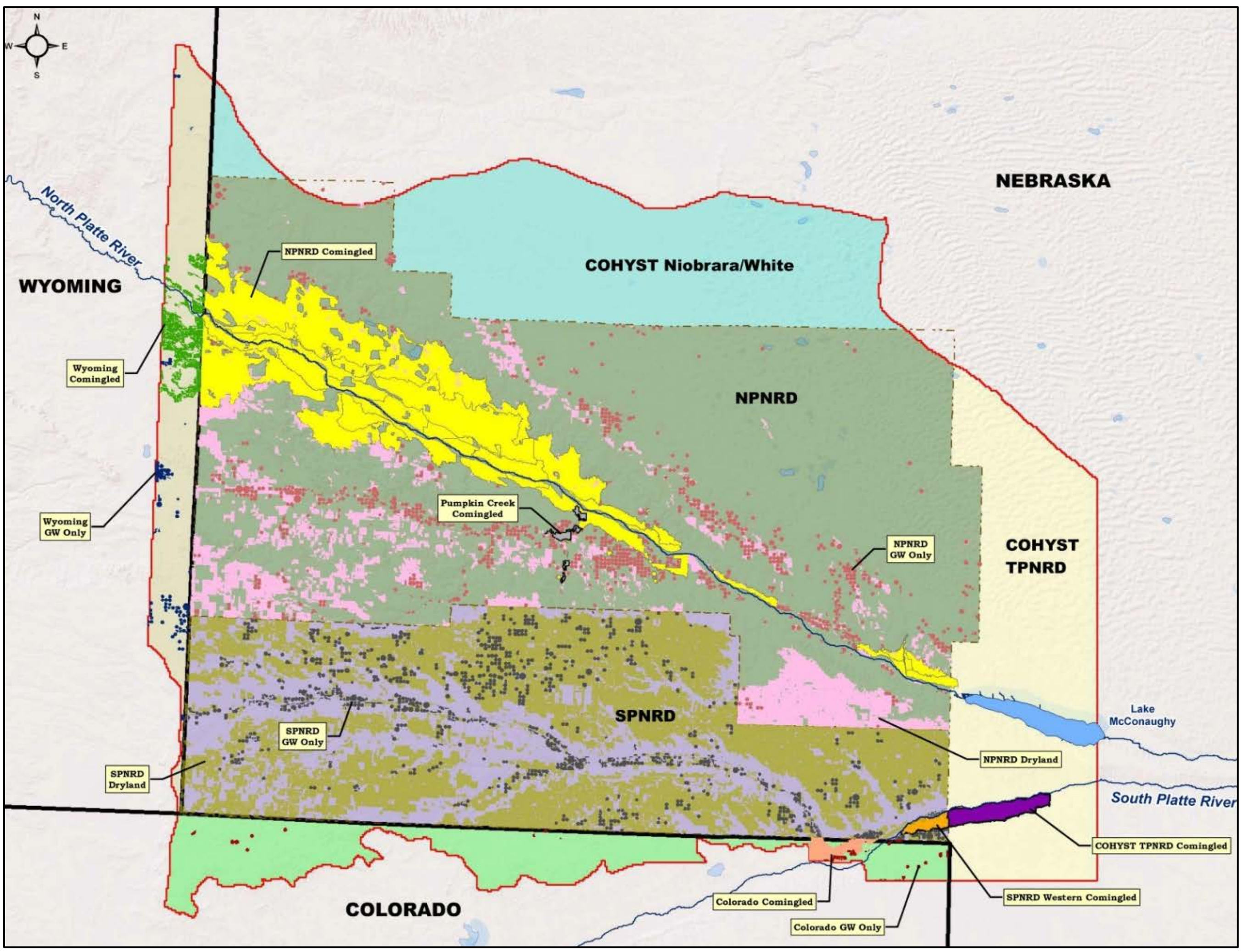
WWUM Technical Memorandum
Colorado Pumping and Recharge Estimates
December 19, 2012

Overview: The Western Water Use Management Model (WWUM) ground water model extent encompasses the North Platte and South Platte NRD areas, and extends beyond the NRD boundaries to include relatively small areas of land in Wyoming, Colorado, and neighboring NRDs in Nebraska as shown in **Figure 1**. The pumping and irrigation recharge associated with irrigated lands in these surrounding areas must be included in the overall ground water model; this technical memorandum discusses the estimation of pumping and recharge for irrigated lands in Colorado.

