IV. Augmentation Plan Requirements and Supplies

The South Platte River
and Alluvial Aquifer
HB 1278 South Platte Groundwater Study

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IV. Augmentation Plan Requirements and Supplies

a. Summary of Wells Associated with Augmentation Plans

HB 1278
Summary of Wells Associated with Augmentation Plans
September 13, 2013

The Colorado Water Institute has requested assistance with estimating the number of wells associated with augmentation plans, and comparing this information to the SPDSS Task 7.2 – Well Use and Well Augmentation Plans memorandum. The following approach was used to collect well count information and develop the summaries discussed herein.

Approach

1. **Review Task 7.2 memorandum to understand how well count information was collected and summarized.** The SPDSS Task 7.2 effort consisted of an in-depth review of large-scale augmentation plans in the South Platte River Basin in order to develop a modeling approach for overall SPDSS modeling efforts. The in-depth review for the large-scale plans consisted of mapping of wells and associated acreage, interviewing plan representatives, reviewing decrees for the history and operational details of the plans, and comparison of wells included in the decree versus those reflected in the HydroBase Structure Association Table (from 2006) and tied to CDSS 2001 irrigated acreage. The memorandum also developed recommendations for representing the augmentation plan components in future consumptive use and surface water modeling efforts. Table 4 from the memorandum, shown here, summarizes the number of wells included in each augmentation plan based on the 2006 HydroBase Structure Association Table *and* tied to CDSS 2001 irrigated acreage as noted in the footnotes.

Well Augmentation Plans in SPDSS Study Area

No.	Plan Name	Plan ID	Plan Wells*	Plan Acreage
1	CENTRAL REPL	0203334	857	54,415
2	CENTRAL WAS AUG	0203394	401	29,382
3	LOGAN WELL USERS AUG	6402539	307	28,176
4	BIJOU AUG PLAN	0103339	196	24,859
5	POUDRE PLAN	0303336	709	23,584
6	LOWER LOGAN WELL USERS A	6402536	129	12,841
7	LOWER PLATTE BEAVER AUG	0102535	95	12,816
8	SEDGWICK CTY WL USERS A	6402517	121	11,235
9	UPPER PLATTE BEAVER AUG	0102529	88	10,263
10	FT MORGAN CNL AUG PLAN	0102528	85	10,208
11	LOWER LATHAM RES CO AUG	0103332	89	9,073
12	RIVERSIDE AUG	0102522	88	6,299
13	ORPHAN WELLS OF WIGGINS AUG	0102557	37	5,189
14	HARMONY DITCH CO AUG	6402518	44	4,266
15	ROTHE AUG	0102513	17	4,232
16	NEW CACHE AUG	0103397	116	4,085
17	LSPWCD AUG	6402542	45	3,584
18	UNION DITCH AUG	0202539	46	3,130
19	PIONEER AUG PLAN	0102518	32	2,596
20	LOW LINE DITCH CO AUG	6402540	14	2,480
21	NORTH STERLING AUG	6403392	20	2,317
22	DINSDALE AUG	6402519	15	2,289
23	CONDON AUG	6402525	13	2,242
24	NATIONAL HOG FARMS AUG	0102624	5	2,216
25	WATER SUPPLY STRG AUG	0303399	70	1,931
		TOTALS*	3,639	273,708
26 to 125	SMALLER PLANS ASSOCIATED TO WELLS IN HYDROBASE	Various	201	25,240
		TOTALS*	3,840	298,948

ource: SPDSS 2001 GIS Irrigated Acreage Assessment (June 19, 2007) and HydroBase (V20060816).

2. **Obtain available HydroBase Structure Association Tables.** The Structure Association Table associates augmentation plans with structures that are included in their *decrees at the time the table was queried from HydroBase*. This results in a "snapshot" of the wells, recharge areas, impact reaches, etc. associated with an augmentation plan on a specific date (i.e. when the table was queried from HydroBase). The Division of Water Resources makes changes daily, as necessary, based on water court actions and decrees for the augmentation plans keeping the Structure Association Table in HydroBase current. Therefore, several lists or "snapshots" are necessary to understand general trends of changes to augmentation wells over time. Available lists for the comparison summarized herein were from November of 2006, February of 2007 and September of 2013 (referred to by their years in this summary).

