method: Gravity Fill

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Unknown

Source Water Quality: Unknown

Constructability: High

Scalability: Medium

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat No

Solution Compatibility: Yes

## ENVIRONMENTAL

| | |
|---|---|
| National Wetlands Inventory: | Medium |
| Critical Habitat in Environmentally Sensitive Areas: | No |
| Wildlife Species Impact: | Neutral |
| Wildlife Habitat Impact: | Neutral |
| Migratory Bird Impact | Neutral |
| Bald Eagle Nests Impact: | Low |
| Presence of Oil and Gas Wells: | None |

## PERMITTING

| | |
|---|---|
| Federal Nexus: | Yes |
| SPWRAP Potential: | No |

Notes: New Capacity = Total volume 5,334,380 Acre-ft x 0.2 Aquifer Porosity; NWI - 74 acres is PFO/PSS. Keep this site- internal meeting on 5/4/17

Site ID: 141

# Lower Kiowa Creek

Category: Aquifer Storage

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 10

☐ Site Screened Out — Second Screening- Dropped in favor of Upper/Lower Lost Creek and Badger/Be

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 806,000 ac-ft

Total Capacity 806,000 ac-ft

Inundated Area: 0 acres

Evaporation Potential: Low

Soil Type Yes

Fill Method: Gravity Fill

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Yes

Source Water Quality: Yes

Constructability: High

Scalability: Medium

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat No

Solution Compatibility: Yes

## ENVIRONMENTAL

| | |
|---|---|
| National Wetlands Inventory: | Low |
| Critical Habitat in Environmentally Sensitive Areas: | No |
| Wildlife Species Impact: | Neutral |
| Wildlife Habitat Impact: | Neutral |
| Migratory Bird Impact | Neutral |
| Bald Eagle Nests Impact: | Low |
| Presence of Oil and Gas Wells: | None |

## PERMITTING

| | |
|---|---|
| Federal Nexus: | Yes |
| SPWRAP Potential: | No |

Notes: New Capacity = Total volume 4,032,145 x Porosity 0.2. Unclear - site buffer crosses COSPLS02b which has parameters on 303(d) list. Need to confirm if water from this segment is being used as existing/source water. Federal nexus - depends on details.

Site ID: 139

# Lower Lost Creek

Category: Aquifer Storage

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 11.5

☐ Site Screened Out

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 157,000 ac-ft

Total Capacity 157,00 ac-ft

Inundated Area: 0 acres

Evaporation Potential: Low

Soil Type Yes

Fill Method: Gravity Fill

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: No

Source Water Quality: No

Constructability: High

Scalability: Medium

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat No

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Low

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Neutral

Wildlife Habitat Impact: Neutral

Migratory Bird Impact Neutral

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: Low

## PERMITTING

Federal Nexus: No

SPWRAP Potential: No

Notes: New Capacity = Total volume 782,939 x Porosity 0.2. Federal nexus could still exist depending on project details. Keep this site- ranked favorably on CGS evaluation. Similar to Upper Lost Creek, but closer to South Platte River.

Site ID: 111

# McCarthy Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 5.5

☐ Site Screened Out

## FEATURES

Existing Capacity: ac-ft

New Capacity 10,000 ac-ft

Total Capacity ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type No

Fill Method: Pumping

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Low

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: Treated as a new site, even though a small flood control reservoir exists (3-17-17 Workshop #1). Land owner from GIS shapefile. For soils- 1.5 mile buffer used. Site crosses segment COSPLS02b which is on 303d list, need to confirm if imparied water will be used.

Site ID: 193

# North Sterling Regulating Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 7

☐ Site Screened Out

## FEATURES

| | |
|---|---|
| Existing Capacity: | 0 ac-ft |
| New Capacity | 7,600 ac-ft |
| Total Capacity | 7,600 ac-ft |
| Inundated Area: | acres |
| Evaporation Potential: | High |
| Soil Type | No |
| Fill Method: | Gravity Fill |
| Land Owner | Private |
| Reservoir Owner: | |
| Consumptive Partnerships: | Unknown |
| Non-Consumptive Partnerships: | Unknown |
| Regional Integration: | Yes |
| Existing Water Quality: | Not Applicable |
| Source Water Quality: | Yes |
| Constructability: | High |
| Scalability: | Low |
| Use Existing Infrastructure: | Yes |
| Ease To Use Existing Infrastructure: | Difficult |

## COST (Site- Level)

| | |
|---|---|
| Storage Unit Cost ($/ac-ft): | 2,610 |
| Total Storage Cost ($) | 19,800,000 |
| Cost Estimate Year | 2001 |

## BENEFITS (Site- Level)

| | |
|---|---|
| Flood Control Rank: | Low |
| Migratory Bird Habitat | Yes |
| Solution Compatibility: | No |

## ENVIRONMENTAL

National Wetlands Inventory: Low

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: Kept as best fit site (3-17-17 Workshop #1).  For soils- site location may not be exact, 1.5 mile buffer used. Wind turbines spotted in aerieal imagery

Site ID: 99

# North Sterling Reservoir

Category: Enlargement

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 7

☐ Site Screened Out

## FEATURES

Existing Capacity: 72,000 ac-ft

New Capacity 12,000 ac-ft

Total Capacity 84,000 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type No

Fill Method: Gravity Fill

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Yes

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Easy

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat Yes

Solution Compatibility: No

## ENVIRONMENTAL

National Wetlands Inventory: Medium

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: Based on raising dam 4ft (State sometimes refers to this site as Point of Rocks. Not the same as SiteID 17. Land owner from GIS shapefile. For soils- 1.5 mile buffer used. Fill method, existing capaicty (estimated) from CPW flier. Existing surface area 2,880 acres from CPW flier

Site ID: 186

# Ovid Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 6.5

☐ Site Screened Out

## FEATURES

| | |
|---|---|
| Existing Capacity: | 0 ac-ft |
| New Capacity | 7,700 ac-ft |
| Total Capacity | 7,700 ac-ft |
| Inundated Area: | 286 acres |
| Evaporation Potential: | High |
| Soil Type | No |
| Fill Method: | Gravity Fill |
| Land Owner | Private |
| Reservoir Owner: | District 64 Reservoir Company |
| Consumptive Partnerships: | Unknown |
| Non-Consumptive Partnerships: | Unknown |
| Regional Integration: | Yes |
| Existing Water Quality: | Not Applicable |
| Source Water Quality: | Yes |
| Constructability: | High |
| Scalability: | Low |
| Use Existing Infrastructure: | Yes |
| Ease To Use Existing Infrastructure: | Medium |

## COST (Site- Level)

| | |
|---|---|
| Storage Unit Cost ($/ac-ft): | 1,640 |
| Total Storage Cost ($) | 12,600,000 |
| Cost Estimate Year | 2003 |

## BENEFITS (Site- Level)

| | |
|---|---|
| Flood Control Rank: | Low |
| Migratory Bird Habitat | Yes |
| Solution Compatibility: | No |

## ENVIRONMENTAL

| | |
|---|---|
| National Wetlands Inventory: | High |
| Critical Habitat in Environmentally Sensitive Areas: | No |
| Wildlife Species Impact: | Negative |
| Wildlife Habitat Impact: | Negative |
| Migratory Bird Impact | Negative |
| Bald Eagle Nests Impact: | Low |
| Presence of Oil and Gas Wells: | None |

## PERMITTING

| | |
|---|---|
| Federal Nexus: | Yes |
| SPWRAP Potential: | Yes |

Notes: NWI = 776 acres. COSPL201 crosses site and is on 303d list. Need to confirm existing/source water.

Site ID: 200

# Pawnee Pass Dam

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 7

☐ Site Screened Out

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 65,000 ac-ft

Total Capacity 65,000 ac-ft

Inundated Area: 8,100 acres

Evaporation Potential: High

Soil Type No

Fill Method: Pumping

Land Owner Private

Reservoir Owner: Logan County Water Conservancy District

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Difficult

## COST (Site- Level)

Storage Unit Cost ($/ac-ft): 913

Total Storage Cost ($) 91,366,000

Cost Estimate Year 2010

## BENEFITS (Site- Level)

Flood Control Rank: Medium

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Medium

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: Formerly named W-P6 (Large and Small). For soils- 1.5 mile buffer used.

Site ID: 17

# Point of Rocks Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 8.5

☐ Site Screened Out — Second Screening- Dropped in favor of Sandborn. Aerial images showed oil and

## FEATURES

| | | |
|---|---|---|
| Existing Capacity: | 0 | ac-ft |
| New Capacity | 224,000 | ac-ft |
| Total Capacity | 224,000 | ac-ft |
| Inundated Area: | | acres |
| Evaporation Potential: | High | |
| Soil Type | No | |
| Fill Method: | Gravity Fill | |
| Land Owner | Private | |
| Reservoir Owner: | | |
| Consumptive Partnerships: | Unknown | |
| Non-Consumptive Partnerships: | Unknown | |
| Regional Integration: | Yes | |
| Existing Water Quality: | Not Applicable | |
| Source Water Quality: | Yes | |
| Constructability: | High | |
| Scalability: | Low | |
| Use Existing Infrastructure: | Yes | |
| Ease To Use Existing Infrastructure: | Medium | |

## COST (Site- Level)

| | |
|---|---|
| Storage Unit Cost ($/ac-ft): | |
| Total Storage Cost ($) | |
| Cost Estimate Year | |

## BENEFITS (Site- Level)

| | |
|---|---|
| Flood Control Rank: | Low |
| Migratory Bird Habitat | Yes |
| Solution Compatibility: | Yes |

## ENVIRONMENTAL

National Wetlands Inventory: Low

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: High

## PERMITTING

Federal Nexus: No

SPWRAP Potential: Yes

Notes: For soils- site location may not be exact, 1.5 mile buffer used. There still could be a federal trigger depending on project details. Could be filled with extention of Greeley No 2 Canal

Site ID: 1

# Prewitt Reservoir

Category: Rehabilitation

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 9

☐ Site Screened Out

## FEATURES

Existing Capacity: 28,600 ac-ft

New Capacity 4,634 ac-ft

Total Capacity 33234 ac-ft

Inundated Area: 3,800 acres

Evaporation Potential: High

Soil Type No

Fill Method: Gravity Fill

Land Owner Private

Reservoir Owner: Logan Irrigation District

Consumptive Partnerships: Yes

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: No

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Easy

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Medium

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: Info updated on 2/9/17 based on email conversation with Jim Yahn (jim@northsterling.org). For soils- 1.5 mile buffer used. Fill method from Google Earth view.