Figure 1: WWUM Ground Water Model Boundary



Data Source: Through the development of the South Platte Decision Support System (SPDSS), the State of Colorado performed a historical consumptive use (CU) analysis of irrigated lands in the South Platte River basin and documented the analysis approach and results in the *Historical Crop Consumptive Use Analysis, South Platte Decision Support System, March, 2010*. The South Platte historical CU analysis was performed using StateCU, a generic data-driven CU modeling software, which estimates potential CU based on irrigated acreage information, crop types and monthly climate data, and estimates actual supply-limited CU based on efficiency information, diversion records, and well information. The SPDSS analysis was performed on a monthly timestep for the 1950 through 2006 period, and can be used to estimate the historical pumping, canal recharge, and irrigation recharge associated with irrigated lands located in Colorado in the WWUM ground water model area. The South Platte CU report and StateCU model files are available on the CDSS website (cdss.state.co.us). Details of the CU analysis are not repeated in this technical memorandum; the approach below focuses on how the results of the CU analysis were queried for use in the WWUM ground water model.

Structures: A spatial analysis using the WWUM ground water model boundary, the SPDSS irrigated acreage coverage, and the SPDSS service area coverage was performed to determine what diversion or well structure served the irrigated lands within the WWUM ground water model boundary. Irrigation districts are generally modeled explicitly in the SPDSS analysis, and ground water only lands are modeled in aggregate. Portions of the SPDSS surface water structures and ground water aggregate structures shown in **Table 1** are located in the WWUM ground water model boundary.

Table 1: SPDSS Structures in the WWUM GW Model Area

Structure Name	Structure ID	Irrigated Acreage Percent	Canal Percent
Liddle Ditch	6400502	41%	51%
Peterson Ditch	6400504	83%	45%
Settlers Ditch	6400508	6%	7%
Julesburg Irrig. District	6403906	15%	26%
District 64 GW Agg. 2	64AWP002	60%	N/A
District 64 GW Agg. 3	64AWP003	70%	N/A
District 64 GW Agg. 5	64AWP005	72%	N/A
District 64 GW Agg. 6	64AWP006	38%	N/A
District 64 GW Agg. 16	64AWP016	88%	N/A

For structures that receive surface water, the irrigated acreage percent was determined by the percent of the total service area in the WWUM ground water model area. Note that less than 1 percent of the North Sterling Irrigation District was located within the WWUM ground water model area and was excluded. Likewise, there is a limited amount of historical irrigated acreage and no current irrigated acreage in the Water District 64 GW Aggregate 1 within the WWUM ground water model area, and it was excluded. The canal percent was determined by the percent of the total canal length in the WWUM ground water model area. For ground water aggregate structures, the percent of structure was determined by the percent of the 1950 to 2006 average irrigated acreage in each aggregate area in the WWUM ground water model area.

Approach: The SPDSS CU analysis resulted in an estimate of historical potential CU, water supply limited CU, irrigation shortages, pumping, canal recharge and irrigation recharge for irrigation structures. The results of this analysis are reported in several summary output files and are stored in a binary output file (*.BD1 file). TSTool, a data management interface, uses commands to access specific results from the binary file, perform user-specified data calculations, and output the results to a format that can be integrated with the WWUM ground water model. The following steps summarize the actions performed by TSTool for each type of SPDSS structure.

For surface water structures:

1. Read the SPDSS StateCU Binary File (SP2008_crop.BD1) into TSTool.
2. Query for the “SW & GW Non-Consumed” and the “Conveyance Loss” monthly results for each of the structures. The “SW & GW Non-Consumed” represents the amount of non-consumed water from both surface and ground water supplies at the field (i.e. irrigation recharge); the “Conveyance Loss” represents the amount of non-consumed surface water at the canal (i.e. canal recharge).
3. Scale the monthly “SW & GW Non-Consumed” for each structure by their respective irrigated acreage percentages shown in **Table 1** to estimate the amount that occurs within the WWUM ground water model area.
4. Scale the monthly “Conveyance Loss” for each structure by their respective canal percentages shown in **Table 1** to estimate the amount that occurs within the WWUM ground water model area.
5. Add together the scaled “SW & GW Non-Consumed” and the “Conveyance Loss” monthly results for each structure to calculate the total recharge from each structure.
6. Query for the “GW Diversion” monthly results from each of the structures. This represents the amount of supplemental pumping on lands that receive both surface and ground water supplies (i.e. co-mingled lands). Note that StateCU calculates supplemental pumping based on the amount of irrigation water requirement not met from surface water supplies and the irrigation application efficiency assigned to the structures.
7. Extend the monthly pumping and recharge data in the 2007 through 2010 time period using a wet/dry/average pattern from an “indicator” gage. Each month of the streamflow at the “indicator” gage was categorized as a wet/dry/average month through a process referred to as “streamflow characterization”. Months with gage flows at or below the 25th percentile for that month are characterized as “dry”, while months at or above the 75th percentile are characterized as “wet”, and remaining months are characterized as “average”. Using this characterization, missing data points were filled based on the wet, dry, or average pattern. For example, a data point missing for a wet March was filled with the average of other wet Marches in the partial time series, rather than all Marches. The pattern streamflow gage used is the South Platte River at Julesburg, CO (06764000).
8. Output the scaled/filled monthly pumping and recharge to a text file (WWUM_COIrrigLand_GWModel.stm) for integration into the WWUM ground water model.

For ground water aggregate structures:

1. Read the SPDSS StateCU Binary File (SP2008_crop.BD1) into TSTool.
2. Query for the “SW & GW Non-Consumed” monthly results for each of the structures, which represents the amount of non-consumed water from ground water supplies at the field (i.e. irrigation recharge).