3. **Query the wells associated with the large-scale augmentation plans identified in Task 7.2.** Previous review of augmentation supplies and augmentation requirements for the HB 1278 confirmed that the augmentation plans in Task 7.2 still include the large-scale plans in the basin. Additionally, the Groundwater Appropriators of the South Platte (GASP) was historically significant in the basin, but was no longer in operation at the time of the Task 7.2 efforts, therefore not included. The list of augmentation plans presented in Table 4 of Task 7.2 was used to query and summarize well counts by augmentation plan for this effort.
    a. As noted in the Task 7.2 memorandum, wells are often associated with more than one augmentation plan. For example, due to the quotas assigned to Central GMS and WAS augmentation plans, well users have also sought augmentation supplies from other augmentation plans and their well is now associated with more than one plan. This one-to-many association was carried forward into this summary as well, as an indicator to the size of each augmentation plan.
    b. This summary, however, does not limit the well counts based on their association with irrigated acreage, primarily due to the complication of which irrigated acreage assessment is representative of which association table list (e.g. 2001, 2005, 2012 acreage assessments vs. 2006, 2007, 2013 lists). An additional complication is the fact that the irrigated acreage assessments, particularly the subset of wells assigned to acreage served by groundwater, is currently under review at the Division of Water Resources. Therefore any comparison to irrigated acreage would be quickly outdated as the acreage assessments will be revised soon.
    c. Structure type is designated in the Structure Association Table; structures with a Structure Type = Well (2) or Well Field (WF) were queried for this summary. This filter limits the list to well structures only, and prevents the inclusion of other structures such as recharge areas, impact reaches, ditches, and reservoirs that may

be associated with a plan. The query and filter efforts were completed in a spreadsheet (Task7.2_Comp_and_PlanAugReqDeplComp.xlsx)

Summary of Results

The following table summarizes the number of wells associated with the augmentation plans originally presented in the Task 7.2 memorandum.

Table 4.1. Wells associated with augmentation plans originally presented

No.	Plan Name	Plan ID	2006 List	2007 List	2013 List
1	CENTRAL GMS AUG	0203334	929	930	950
2	CENTRAL WAS AUG	0203394	432	219	247
3	LOGAN WELL USERS AUG	6402539	389	376	438
4	BIJOU AUG PLAN	0103339	207	207	208
5	POUDRE PLAN	0303336	852	854	958
6	LOWER LOGAN WELL USERS A	6402536	161	161	163
7	LOWER PLATTE BEAVER AUG	0102535	105	105	102
8	SEDGWICK CTY WL USERS A	6402517	142	142	142
9	UPPER PLATTE BEAVER AUG	0102529	96	96	96
10	FT MORGAN CNL AUG PLAN	0102528	105	104	101
11	LOWER LATHAM RES CO AUG	0103332	59	59	91
12	RIVERSIDE AUG	0102522	123	123	131
13	ORPHAN WELLS OF WIGGINS AUG	0102557	43	46	4
14	HARMONY DITCH CO AUG	6402518	48	49	49
15	ROTHE AUG	0102513	21	21	13
16	NEW CACHE AUG	0103397	119	88	63
17	LSPWCD AUG	6402542	64	64	77
18	UNION DITCH AUG	0202539	46	46	31
19	PIONEER AUG PLAN	0102518	38	36	33
20	LOW LINE DITCH CO AUG	6402540	16	17	17
21	NORTH STERLING AUG	6403392	47	47	49
22	DINSDALE AUG	6402519	24	24	25
23	CONDON AUG	6402525	22	23	22
24	NATIONAL HOG FARMS AUG	0102624	9	9	8
25	WATER SUPPLY STRG AUG	0303399	72	72	84
		TOTALS*	4,169	3,918	4,102
26 to 125	SMALLER PLANS ASSOCIATED TO WELLS IN HYDROBASE	Various	5,388	5,582	7,713

Notes: *Well totals reflect wells and well fields associated with augmentation plans in Division 1, not limited based on irrigated acreage or other considerations. Wells included in Plan IDs are not unique since multiple wells may be associated with multiple plans in HydroBase.

Refer to row number for the following notes:

1. Includes Plan IDs 0103334, 0203334, 0303334, 0403334, and 0503334 since Central GMS Aug wells assigned to different Plan IDs based on Water District where well is located.
2. Includes Plan IDs 0103394, 0203394, 0303394, and 0403394 since Central WAS Aug wells assigned to different Plan IDs based on Water District where well is located.
3. Includes Plan IDs 6402537, 6402539, 6402546, 6402547, 6502548, and 6402554 to account for Logan Well Users and other well users included in original Logan Well Users decree that subsequently split off to form their own plans, which commonly use the same augmentation sources.
4. Includes Plan IDs 0103339 and 0102574 to account for Bijou Canal wells and five wells in Fort Morgan Farms augmentation plan that irrigate the same lands as those irrigated by Bijou Canal wells.
5. Includes Plan IDs 0103336, 0203336, and 0303336.

12. Includes Plans IDs 0102522, 0102525, 0102536, 0102581, and 0102725 to account for well users under Riverside Canal that receive surface water deliveries from Riverside Canal and share the same augmentation sources.