Site ID: 10

# Riverside Reservoir

Category: Rehabilitation

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 10

☐ Site Screened Out

## FEATURES

Existing Capacity: 65,000 ac-ft

New Capacity 2,500 ac-ft

Total Capacity 67500 ac-ft

Inundated Area: 3,811 acres

Evaporation Potential: High

Soil Type No

Fill Method: Gravity Fill

Land Owner Private

Reservoir Owner: Riverside Irrigation District

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: No

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Easy

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

| | |
|---|---|
| National Wetlands Inventory: | Medium |
| Critical Habitat in Environmentally Sensitive Areas: | No |
| Wildlife Species Impact: | Neutral |
| Wildlife Habitat Impact: | Neutral |
| Migratory Bird Impact | Neutral |
| Bald Eagle Nests Impact: | High |
| Presence of Oil and Gas Wells: | Low |

## PERMITTING

| | |
|---|---|
| Federal Nexus: | Yes |
| SPWRAP Potential: | Yes |

Notes: For soils- 1.5 mile buffer used. Fill method from Google Earth view.

Site ID: 16

# Sandborn Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 7

☐ Site Screened Out

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 224,000 ac-ft

Total Capacity 224,000 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type No

Fill Method: Gravity Fill

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Difficult

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Low

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: Low

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: Land owner from GIS shapefile. For soils- site location may not be exact, 1.5 mile buffer used. Kept as "best fit" between Greasewood and Point of Rocks. Could be filled with extention of Greeley No 2 Canal

Site ID: 6

# South Platte (Narrows) Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 7

☐ Site Screened Out

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 973,000 ac-ft

Total Capacity 973,000 ac-ft

Inundated Area: 14,900 acres

Evaporation Potential: High

Soil Type No

Fill Method: Gravity Fill

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Yes

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: Low

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Easy

## COST (Site- Level)

Storage Unit Cost ($/ac-ft): 232

Total Storage Cost ($) 226,000,000

Cost Estimate Year 1980

## BENEFITS (Site- Level)

Flood Control Rank: High

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: High

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: No

Notes: Check on owner- may be USBR. Will provide recreatio benefit, instream flow benefit. Annual O&M and replacement cost = $1.4M (1980 dollars). For soils- 1.5 mile buffer used. 285 acres= NWI. COSPLS01 is on 303d list - need to confirm existing/source water. Chosen as "best fit" for Hardin.

Site ID: 271

# Sunken Lake Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 6.5

☐ Site Screened Out: Second Screening- Storage barely over 5,000 ac-ft cutoff

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 5,093 ac-ft

Total Capacity: 5,093 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type: Yes

Fill Method: Pumping

Land Owner: Private

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat: Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Medium

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: Need to ask if anyone has information on. Land owner from GIS shapefile. For soils- 1.5 mile buffer used.

Site ID: 196

# Troelstrup

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 6.5

☐ Site Screened Out

## FEATURES

| | | |
|---|---|---|
| Existing Capacity: | 0 | ac-ft |
| New Capacity | 5,000 | ac-ft |
| Total Capacity | 5,000 | ac-ft |
| Inundated Area: | | acres |
| Evaporation Potential: | High | |
| Soil Type | No | |
| Fill Method: | Gravity Fill | |
| Land Owner | Private | |
| Reservoir Owner: | | |
| Consumptive Partnerships: | Unknown | |
| Non-Consumptive Partnerships: | Unknown | |
| Regional Integration: | Yes | |
| Existing Water Quality: | Not Applicable | |
| Source Water Quality: | Yes | |
| Constructability: | High | |
| Scalability: | Low | |
| Use Existing Infrastructure: | Yes | |
| Ease To Use Existing Infrastructure: | Medium | |

## COST (Site- Level)

| | |
|---|---|
| Storage Unit Cost ($/ac-ft): | 1,730 |
| Total Storage Cost ($) | 8,640,000 |
| Cost Estimate Year | 2001 |

## BENEFITS (Site- Level)

| | |
|---|---|
| Flood Control Rank: | Low |
| Migratory Bird Habitat | Yes |
| Solution Compatibility: | No |

## ENVIRONMENTAL

National Wetlands Inventory: High

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: For soils- site location may not be exact, 1.5 mile buffer used. NWI = 561 acres. COSPLS01 is crossed by site and is on 303d list - need to confirm existing/source water.

Site ID: 161

# Upper Bijou Creek

Category: Aquifer Storage

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 8.5

☐ Site Screened Out: Outside of study Area

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 466,000 ac-ft

Total Capacity: ac-ft

Inundated Area: acres

Evaporation Potential: Low

Soil Type: Yes

Fill Method: Pumping

Land Owner: Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: No

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Medium

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat: No

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Low

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Neutral

Wildlife Habitat Impact: Neutral

Migratory Bird Impact Neutral

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Maybe

SPWRAP Potential: No

Notes:

Site ID: 160

# Upper Kiowa Creek

Category: Aquifer Storage

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 8.5

☐ Site Screened Out — Initial screening - distance from river

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity: 234,000 ac-ft

Total Capacity: ac-ft

Inundated Area: acres

Evaporation Potential: Low

Soil Type: Yes

Fill Method: Pumping

Land Owner: Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: No

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Medium

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat: No

Solution Compatibility: Yes

## ENVIRONMENTAL

| | |
|---|---|
| National Wetlands Inventory: | Low |
| Critical Habitat in Environmentally Sensitive Areas: | No |
| Wildlife Species Impact: | Neutral |
| Wildlife Habitat Impact: | Neutral |
| Migratory Bird Impact | Neutral |
| Bald Eagle Nests Impact: | Low |
| Presence of Oil and Gas Wells: | None |

## PERMITTING

| | |
|---|---|
| Federal Nexus: | Maybe |
| SPWRAP Potential: | No |

Notes:

Site ID: 140

# Upper Lost Creek

Category: Aquifer Storage

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 10

☐ Site Screened Out

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 1,260,000 ac-ft

Total Capacity 1,260,000 ac-ft

Inundated Area: 0 acres

Evaporation Potential: Low

Soil Type Yes

Fill Method: Gravity Fill

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: No

Existing Water Quality: Not Applicable

Source Water Quality: No

Constructability: High

Scalability: Medium

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat No

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Low

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Neutral

Wildlife Habitat Impact: Neutral

Migratory Bird Impact Neutral

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: No

Notes: New Capacity = Total volume 6,298,259 x Porosity 0.2. Federal nexus - depends on project details. Keep this site- ranked favorably on CGS evaluation. Avoids conflicts with other infrastructure and recovery of stored water.

Site ID: 272

# West Nile Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 5.5

☐ Site Screened Out

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 26,950 ac-ft

Total Capacity 26,950 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type No

Fill Method: Pumping

Land Owner Public

Reservoir Owner:

Consumptive Partnerships: Unknown

Non-Consumptive Partnerships: Unknown

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: No

Ease To Use Existing Infrastructure: N/A

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Low

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: Site most likely drains to Kiowa Creek. Aquifer recharge area? Land owner from GIS shapefile. For soils- 1.5 mile buffer used

Site ID: 5

# Wildcat Reservoir

Category: New Site

☐ IPP ☐ Gravel Lake

Site Score (Equal Weighting): 9

☐ Site Screened Out

## FEATURES

Existing Capacity: 0 ac-ft

New Capacity 60,000 ac-ft

Total Capacity 60,000 ac-ft

Inundated Area: acres

Evaporation Potential: High

Soil Type No

Fill Method: Gravity Fill

Land Owner Private

Reservoir Owner: Riverside Irrigation Company

Consumptive Partnerships: Yes

Non-Consumptive Partnerships: Yes

Regional Integration: Yes

Existing Water Quality: Not Applicable

Source Water Quality: Yes

Constructability: High

Scalability: Low

Use Existing Infrastructure: Yes

Ease To Use Existing Infrastructure: Medium

## COST (Site- Level)

Storage Unit Cost ($/ac-ft):

Total Storage Cost ($)

Cost Estimate Year

## BENEFITS (Site- Level)

Flood Control Rank: Low

Migratory Bird Habitat Yes

Solution Compatibility: Yes

## ENVIRONMENTAL

National Wetlands Inventory: Medium

Critical Habitat in Environmentally Sensitive Areas: No

Wildlife Species Impact: Negative

Wildlife Habitat Impact: Negative

Migratory Bird Impact Negative

Bald Eagle Nests Impact: Low

Presence of Oil and Gas Wells: None

## PERMITTING

Federal Nexus: Yes

SPWRAP Potential: Yes

Notes: For soils- 1.5 mile buffer used

# APPENDIX E

# AQUIFER STORAGE AND RECOVERY COST ESTIMATES

# SPSS Draft Memorandum

**To:** Chip Paulson, Stantec
**From:** Leonard Rice Engineers, Inc.
**Date:** November 20, 2017
**Project:** South Platte Storage Study
**Subject:** **DRAFT Task 4.5: Aquifer Storage and Recovery Cost Estimates**

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This memorandum presents the Aquifer Storage and Recovery (ASR) cost estimates developed for the South Platte Storage Study (SPSS). These are Class 5 capital cost estimates based on simplifying assumptions that allow them to be linearly scaled for desired rates of recharge or recovery. In order to provide representative cost comparisons, the recharge and recovery rates shown are defined by the water delivery and demand scenarios being considered for surface water sites. Realistically, these rates of recharge and recovery will be limited at specific ASR sites because of local hydrogeologic conditions. The general cost estimates presented can be adapted to ASR sites considered in the SPSS based on their site specific hydrogeologic characteristics.

## ASR Site Conceptual Design

We developed a conceptual design for an infiltration basin ASR site in an alluvial aquifer setting. The conceptual alluvial ASR site has the following components:

- Recharge basins
- Recovery wells
- Well instrumentation and controls (I&C)
- Yard piping for distribution of water on site
- Piping and power connections
- Supervisory Control and Data Acquisition (SCADA) Systems
- Well house or vault structures

The conceptual alluvial ASR site does not include electrical grid upgrades, transmission piping or pumping facilities for transporting water to and from the site.