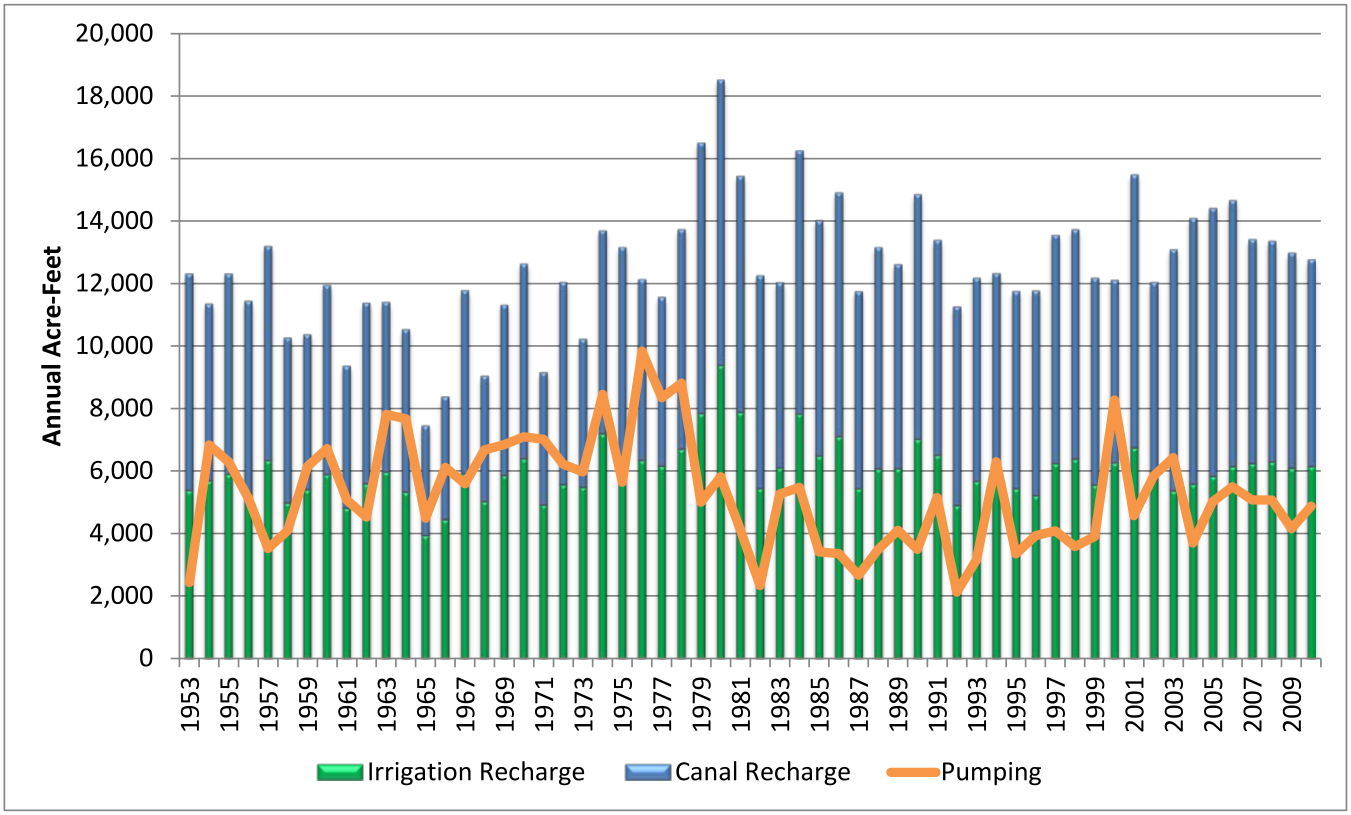
3. Query for the "GW Diversion" monthly results from each of the structures, which represents the amount of historical pumping on these lands. Note that StateCU calculates pumping based on the amount of irrigation water requirement and the irrigation application efficiency assigned to the structures.
4. Scale the monthly pumping and recharge for each structure by their respective percentages shown in **Table 1** to estimate the amount that occurs within the WWUM ground water model area.
5. Extend the monthly pumping and recharge data in the 2007 through 2010 time period using a wet/dry/average pattern from an "indicator" gage. Each month of the streamflow at the "indicator" gage was categorized as a wet/dry/average month through a process referred to as "streamflow characterization". Months with gage flows at or below the 25th percentile for that month are characterized as "dry", while months at or above the 75th percentile are characterized as "wet", and remaining months are characterized as "average". Using this characterization, missing data points were filled based on the wet, dry, or average pattern. For example, a data point missing for a wet March was filled with the average of other wet Marches in the partial time series, rather than all Marches. The pattern streamflow gage used is the South Platte River at Julesburg, CO (06764000).
6. Output the scaled/filled monthly pumping and recharge to a text file (WWUM_COIrrigLand_GWModel.stm) for integration into the WWUM ground water model.

Results: The resulting text file (WWUM_COIrrigLand_GWModel.stm) contains monthly values of pumping and recharge for the structures listed in **Table 1** for the 1953 through 2010 period. **Table 2** below summarizes the average annual pumping and recharge for the surface water structures and ground water aggregate structures, and **Figures 1 and 2** provides pumping, canal recharge and irrigation recharge over the study period.

Table 2: Average Annual Pumping and Recharge (1953 – 2010)