Results Observations

- The general increase in total wells associated with augmentation plans throughout Division 1 may be a result of more strict administrative of augmentation plans after the early 2000s drought, and then subsequent water court action and decrees reflecting revisions to augmentation plans. It may also be a result of wells seeking more than one augmentation supply due to quotas put in place by the Central Augmentation Plans.
- The drop in Central WAS Aug plan wells from 2006 to 2007 is likely a result of water court action and changes to the augmentation plan decree between the 2006 and 2007 lists.
- Many augmentation plans, primarily those with sufficient supplies, have maintained the same number of wells throughout the 2006 to 2013 period. Due to drier hydrology and potentially insufficient augmentation supplies, well users have likely “migrated” to augmentation plans with more reliable supplies or those with the financial ability and opportunity to obtain additional supplies.
- Efforts have been made in recent years to “clean” up augmentation plan decrees, and wells have been removed or added to more accurately reflect the wells that are currently operational under the plan. Note that augmentation plans can include wells used to meet many uses, including agricultural, municipal, or industrial.
- Although trends can be gleaned from this summary, additional lists back in time or annual lists between 2007 and 2013 would be beneficial in providing a more complete “picture” of the wells associated with augmentation plans.
- An additional aspect of the Task 7.2 memorandum is the identification of augmentation plan supply structures and water rights. A quantitative analysis based on a comparison of associated structures between the 2006 and 2013 lists is difficult due to a more detailed coding approach reflected in 2013 (e.g. more explicit WDID assignment to recharge areas and impact reaches) and due to the format of the Task 7.2 summary of supplies. The following general observations were made based on a qualitative review:
    - The number of associated recharge areas for each augmentation plan has generally increased from 2006 to 2013 correlating with the number of new areas constructed.
    - The quantity associated with direct rights changed for augmentation has a seen a smaller increase.
    - Based on recent diversion coding, it appears that more reusable effluent is being used as an augmentation supply.

- There has been more short-term or intermittent leasing of excess augmentation supplies.
- Based on discussions with Division of Water Resources staff, augmentation plan operators have increased the options associated with their supplies, including filing for exchange of unused credits for re-diversion into recharge areas.
- New leasing markets for augmentation credits, and the prospect of rotational fallowing programs, will likely change the "look" of augmentation supplies in the future.

Comments, Concerns, and Recommendations

The following summarizes comments and concerns with the development of this summary, the data products used in this summary as well as the augmentation plan supply and requirement summary, and recommendations for improvement.

- In order for a more accurate comparison of augmentation requirements and supplies to be made, it is necessary to have not only the HydroBase Structure Association Table list that corresponds to each irrigated acreage assessment, but also interim lists to see how associated supply and requirement structures may have changed between assessment years. It is recommended that changes to the HydroBase Structure Association Table be "time-stamped" and historically active well associations and augmentation plans remain in the table. Comments on the reason behind a change to the table, or at a minimum a water court case number, should also be captured.
- For this HB 1278 analysis, as well as the current SPDSS analysis, pumping and augmentation requirements have been estimated based on a full supply because metered pumping is generally not available in HydroBase. For this analysis alone, it was necessary to estimate the portion of pumping assigned to each well based on its assignment to irrigated acreage and the crop irrigation requirement, and then estimate the portion of the total depletions that may be attributable to more than one augmentation plan. Each level of estimation introduces error, which may be partially alleviated by the availability of pumping records. It is recommended that metered pumping be made available in HydroBase as soon as possible in order to more accurately reflect total pumping and augmentation requirements.
- For many augmentation plans prior to 2010, the diversion or release class does not include sufficient information to account for the diversion from a specific source, to a specific destination, and attributable to a specific augmentation plan. The Division of Water Resources new diversion coding standards will address this issue by requiring specific information in each coding. Although the new diversion coding standards have been fully implemented by Division Offices and Water Commissioners, the version of

HydroBase made available to the public allows only partial viewing of the new coding. It is recommended that the HydroBase structure be revised in order to accommodate the new coding.

- In addition to the new coding standards, the Division of Water Resources as well as the Colorado Water Conservation Board through their CDSS modeling efforts have improved the accuracy, availability, and detail of information in HydroBase and CDSS products. This includes, but is not limited to, more accurate locations of wells due to GPS measurements, more accurate assignments of surface and groundwater supplies to irrigated acreage in the CDSS acreage assessments, and more detailed identification and coding of augmentation plan impact reaches and other recharge structures. Additionally, staff at both agencies have been supportive of these planning and investigative efforts, and have made themselves available to answer questions and provide information as requested.
- Currently HydroBase is made available to the public on an annual basis by the Division of Water Resources, capturing the water resources data for the period up to the date the database is distributed. As noted herein, changes to the HydroBase Structure Association Table can occur daily based on water court activity. It is recommended that distribution of the HydroBase database be made more frequently, perhaps semi-annually, by the Division of Water Resources.
- In order to estimate the impact of a well depletion to the river, it is necessary to know the total amount of well pumping, the portion of the pumping that was consumptively used, and the decreed lagging pattern of the depletion to the river. These factors, even generally, are included in decrees available through the Division of Water Resources Laserfiche system, however it is laborious to obtain the information for a large number of wells. The AAADAT project currently underway may develop a procedure or platform to easily access and organize this decreed information, and consideration should be made to integrate it with HydroBase data and make it available to the public.