*Recharge Basins*

The conceptual recharge basins are designed to have a 20 acre bottom area for infiltration. We estimated excavation depth to be 10 feet deep to allow for the removal of any low permeability soil overburden. It is assumed that no clearing/grubbing, hauling, backfill or compaction will be necessary. The conceptual recharge basins have 3:1 side slopes, with 4:1 end slopes that can accommodate heavy equipment entering and exiting the basins for construction and maintenance. The 20 acre basin bottom areas are designed to be 2,000 feet long by 436 feet wide. The top area will be 2,080 feet long by 496 feet wide. Each basin will require the excavation of approximately 350,000 cubic yards of material. Recharge basins will receive water through inlet piping at various locations along the basin bottom.

The recharge basins are designed to have one to two feet of water depth. We selected a conceptual infiltration rate of one foot per day for recharge calculations, which results in a recharge rate of 20 acre feet (ac-ft) per day, per basin.

**Figure 1** shows a plan and profile drawing of a conceptual alluvial ASR recharge basin.

*Recovery Facilities*

Once water is stored at an alluvial ASR site, it will be recovered through a well field located at the same site, or at some separate, downgradient recovery facility. The recovery facility location will be dependent on site specific hydrogeology.

For general costing purposes, the recovery wells are conceptually designed as 150 foot deep, 12-inch diameter wells capable of pumping 500 gallons per minute (GPM) against 200 feet of total dynamic head (TDH). The wells will include a variable frequency drive with water level, pressure, and pumping rate monitoring. The recovery wells will be operated through a SCADA system. Well controls, valving, and associated appurtenances will be protected in well vaults or buildings.

## Cost Estimate Approach

Preliminary capital cost estimates are based on SPSS maximum delivery and demand scenarios. It is unlikely that these scenarios represent reasonable rates of alluvial aquifer recharge and recovery for one alluvial ASR site, but they are being used to provide a similar cost comparison to surface water storage options.

*Maximum Delivery Scenario*

We assumed that monthly inflow of water for storage at an ASR site would be 5,000 acre-feet (AFM). There are several construction and operational assumptions related to this maximum delivery amount:

- We are assuming that there is 10,000 ac-ft of "regulating storage" (e.g. gravel pits) that can temporarily store water and deliver it to an ASR storage site at a lower rate, and/or for a longer period of time.

- Recharging the maximum amount of 5,000 ac-ft for one month will define the infiltration area required. We are assuming that the maximum delivery amount will only occur for a portion of the year. This will allow for portions of the recharge facility to remain inactive the majority of the time. Frequent drying/maintenance of basins will be necessary to maintain infiltration capacity.

- We are assuming that land availability and hydrogeologic conditions will not constrain site construction or operations. This is unlikely and specific alluvial ASR recharge sites will require additional evaluation to refine the maximum inflow/recharge rate they can accept.

Given the alluvial ASR conceptual design characteristics detailed above, this maximum delivery rate will require 165 acres of recharge area and a total of 8 recharge basins.

*Demand Scenario*

The stored water demand is assumed to be 4,000 AFM. This will define the rate of water recovery/outflow and the scale of associated ASR components, mainly the number of wells.

As with recharge water delivery, the maximum demand scenario is based on simplifying assumptions that are unlikely to be applicable at all alluvial ASR sites being considered. The most important consideration is that we are assuming land availability and hydrogeologic conditions will not constrain the construction and operation of a recovery facility.

The conceptual alluvial ASR facilities described above would require 60 wells to recover water out of aquifer storage at the 4,000 AFM demand rate.

## Cost Estimate Results

Capital costs were estimated for the components of a conceptual alluvial ASR site based on information from construction contractors, previous projects, and published data. The estimated costs are presented in **Table 1**. The costs presented are only for onsite equipment and construction. Costs are not considered for electrical grid upgrades or transmission of water to and from the site. There is no contingency included, but the unit prices are presented as ranges to reflect uncertainty in cost estimates. The median cost estimate was used for calculating the total price.

Costs for construction, engineering, and permitting were estimated as a percentage of other component costs.

**Figure 2** shows the estimated costs for conceptual ASR site components as a percentage of the total price. The majority of costs come from recharge cell excavation, and there will be ways to minimize these costs. For example, excavated material can be placed next to the basins to act as a berm.

The conceptual alluvial ASR site cost estimates are based on the maximum delivery and demand scenarios discussed above. However they are configured to be linearly scalable based on the amount of water delivery or demand. This cost estimate configuration will enable scaling for specific alluvial ASR sites that may have different recharge and recovery capacities.

## Limitations

These Class 5 capital cost estimates are intended for preliminary planning and have order of magnitude confidence intervals. The generalization for each of the conceptual ASR site components contributes to additional cost uncertainty when applied to specific sites. They should only be used for evaluation of alluvial ASR sites being considered in the SPSS.

### Table 1 – Alluvial ASR Site Level 5 Cost Estimate

| Item | Description | Unit | Unit price | Quantity | Total Price (Median Basis) | Notes |
|---|---|---|---|---|---|---|
| 1 | Recharge Cell Excavation | Cubic Yards | $2 - $15 | 2,909,091 | $24,727,273 | Assumes 20 acre basins with approximately 352,000 cubic yards of excavation per cell. Assumes no material hauling, backfill/compaction, or clearing/grubbing necessary. |
| 2 | Recovery Wells | Well | $60,000 - $150,000 | 60 | $6,279,267 | Includes 150 foot deep wells (12-inch diameter, stainless steel), pump/motor capable of 500 GPM @200 feet of TDH, discharge piping, downhole power. |
| 3 | Well I&C, yard piping, manifold & power connections, SCADA, well house | Well | $60,000 - $100,000 | 60 | $4,784,204 | Assume VFD with level, pressure, and pumping rate monitoring, 200 feet of yard piping, connection to existing on site power. |
| 4 | Recharge Cell Infrastructure | Cell | $20,000 - $50,000 | 8 | $289,256 | Slope stabilization, inflow distribution/piping |
| 5 | Construction | Lump Sum | | | $1,014,692 | %20 of subtotal from items 3-4 |
| 6 | Engineering and Construction Support | Lump Sum | | | $1,136,000 | %10 of subtotal from items 2-4 |
| 7 | Permitting | Lump Sum | | | $1,136,000 | %10 of subtotal from items 2-4 |
| 8 | Land Acquisition | Acre | $1,000 - $1,500 | 248 | $309,917 | Assuming recharge area plus 50% increase for facility size. Based on 2015 price of non-irrigated land (no water rights purchase). |
| | | | | **Grand Total:** | $39,366,692 | |
| | | | | **Recharge Rate (AFM):** | 5,000 | |
| | | | | **Recovery Rate (AFM):** | 4,000 | |

**Notes**

No contingency included.
GPM - gallons per minute
TDH - total dynamic head
AFM - acre feet per month
VFD - variable frequency drive
SCADA - supervisory control and data acquisition