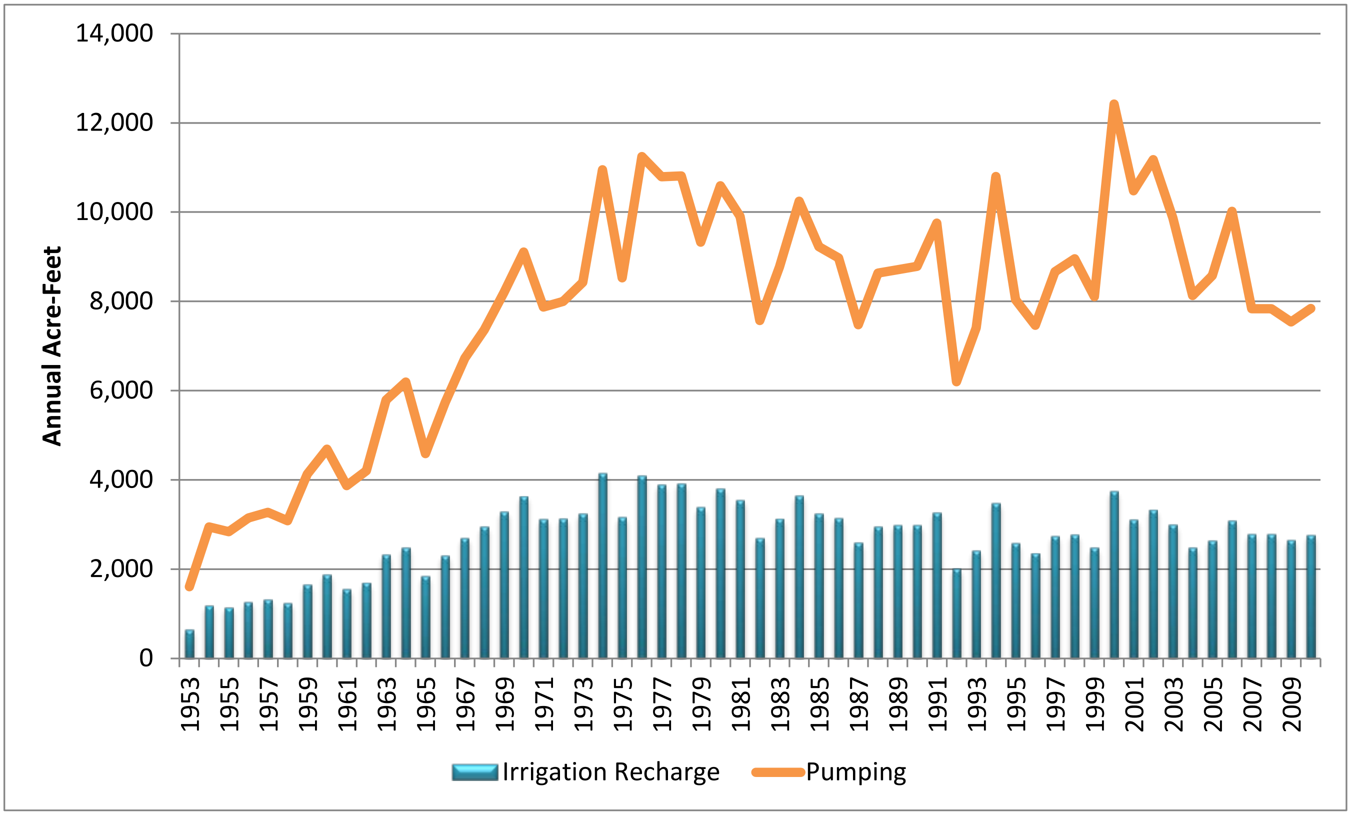
Structure Name	Ave. Annual Pumping	Ave. Annual Recharge
Liddle Ditch	267	600
Peterson Ditch	4,281	4,664
Settlers Ditch	558	308
Julesburg Irrig. District	166	6,946
District 64 GW Agg. 2	454	178
District 64 GW Agg. 3	1,552	490
District 64 GW Agg. 5	4,006	1,519
District 64 GW Agg. 6	525	196
District 64 GW Agg. 16	1,211	344
Total	**13,020**	**15,245**

Figure 1: Surface Water Structures Annual Pumping and Recharge (1953 – 2010)



The annual variability associated with recharge values can be attributed to variable hydrologic conditions each year and its impact on surface water availability and crop demand. Periods of greater water availability, such as in the early 1980's, generally lead to increased surface water diversions and resulted in increased canal and irrigation recharge. This hydrologic variability appears to have the opposite impact on pumping estimates, whereby increased water availability leads to a decrease in supplemental pumping.

Figure 2: Ground Water Aggregate Structures Annual Pumping and Recharge (1953 – 2010)



The annual variability seen in pumping and recharge for ground water structures can be attributed to the variable climatic conditions and its impact on irrigation water requirement. The general increase in pumping and recharge in the early years of the study period can be attributed to the increase in ground water acreage in the South Platte River basin.

Integration: In order to integrate the historical SPDSS pumping and recharge into the WWUM ground water model, it is necessary for the tabular information to be projected spatially. In general, the total pumping and recharge calculated for each structure was evenly distributed over the WWUM ground water model cells that coincide with the service area for the surface water structures and the irrigated acreage for the ground water aggregate structures. The *WWUM Integration and Calibration Plan* report provides more detail on the integration of this information into the ground water model.