IV. Augmentation Plan Requirements and Supplies

b. Summary of Potential Augmentation Requirements and Augmentation Supplies (Groundwater Depletions)

HB 1278
Summary of Augmentation Requirements and Augmentation Supplies
September 10, 2013

The Colorado Water Institute has requested assistance with developing estimates of total pumping and depletions, associated augmentation requirements, and augmentation plan supplies for the lower South Platte basin (Water Districts 1, 2, and 64.) The graphs below summarize the following parameters by Water District.

- Total Groundwater Diversions for Irrigation (Pumping) is estimated based on crop consumptive needs and application efficiency after surface water supplies, if any, are taken into account.
- Total Groundwater Crop Consumptive Use is the portion of pumping that is consumed by crops, including the portion temporarily stored in the soil moisture reservoir prior to be consumed by crops. For this analysis, groundwater crop consumptive use was considered in two ways:
    - Non-Depletive Groundwater is the portion of groundwater crop consumptive use that is estimated not to deplete flows in the South Platte or is decreed as non-depletive. Non-depletive groundwater is further divided into two categories:
        - Ground water consumptive use in designated groundwater basins
        - Ground water consumptive use from Coffin Well pumping
    - Groundwater Depletions are the portion of total groundwater crop consumptive use that is estimated to deplete flows in the South Platte. These groundwater depletions generate Augmentation Requirements when the depletions impact the river at the time when there is a senior call. For this trend analysis, the lagged timing of the depletions and the call regime is not considered; instead monthly depletions are summed on an annual basis as estimated to require full augmentation. Ground water depletions were further divided for the analysis into two categories:
        - Depletions that are associated with an augmentation plan
        - Depletions that could not be readily tied to an augmentation plan
- Augmentation Supplies are the supplies associated with augmentation plans, used to cover augmentation requirements when there is a senior call on the river. For this analysis, annual supplies, some of which include lagged recharge, are summed on an annual basis. Augmentation supplies are further divided into two general categories:
    - Recharge Augmentation Supplies include water diverted for in-ditch recharge or to recharge ponds. The lagged timing of these recharge supplies is not specifically considered. Instead, the monthly diversions to recharge are summed on an annual basis and trends are considered based on a decadal average. Note that recharge augmentation supplies accrue to the river regardless of whether a call requires augmentation during that time period.

- Surface Augmentation Supplies include controlled water released from a storage reservoir; water diverted and released to the river via an augmentation station; and reusable effluent. Surface augmentation supplies only are released to the river when a call requires augmentation during that time period.

In addition, graphical comparisons of augmentation requirements and associated augmentation supplies are also shown by Water District and for the larger augmentation plans. Following each graph are comments on the development and observations on the general trends of each parameter. Recommendations on future data collection and analyses to better track and understand pumping depletions, associated augmentation requirements, and augmentation supplies are also summarized.