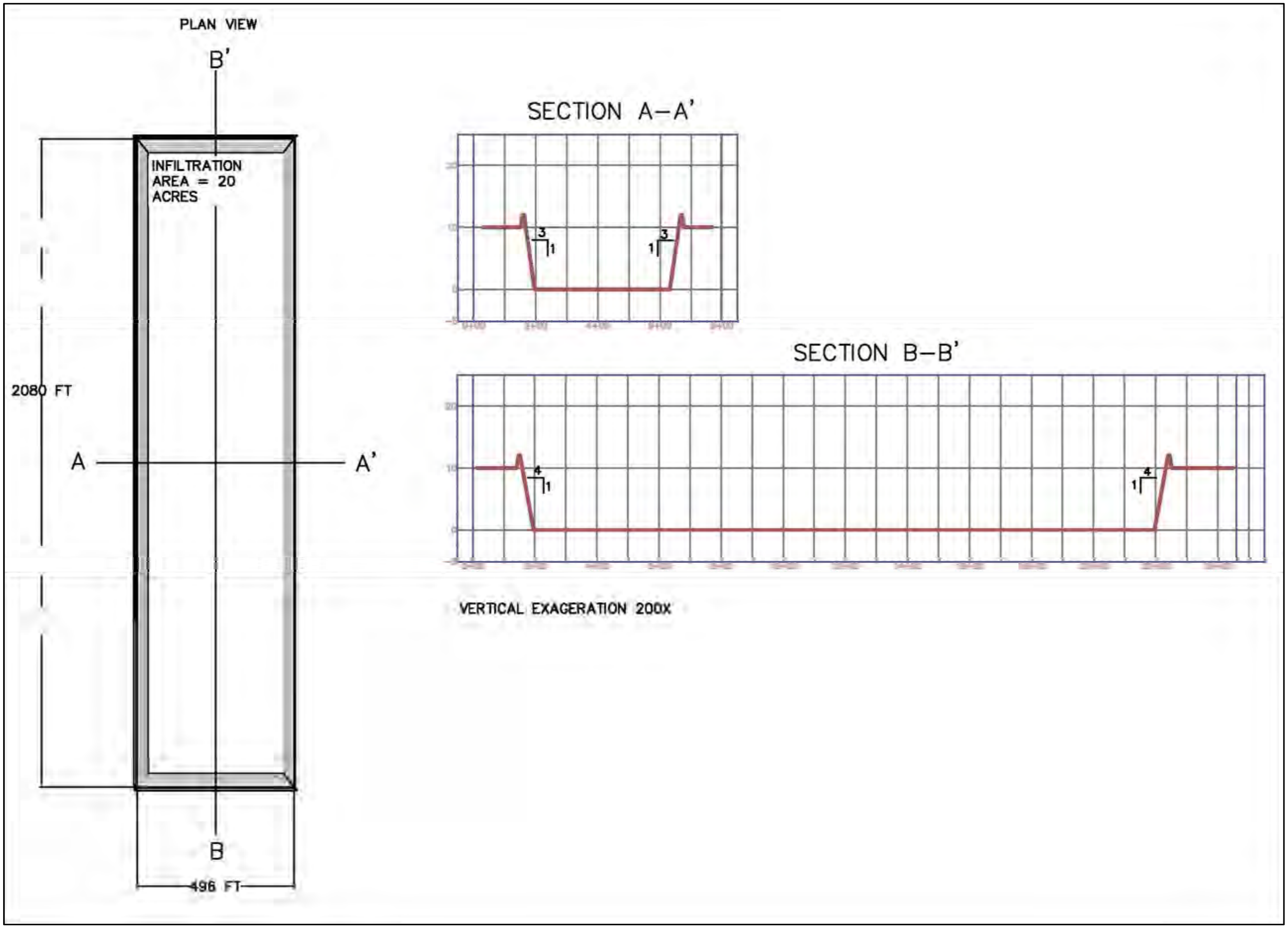


**Figure 1 - Conceptual Alluvial ASR Recharge Basin Dimensions**

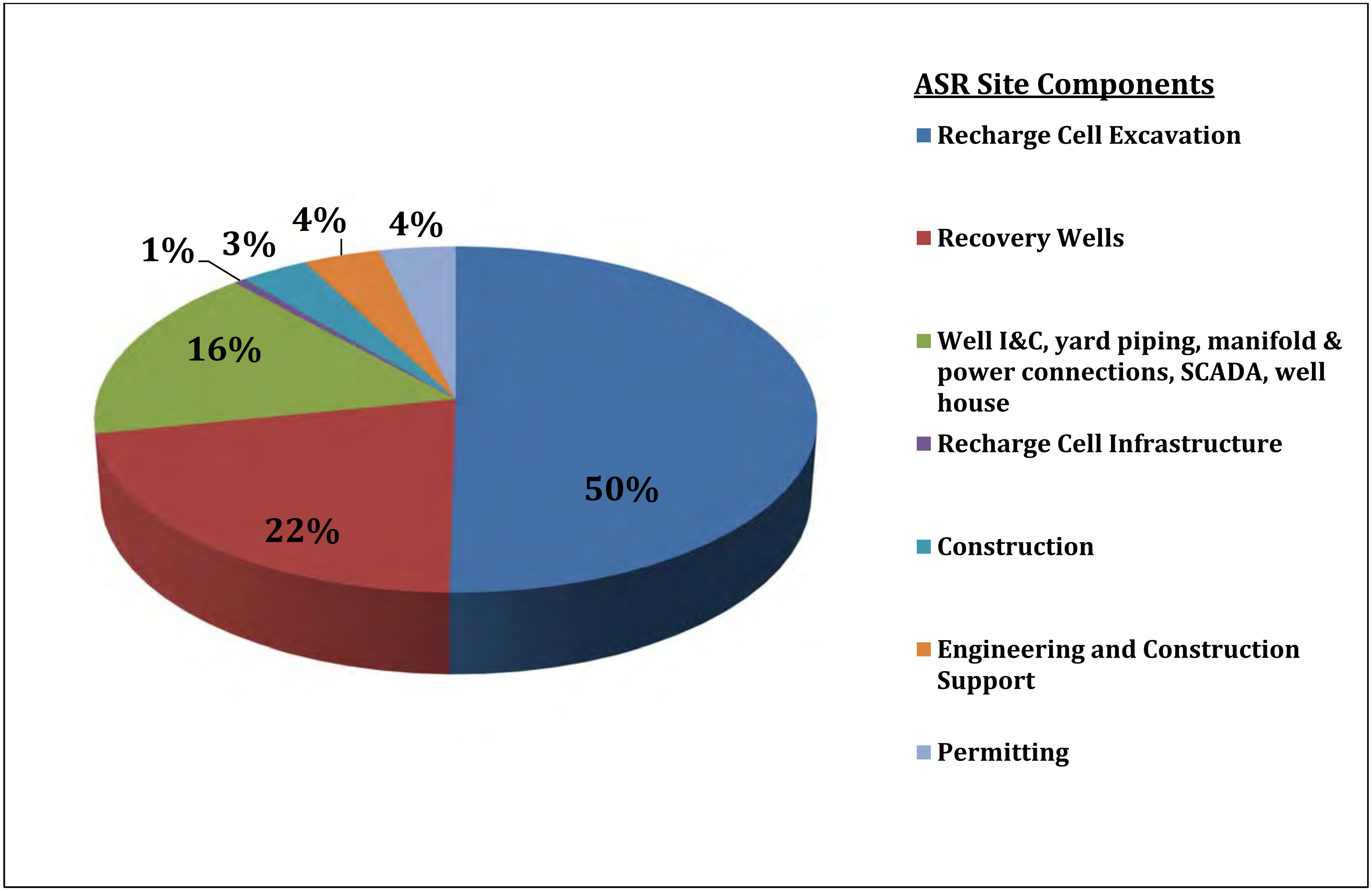


**Figure 2 - Conceptual Alluvial ASR Site Component Estimated Costs as a Percentage of Total Cost**

# APPENDIX I – COST ESTIMATES TM

NOTE: SOME OF THE INFORMATION IN THIS TM WAS CHANGED DURING PREPARATION OF THE FINAL REPORT

MWH now part of Stantec

# MEMORANDUM

**TECHNICAL MEMORANDUM**

| | | | |
|---|---|---|---|
| To: | Joe Frank, Andy Moore | From: | Chip Paulson, Pranay Sanadhya, Wonnie Kim |
| | Lower South Platte Water Conservancy District, Colorado Water Conservation Board | | MWH Now Part of Stantec |
| Subject: | **Cost Estimation of Potential Reservoir Alternatives in the South Platte River Basin** | Date: | November 28, 2017 |

## INTRODUCTION

HB 16-1256, which authorized the South Platte Storage Study (SPSS), included a requirement to develop cost estimates for the storage alternatives that could be effective in storing surplus water in the South Platte River Basin. These alternatives include surface reservoirs and groundwater aquifer storage. This technical memorandum (TM) documents the methods used to prepare cost estimates for the SPSS.

Due to the conceptual nature of the storage projects and water supply concepts evaluated in the SPSS, cost estimates were prepared at a conceptual level only. Cost estimates are AACE International Class 5 cost estimates. Class 5 estimates are generally prepared based on limited site-specific information, and subsequently have wide accuracy ranges. Typically, engineering is from 2% to 10% complete. They are often prepared for strategic planning purposes, market studies, assessment of viability, project location studies, and long range capital planning. Most Class 5 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric techniques. Expected accuracy ranges are from –20% to –50% on the low side and +30% to 100% on the high side, depending on technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination.

This TM describes the methods and data used to prepare cost estimates for new surface reservoirs, enlargements and rehabilitations, diversion structures, gravel pits, and pipelines and pump stations. Costs for aquifer storage options are documented in a separate TM. Because any storage project must be integrated into a broad water supply concept or strategy, costs for delivering water from South Platte River into storage and then from storage to assumed demand centers were included in the SPSS cost analysis.

Due to the conceptual nature of the SPSS analysis, past studies were relied on where possible and previous cost estimates were updated to current conditions. Cost estimates were developed in 2017 dollars.

The SPSS analysis included developing estimates of permitting, design, construction, and land acquisition costs. It is noted that many of the storage sites and storage concepts would involve significant operation and maintenance (O&M) costs due to pumping requirements for filling and delivering water to demand centers. O&M cost estimates were not developed for this study.

**COST ESTIMATES FOR SURFACE RESERVOIRS**

Capital costs were estimated for surface storage sites that were short-listed during the SPSS study for incorporation into lower South Platte Basin storage concepts. The short-listed reservoir sites include the following:

- New Sites: Sandborn Reservoir, South Plate (Narrows) Reservoir, Wildcat Reservoir, Pawnee Pass Reservoir, Fremont Butte Reservoir, North Sterling Regulating Reservoir, Johnson Reservoir, Ovid Reservoir, Troelstrup Reservoir, Beaver Creek Reservoir
- Rehabilitation: Julesburg Reservoir
- Enlargement: Julesburg Reservoir
- Storage Restoration: Jackson Lake Reservoir

Costs for other surface storage options could be scaled off of cost estimates for these sites.

For the dams that had conceptual level design costs developed in a previous study, the costs from those previous studies were escalated using information from the United States Bureau of Reclamation (USBR) construction cost trends (USBR, 2017). An escalation factor was calculated from the published earth dam construction cost index between 2017 and the year in which the construction costs were estimated.

For the dams that had conceptual level designs but no costs, quantities were calculated from the conceptual design report and 2017 costs were estimated. In order to maintain as much consistency and comparability between the various cost estimates, the new cost estimates were calculated using the same unit costs as were used in the majority of the previous cost estimates, i.e., the unit costs in the GEI report on Lower South Platte Basin storage options (GEI, 2001). The costs calculated from the 2001 unit costs were also escalated to 2017 conditions in the same manner discussed above.

For the dams that had no previous conceptual level designs, a conceptual level design was prepared by Stantec. Conceptual designs consisted of an assumed dam alignment, an earthfill dam type, a typical overflow spillway, and an allowance for outlet works and other ancillary features. Quantities were estimated based on the conceptual design and 2017 costs were estimated. In order to maintain as much consistency and comparability between the various cost estimates, the new cost estimates were calculated using the same unit costs as were used in the majority of the previous cost estimates, i.e., the GEI, 2001 report. The costs calculated from the 2001 unit costs were also escalated to 2017 conditions in the same manner discussed above.

Construction cost categories included site clearing and excavation, foundation grouting, dam fill materials, outlet works, spillway, and instrumentation. Costs for other piping, diversions, or other appurtentant facilities were not included within the construction costs. The estimated construction costs include and allowance for “unlisted items” of 10% of listed items. Mobilization, bonds, and insurance was also included at 6% of base construction cost. A contingency of 25% (of the base construction cost and mobilization, bonds, and insurance) was also included to get the direct construction subtotal (DCS) cost.

Other costs in addition to the construction costs were included in the capital cost estimate as a percentage of the DCS cost. These costs included design engineering (7.5 percent), permitting (3 percent base cost plus additional cost for complex permitting situations), legal and administration (2 percent), and construction administration and engineering costs (7.5 percent). Land costs were also included, based on an average land cost of $1,000 per acre in Logan and Morgan Counties in 2017 plus $300,000 in legal fees per site.