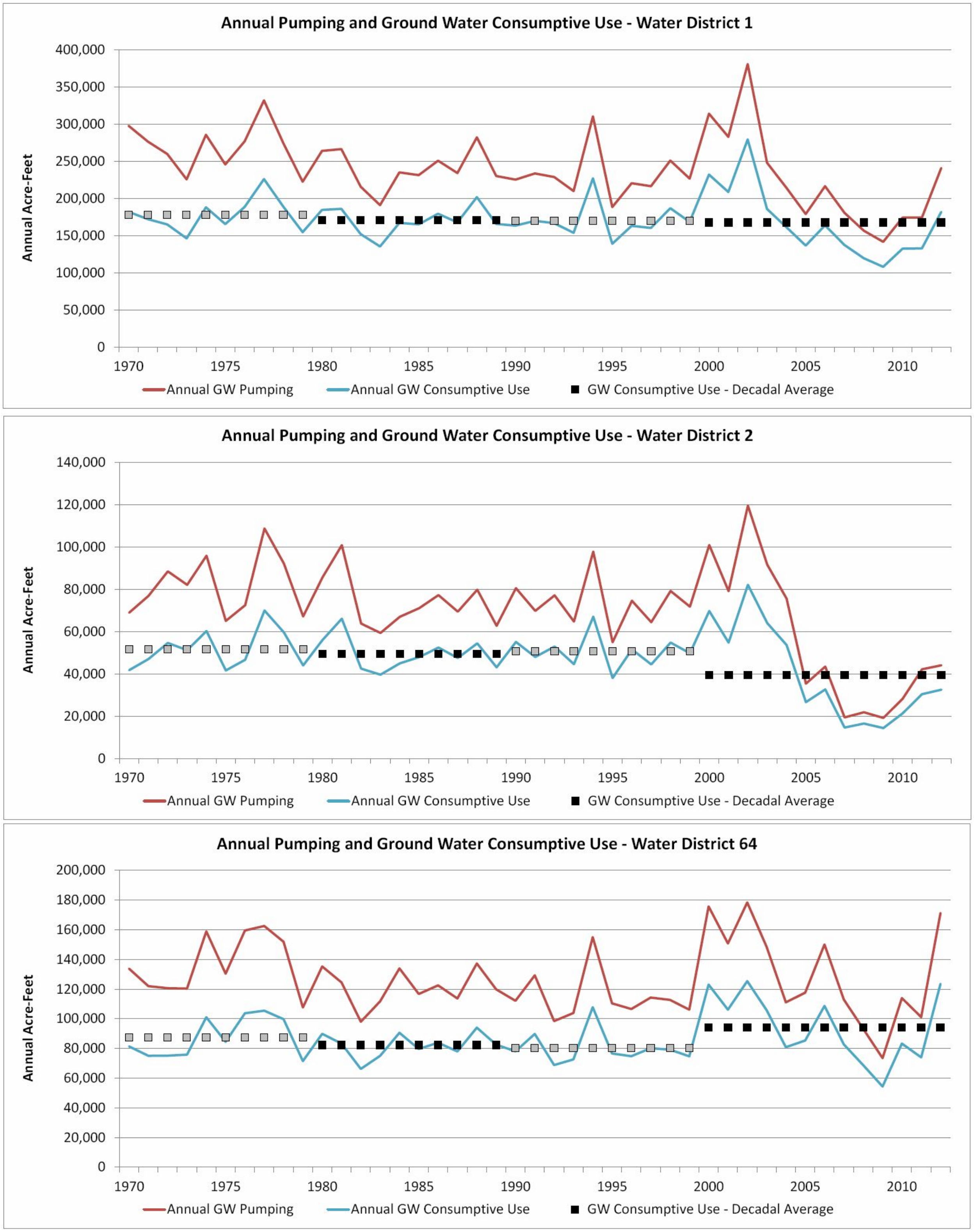

Figure 4.1.Total Groundwater Pumping and Crop Consumptive Use

- Pumping is estimated based on crop irrigation water requirement plus an on-farm application efficiency value associated with flood and sprinkler application methods less any surface water supplies, as estimated by the StateCU analysis initially developed for the South Platte Decision Support System. Estimated pumping for wells included in Central Colorado Water Conservancy District's WAS and GMS augmentation plan, generally in Water Districts 1 and 2, were reduced based on annual quotas, ranging from 0 to 50 percent over the 2005 to 2012 period.
- The difference between pumping and consumptive use reflects the portion of the pumping that is not consumed by the crops and returns to the river or aquifer if in a designated basin. The difference generally decreases over time reflecting the trend towards sprinkler irrigation.
- Annually variability of the pumping can be primarily attributed to varying climate conditions, plus some changes in irrigated acreage. In each of the three Water Districts, irrigated acreage peaked in the mid-1980s; then began to decrease after 2001. Acreage decreased the least in Water District 64; therefore the variability and increase for the 2000 through 2012 average seen in that Water District can be attributed primarily to climate variability.
- The greatest pumping and consumptive use occurs in Water District 1, which correlates with the large amount of acreage served only by groundwater in that District.
- Reduced pumping in Water District 2 after the early 2000 drought likely represents that many wells were not fully covered under augmentation plans; therefore were forced to restrict pumping. Water District 64 has the most recharge and surface augmentation sources; and increased pumping reflects limited surface water due to dryer hydrology.
- Note that consumptive use values shown in these graphs do not take into account the lagged depletive impact at the river.