The estimated conceptual costs were based on Stantec's professional opinion of the cost to develop and construct the project. The estimated costs were based on the sources of information described above and our knowledge of current construction cost conditions in the Front Range region. Actual project construction and development costs are affected by a number of factors beyond our control such as supply and demand for the types of construction required at the time of bidding and in the project vicinity; changes in material supplier costs; changes in labor rates; the competitiveness of contractors and suppliers; changes in applicable regulatory requirements; changes in design contractors and suppliers; changes in design standards; and environmental mitigation requirements and other conditions of project permitting. Therefore, conditions and factors that arise as project development proceeds through planning, design and construction may result in project costs that differ from the estimates document in this report.

Capital cost estimates for surface storage reservoirs are summarized in Table 1.

**Table 1. Surface Storage Capital Cost Summary**

| Dam Type/Name | Storage (acre-ft) | Crest Height (ft) | Dam Length (ft) | Reservoir Area (ac) | Reference | Prelim Cost from Past Study Data | USBR Factor – Earth Dam | Land Cost (2017) | Additional Permitting Cost | Estimated Capital Cost (2017) | Unit Cost ($/ac-ft) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Site | | | | | | | | | | | | |
| Sandborn Reservoir | 224,000 | 132 | 18,654 | 8,844 | MWH 2004 | $68,689,323 | -- | $9,144,000 | $3,000,000 | $130,789,194 | $584 | Quantities and costs estimated by Stantec based on conceptual layout in MWH, 2004 |
| South Platte (Narrows) Reservoir | 1,960,000 | 140 | 14,600 | 22,000 | USBR, 1983 | $59,413,000 | 1.73 | $22,300,000 | $20,000,000 | $144,922,455 | $74 | Cost based on quantities and costs from GEI 2001- converted to 2017 cost |
| Wildcat Reservoir | 60,000 | 94 | 7,762 | 4,664 | -- | $40,029,348 | -- | $4,964,000 | $5,000,000 | $79,105,602 | $1,318 | Conceptual layout, quantities and costs estimated by Stantec |
| Pawnee Pass Dam | 75,000 | 100 | 5,280 | 9,900 | Platte River Hydologic Research Center (PRHRC) 2004 | $158,000,000 | 1.51 | $10,200,000 | $5,000,000 | $254,297,345 | $3,391 | Cost based on quantities and costs from PRHRC 2004 - converted to 2017 cost |
| Fremont Butte | 76,000 | 74 | 10,296 | 4,405 | -- | $38,461,587 | -- | $4,705,000 | $3,000,000 | $74,138,651 | $976 | Conceptual layout, quantities and costs estimated by Stantec |
| North Sterling Regulating Reservoir | 7,600 | 65 | 6,100 | 450 | GEI 2001 | $19,800,000 | 1.73 | $750,000 | $3,000,000 | $37,950,000 | $4,993 | Cost based on quantities and costs from GEI 2001- converted to 2017 cost |
| Johnson Reservoir | 10,600 | 70 | 4,300 | 450 | GEI 2001 | $11,820,000 | 1.73 | $750,000 | $3,000,000 | $24,166,364 | $2,280 | Cost based on quantities and costs from GEI 2001- converted to 2017 cost |
| Ovid Reservoir | 7,700 | 30 | 15,050 | 490 | Applegate Group, Inc. 2003 | $12,600,000 | 1.60 | $790,000 | $3,000,000 | $23,926,449 | $3,107 | Cost based on quantities and costs from Applegate Group, Inc. 2003- converted to 2017 cost |
| Troelstrup | 5,000 | 30 | 17,650 | 500 | GEI 2001 | $8,640,000 | 1.73 | $800,000 | $3,000,000 | $18,723,636 | $3,745 | Cost based on quantities and costs from GEI 2001- converted to 2017 cost |
| Beaver Creek | 95,000 | 80 | 34320 | 7,574 | -- | $30,472,181 | -- | $7,874,000 | $5,000,000 | $65,507,767 | $690 | Conceptual layout, quantities and costs estimated by Stantec |
| Rehabilitation | | | | | | | | | | | | |
| Julesburg Reservoir Rehab | 5,700 | -- | -- | 0 | GEI 2001 | $8,820,000 | 1.73 | $0 | $2,000,000 | $17,234,545 | $3,024 | Cost based on quantities and costs from GEI 2001- converted to 2017 cost |
| Julesberg Reservoir Enlargement | 21,900 | -- | -- | 400 | | $25,100,000 | 1.73 | $700,000 | $2,000,000 | $46,054,545 | $2,103 | Cost based on quantities and costs from GEI 2001- converted to 2017 cost |
| Restoration | | | | | | | | | | | | |
| Jackson Lake Reservoir | 10,000 | 25 | 10,560 | 0 | Smith Geotechnical, 1993 | $896,050 | 2.06/3.14 | 0 | $2,000,000 | $3,846,079 | $385 | Cost based on quantities and costs from Smith Geotechnical 1993- converted to 2017 cost |

## COST ESTIMATES FOR CONVEYANCE SYSTEMS

SPSS conveyance components include pipelines, pump stations, river diversions, and gravel pits for regulating storage.

### Pipelines

Pipelines were required to fill reservoirs from the South Platte River and to deliver water from storage to a demand center. In all cases pipeline costs were based on a unit cost expressed as dollars per inch diameter per linear foot. Pipeline diameter was computed based on an assumed design flow and a criterion to maintain a flow velocity of 6-8 ft/sec. Pipeline alignments were extremely approximate; no effort was made to review property ownership or potential easements or obstructions. Pipeline unit cost was based on information collected by Stantec for previous conceptual infrastructure studies in the Front Range. A unit cost of $7 per inch diameter per lineal foot was used to calculate costs for the large pipelines included in the SPSS alternatives.

### Pump Stations

Pump stations were sized based on the horsepower requirement to lift the design flow rate over the assumed elevation difference between intake at the South Platte River and outlet at the proposed storage site. This included the static head associated with the elevation difference and dynamic head associated with energy losses in the pipeline. Unit pump station costs as a function of total horsepower were based on previous Front Range experience, and are summarized below.

| Total Horsepower (HP) | Unit cost ($/HP) |
|---|---|
| HP<=500 | 5,500 |
| HP>500 and <=1500 | 4,500 |
| HP>1500 and <=3000 | 3,500 |
| HP>3000 | 2,500 |

### South Platte River Diversion Structures

Any off-channel storage projects were assumed to require a new diversion from the South Platte River. To simply the analysis, all new diversion structures were assumed to be similar to the Lower Platte Beaver diversion structure (Id: 518) shown below, consisting of a new concrete check dam and a diversion headgate. The following dimensions and unit costs were used to calculate an approximate cost of $1,900,000 for the dam structure.


| Concrete | |
|---|---|
| Length (ft) | 220 |
| Top Width (ft) | 3 |
| Bottom Width (ft) | 5 |
| Height (ft) | 30 |
| Unit Cost ($/yard of concrete) | 800 |

| Grouted Riprap | |
|---|---|
| Width (ft) | 50 |
| Unit Cost ($/sq-yd of grouted rip rap) | 80 |

A cost of $900,000 was used for gate structure to divert flows at a maximum rate of 800 cfs. The total diversion cost was estimated to be $2.8 million.

**Gravel Pit Storage**

Gravel pit regulating storage was assumed to be part of any alternative involving a new diversion from the South Platte River. This regulating storage would reduce the size of the conveyance system needed to fill a proposed storage option by balancing diversion of high flows from the river. Based on Stantec research in the Arkansas Valley, a unit cost of $1,500/ac-ft was adopted for gravel pit storage. To standardize storage concepts, each was assumed to include a 10,000 ac-ft gravel pit complex with a cost of $15 million.

**Contingency**

A 50% contingency was applied when estimating the cost of conveyance facilities.

**Conveyance Cost Summary**

Table 2 shows the capital cost estimates for conveyance facilities needed to fill reservoirs from the South Platte River. Costs assume up to 800 cfs would be diverted from the river to a gravel pit complex, and up to 400 cfs would be conveyed to the storage option.

Table 3 shows the capital cost estimates for conveyance facilities needed to deliver a maximum of 150 cfs from storage to an assumed SPSS demand center in the Brighton area.

**Table 2. Conveyance Capital Costs for Filling Storage Options in Selected Storage Concepts (400 cfs capacity)**

| Alternative | Description | Pipeline | Pump Stations | Dam and Diversion Structure | Gravel Pit Storage | Contingency | Total Cost |
|---|---|---|---|---|---|---|---|
| Upper Basin Storage- Sandborn Reservoir | Pipeline from SPR to Riverside Reservoir. Pipeline from Riverside Reservoir to Sandborn Reservoir | $43,750,000 | $50,360,000 | $2,800,000 | $15,000,000 | $55,955,000 | $167,865,000 |
| Mid Basin Storage North- Wildcat Reservoir | Pipeline from SPR to Wildcat Reservoir | $26,110,000 | $49,950,000 | $2,800,000 | $15,000,000 | $46,930,000 | $140,790,000 |
| Mid Basin Storage South- Beaver Creek Reservoir | Pipeline from SPR to Morgan Beaver Reservoir. Pipeline from Morgan Beaver Reservoir to Beaver Creek Reservoir. | $140,690,000 | $113,010,000 | $2,800,000 | $15,000,000 | $135,750,000 | $407,250,000 |
| Lower Basin Storage- Trilakes Northeast (Julesburg, Ovid, and Troelstrup) | Separate pipelines from 2 new diversions on SPR to Julesburg Reservoir, Ovid Reservoir and Troelstrup Reservoir | $9,010,000 | $16,750,000 | $5,600,000 | $30,000,000 | $30,680,000 | $92,040,000 |
| Existing Reservoir Improvements- Julesburg, North Sterling, Prewitt, Jackson, and Riverside | Separate pipelines from 3 new diversions on SPR to each reservoir | $34,970,000 | $59,270,000 | $8,400,000 | $45,000,000 | $73,820,000 | $221,460,000 |
| Groundwater Basin Storage West- Lost Creek Aquifer | Pipeline from SPR to feed recharge facilities for Lost Creek Aquifer | $91,030,000 | $126,850,000 | $2,800,000 | $15,000,000 | $117,840,000 | $353,520,000 |
| Groundwater Basin Storage East- Beaver Badger Aquifer | Pipeline from SPR to Morgan Beaver Reservoir. Pipeline from Morgan Beaver Reservoir to recharge facilities for Beaver Badger Aquifer. | $70,790,000 | $135,390,000 | $2,800,000 | $15,000,000 | $111,990,000 | $335,970,000 |

**Table 3. Capital Cost Estimates for Delivery Systems from Storage to Brighton Demand Center (150 cfs capacity)**

| Alternative | Description | Pipeline | Pump Stations | Contingency | Total Cost |
|---|---|---|---|---|---|
| Upper Basin Storage- Sandborn Reservoir | Pipeline from Sandborn Reservoir to Brighton | $114,640,000 | $69,850,000 | $92,245,000 | $276,735,000 |
| Mainstem Storage- South Platte (Narrows) Reservoir | Pipeline from Narrows Reservoir to Brighton | $138,170,000 | $85,130,000 | $111,650,000 | $334,950,000 |
| Mid Basin Storage North- Wildcat Reservoir | Pipeline from Wildcat Reservoir to Brighton | $157,560,000 | $100,780,000 | $129,170,000 | $387,510,000 |
| Mid Basin Storage South- Beaver Creek Reservoir | Pipeline from Beaver Creek Reservoir to Brighton | $158,920,000 | $102,530,000 | $130,725,000 | $392,175,000 |
| Lower Basin Storage- Trilakes Northeast (Julesburg, Ovid, and Troelstrup) | Pipeline from Julesburg Reservoir to Brighton | $324,660,000 | $196,330,000 | $260,495,000 | $781,485,000 |
| Existing Reservoir Improvements- Julesburg, North Sterling, Prewitt, Jackson, and Riverside | Pipeline from Riverside Reservoir to Brighton | $114,640,000 | $69,850,000 | $92,245,000 | $276,735,000 |
| Groundwater Basin Storage West- Lost Creek Aquifer | Pipeline from west of Wiggins to Brighton | $69,860,000 | $47,950,000 | $58,905,000 | $176,715,000 |
| Groundwater Basin Storage East- Beaver Badger Aquifer | Pipeline from south of Brush to Brighton | $141,400,000 | $91,250,000 | $116,325,000 | $348,975,000 |

**References**

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MWH, 2004. Northern Integrated Supply Project Feasibility Study. Prepared for Northern Colorado Water Conservancy District.

Platte River Hydologic Research Center (PRHRC), 2004. Preliminary Conceptual Plan for Proposed Pawnee Pass Dam and Reservoir in Logan County, Colorado. Prepared for Logan County Water Conservancy District, Sterling, Colorado. June

Smith Geotechnical, 1993. Feasibility Study for Jackson Lake Dam, Volume I&II (). Prepared for Jackson Lake Reservoir And Irrigation Company Fort Morgan, Colorado. November.

USBR, 1983. Narrows Unit Pick-Sloan Missouri Basin Program, Colorado. Addendum No. 2 to Definite Plan Report. June

# APPENDIX J – WATER LEAVING THE STATE WITH OPERATION OF STORAGE CONCEPTS

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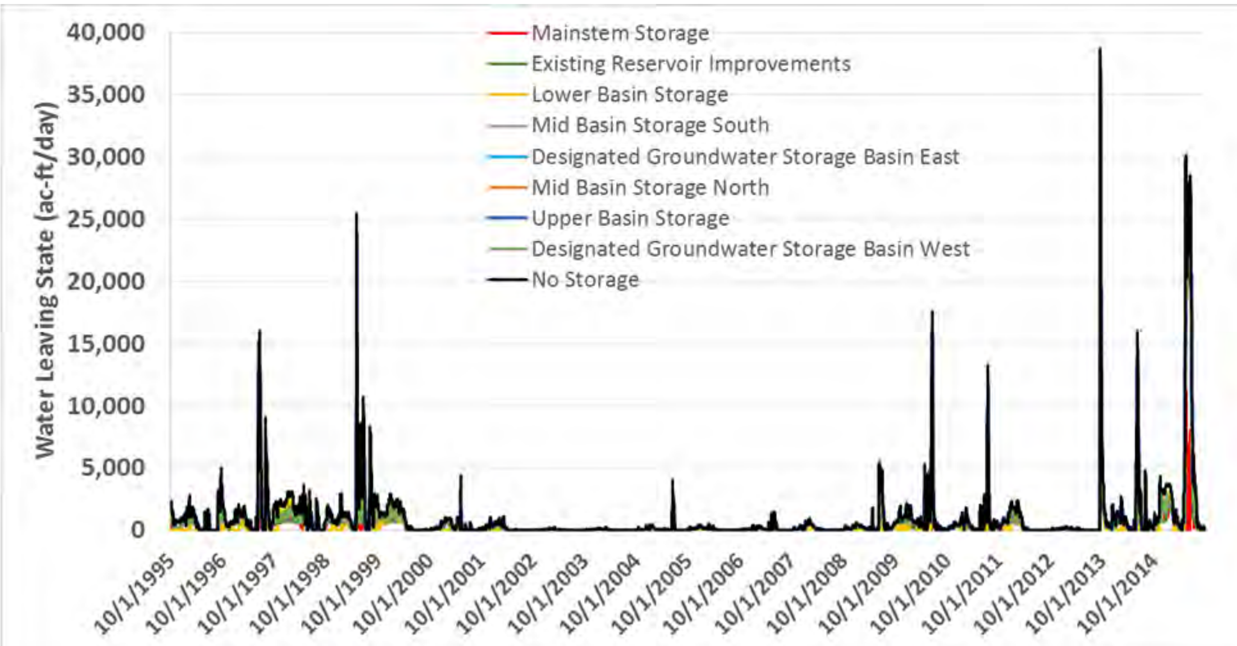
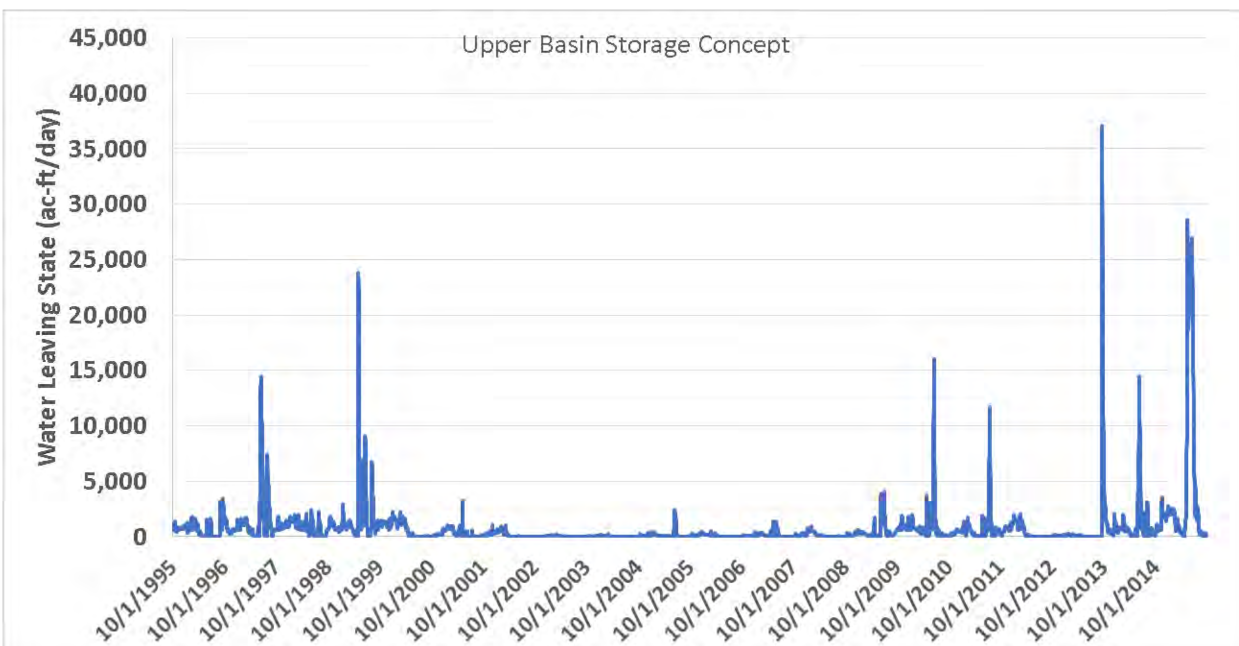
## Daily Plots of Water Leaving State for SPSS Storage Concepts