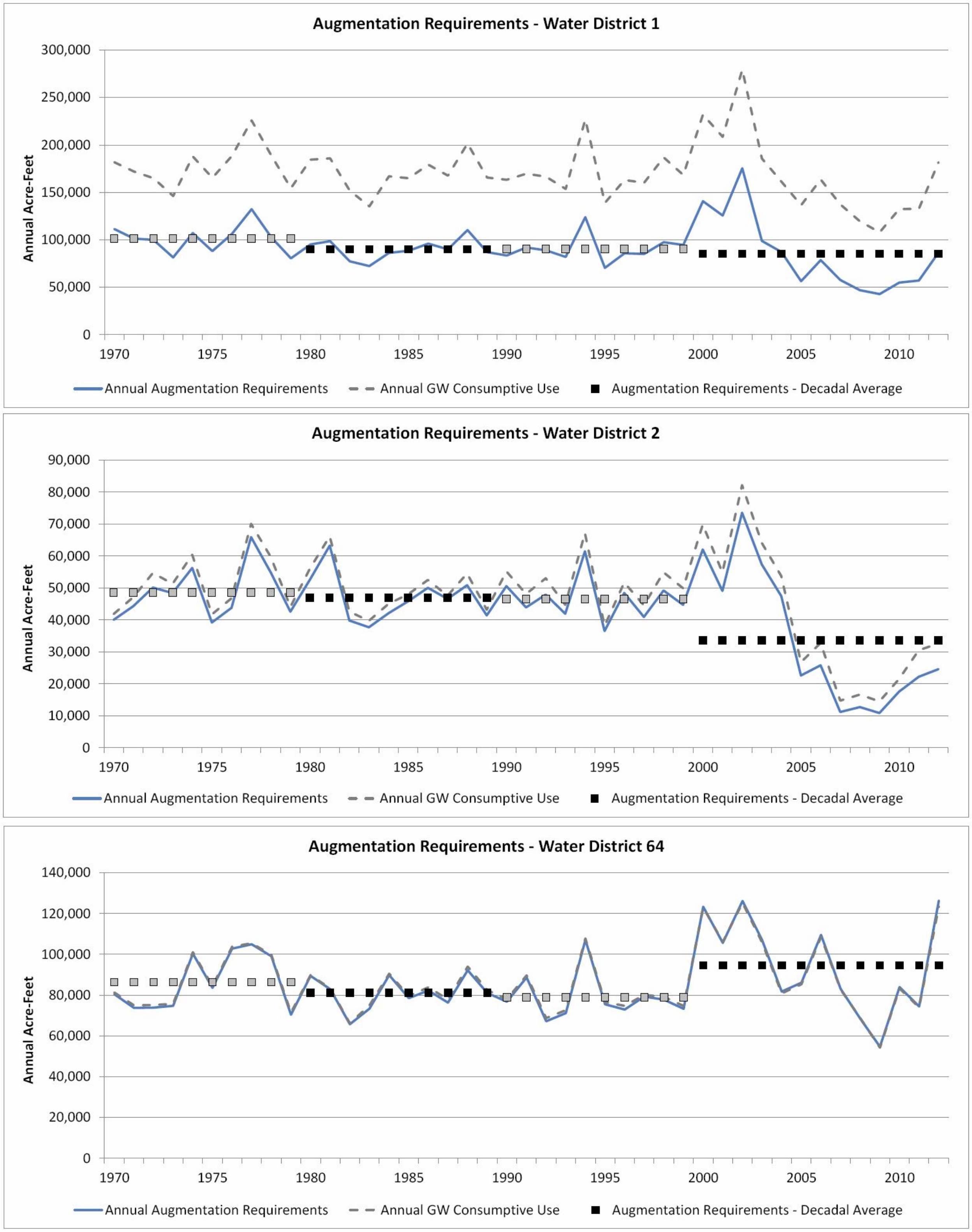

Figure 4.2. Potential Augmentation Requirements (Groundwater Depletions)

- Augmentation requirements were determined by summing the depletions from wells associated with an augmentation plan based on the HydroBase association table from 2007. The 2007 table is more representative of the wells assigned to the 2005 irrigated acreage assessment, used to represent the 2000 to 2012 decade.
- As discussed above, not all groundwater pumping causes depletions to the river; and depletions do not require augmentation if there is not a senior call on the river. The annual augmentation requirements shown in this graph do not represent lagging; nor are they reduced for times when there is not a senior call.
- Consumptive use from Designated Groundwater Basin wells, Denver Basin wells, and "Coffin Wells" does not require augmentation. Consumptive use associated with these wells accounts for the difference between Total Consumptive Use and Augmentation Requirements in the graphs above.
- As shown, Water District 1 has the largest differential between Total Consumptive Use and Augmentation Requirements, which correlates to the large amount of acreage located in designated groundwater basins in that water district.
- Augmentation requirements are greatest in Water District 64, corresponding to significantly more acreage supplied by groundwater in the basin than other Water Districts.
- Augmentation requirements increase in Water District 63, again corresponding to the dryer hydrology and reduce available surface water to meet irrigation needs.