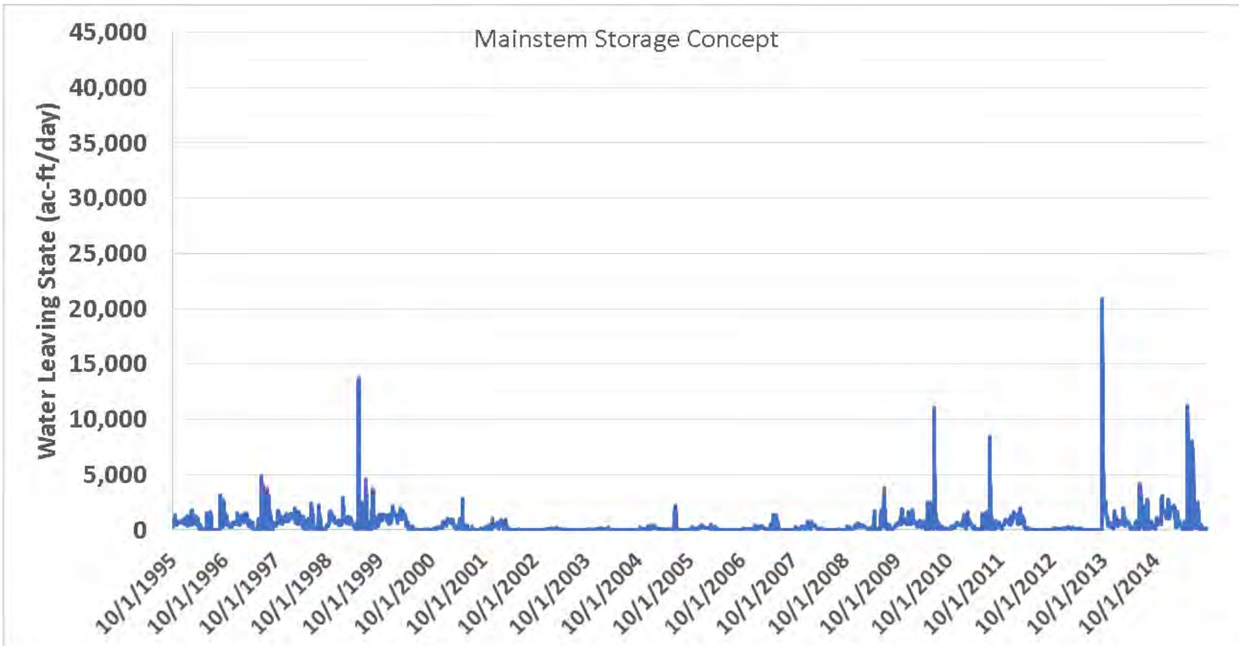
### All Storage Concepts



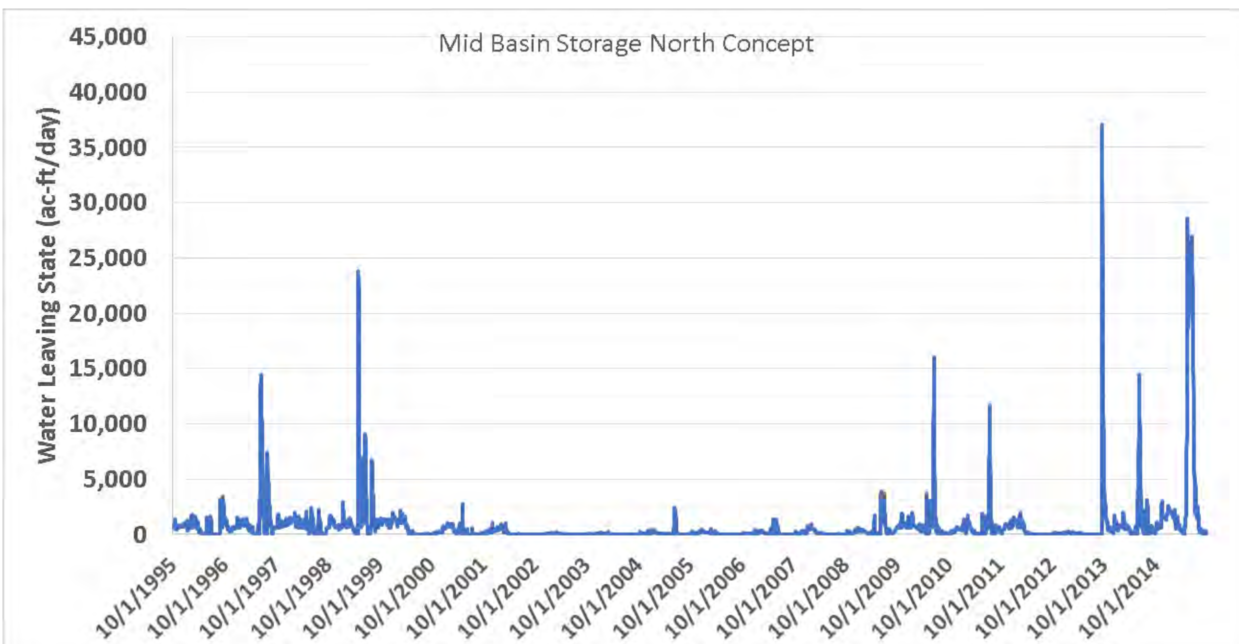

### Upper Basin Storage – Sandborn Reservoir



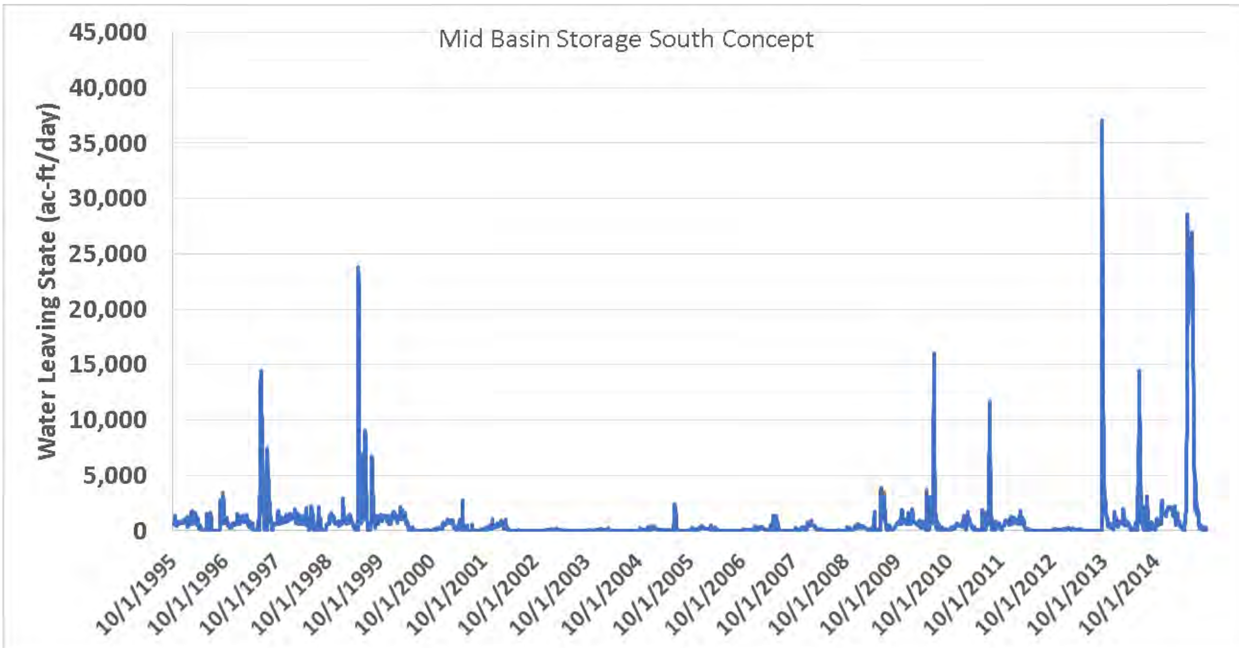
## Mainstem Storage – South Platte (Narrows) Reservoir



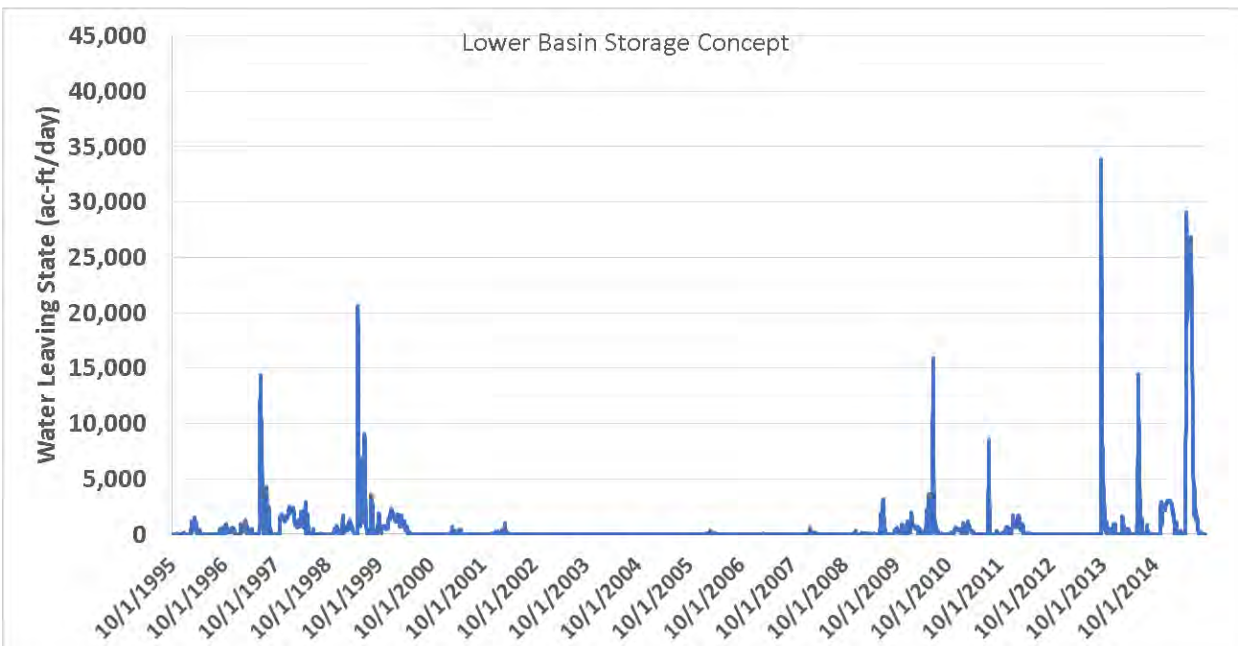

## Mid Basin Storage North – Wildcat Reservoir



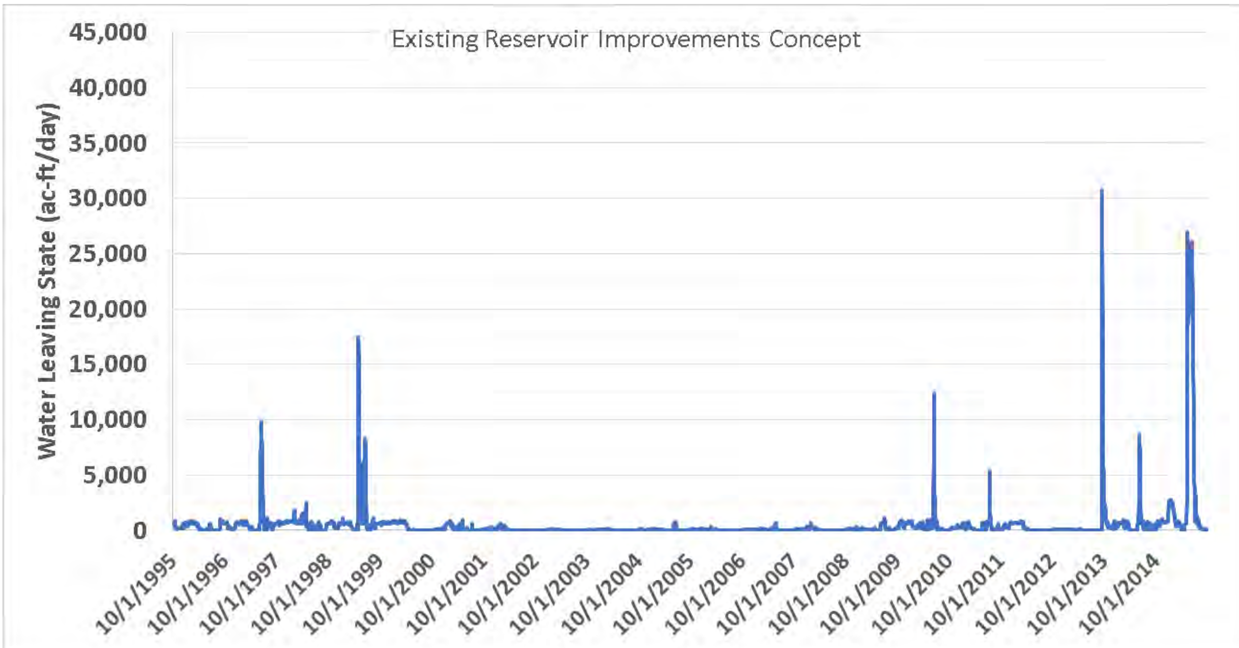
## Mid Basin Storage South – Beaver Creek Reservoir



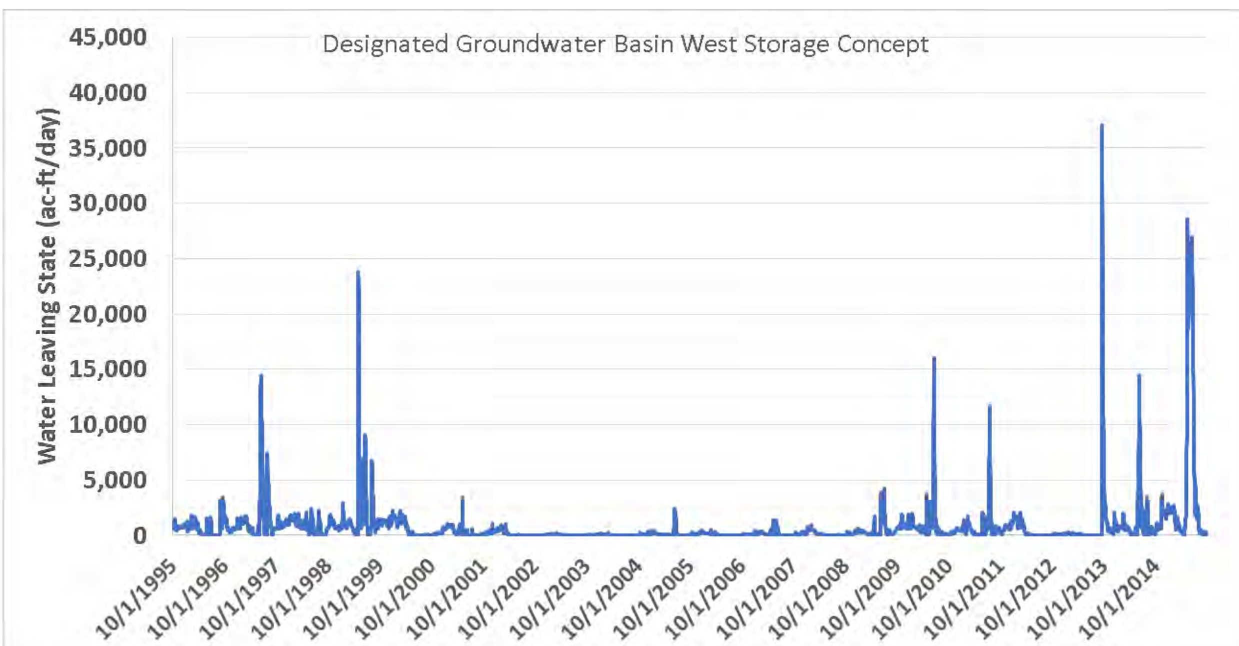

## Lower Basin Storage – Julesburg, Ovid, Troelstrup



**Existing Reservoir Improvements – Julesburg, North Sterling, Prewitt, Jackson Lake, Riverside**

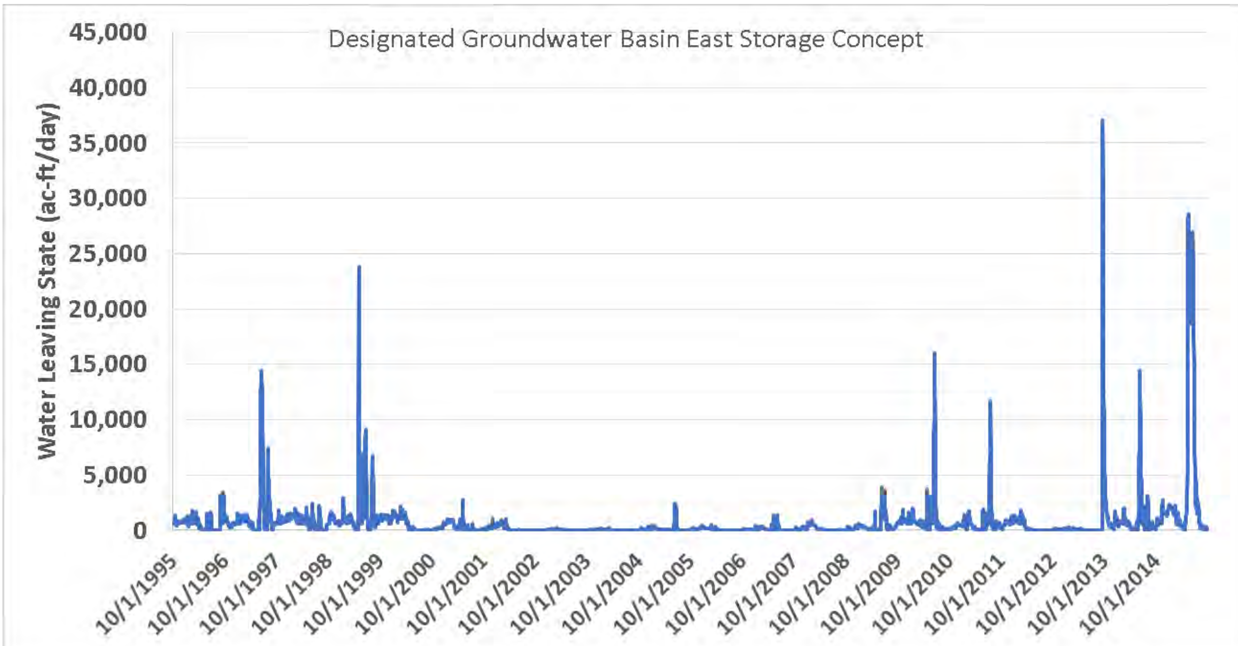



**Designated Groundwater Storage Basin West - Lost Creek Basin – Sized with Large Inlet/Outlet Facilities to be Similar to Surface Storage Concepts**



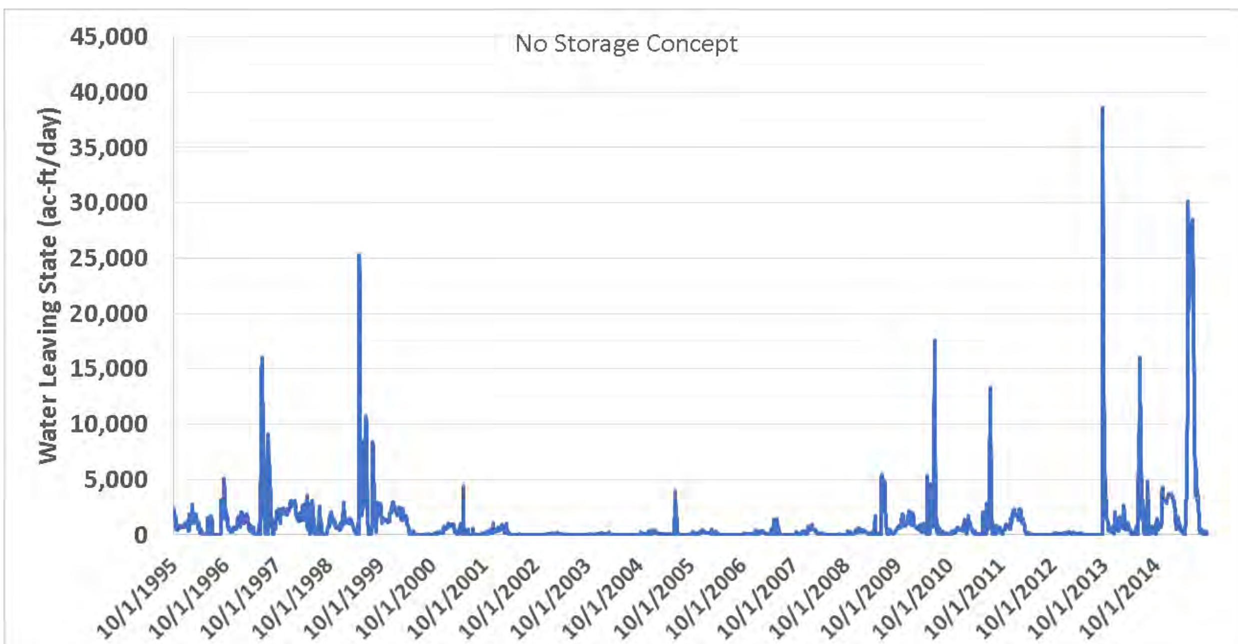

*Water leaving the state for this groundwater option sized based on typical ASR facilities in Colorado would be much higher.*

### Designated Basin Groundwater Storage East – Badger/Beaver Basin – Sized with Large Inlet/Outlet Facilities to be Similar to Surface Storage Concepts




*Water leaving the state for this groundwater option sized based on typical ASR facilities in Colorado would be much higher.*

### No Storage



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