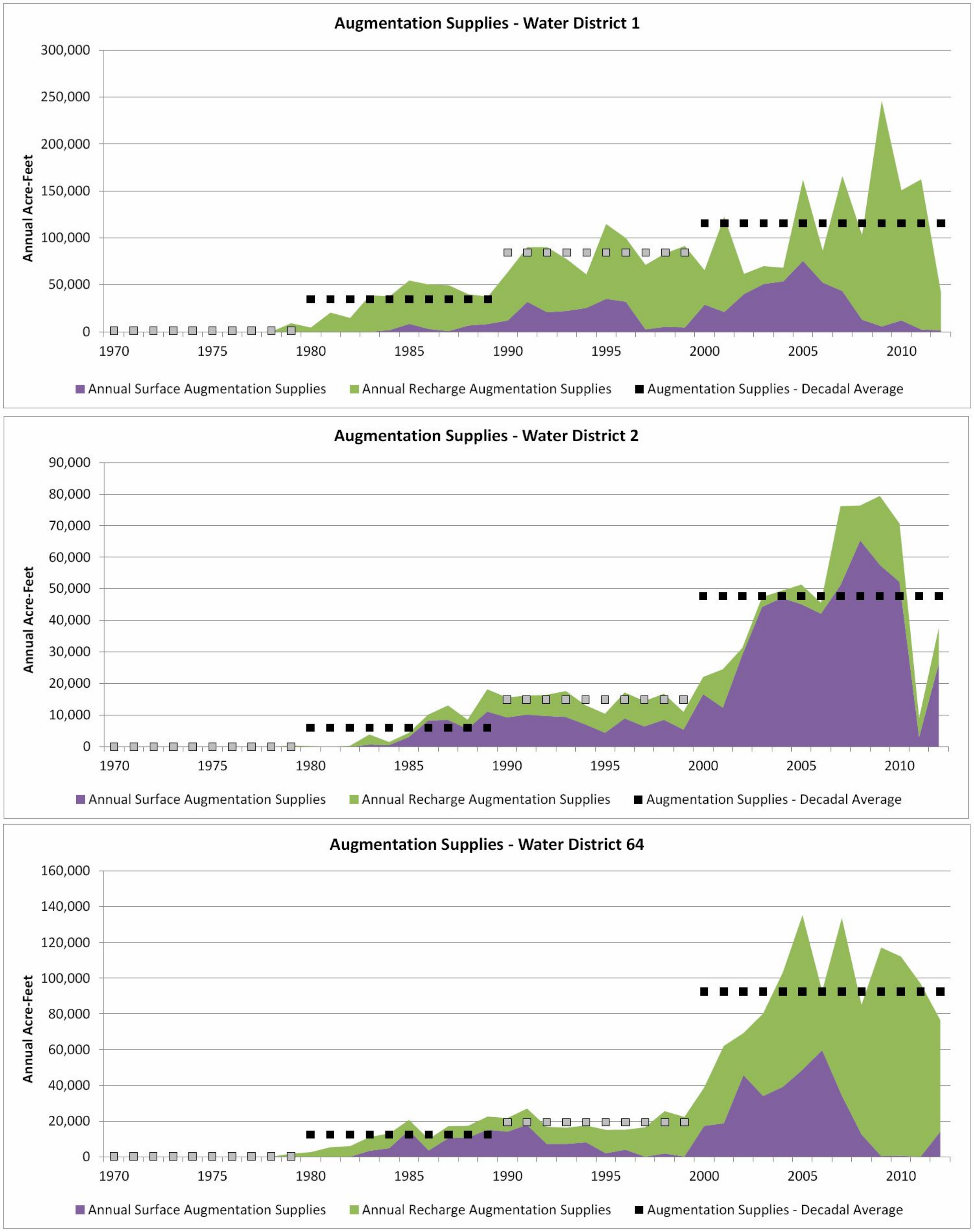

Figure 4.3. Augmentation Supplies

- Based on discussions with DWR staff, diversions to recharge areas are designated in diversion and release classes using a Use Type = Recharge (R). Recharge augmentation supplies are a “lagged” or “timed” source of augmentation plan supply measured at the recharge area site, whereby the diversions are made in advance of the depletions and timed such that the recharge accretions are available to offset future depletions.
- Based on discussions with DWR staff, augmentation released directly to the river (Surface Augmentation Supply) is designated in diversion and release classes using a Use Type = Augmentation (A). Direct augmentation can be considered a “controlled” and more “immediate” type of augmentation plan supply, as opposed to lagged recharge area seepage which accrues to the river even if it is in excess of an augmentation demand.
- The graphical display of recharge augmentation supply is the result of querying HydroBase for water classes with U:R coding, assigning these classes to augmentation plans, then aggregating this augmentation supply by Water District. Water classes were assigned an augmentation plan based on the Group ID included in the water class, the associated augmentation plan based on the HydroBase association table, or the From ID included in the water class if it was in an augmentation plan. Because each water class was assigned to an augmentation plan, the diversions could be appropriately assigned to more than one augmentation plan. For those diversions to recharge not tied to a specific augmentation plan, the diversion was evenly split between the multiple augmentation plans identified in the HydroBase association table.
- The graphical display of surface augmentation supply is the result of querying for water classes with U:A coding, assigning these classes to augmentation plans, then aggregating this augmentation supply by Water District. Water classes were assigned an augmentation plan based on the augmentation plan the class was recorded under, the Group ID included in the water class, the associated augmentation plan based on the HydroBase association table.
- These estimates of recharge supply queried directly from HydroBase were reasonably correlated to annual estimates provided by DWR staff. Deviations from the DWR estimates are generally caused by lack of Group ID designation in water classes. • The increase in recharge augmentation supply in the 2000s is a result of a rise in recharge areas constructed in the Lower South Platte Basin and a more complete recording of classes with U:R coding – specifically in Water District 64.
- Surface augmentation supply reflects releases for augmentation from reservoirs such as Jackson Lake and Prewitt Reservoir, groundwater diversions from augmentation/recharge wells, bypassed diversions measured at augmentation stations, and other sources of direct augmentation.
- The increase in surface augmentation supply from the 1990s to the 2000s is likely a combination of more complete recording of classes with U:A coding and the increased administration after the drought of the early 2000s.

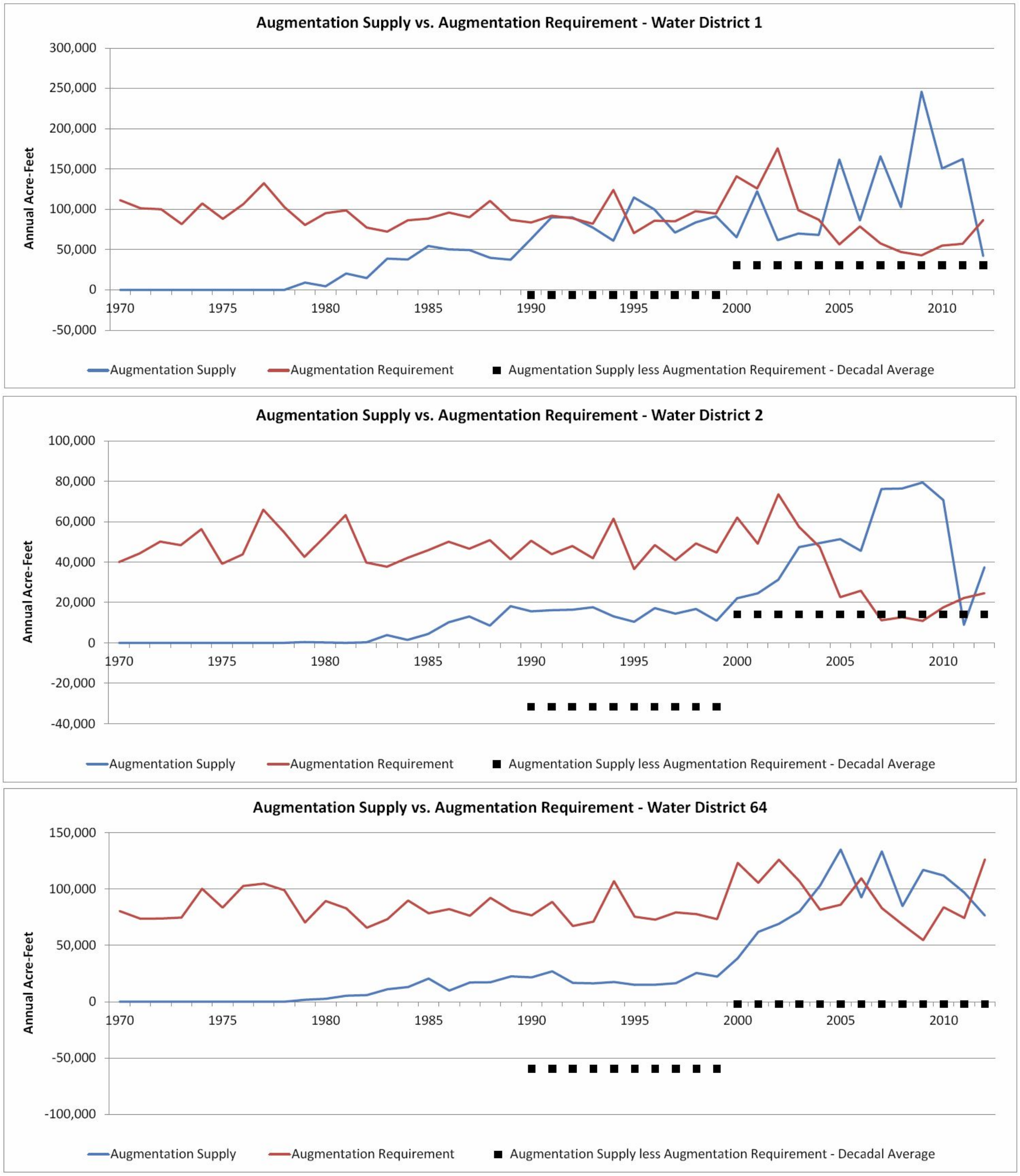

Figure 4.4. Total Augmentation Supply vs. Potential Augmentation Requirements (Groundwater Depletions)

- The decadal averages on the graphs show that augmentation requirements exceeded augmentation supply in Water Districts 2 and 64 prior to more strict administration beginning after the drought in the early 2000s.
- Augmentation requirements and augmentation supply in Water District 1 appear to have generally balanced well beginning in the early 1990s.
- Augmentation supply is greater than augmentation requirements by approximately 25 to 30 percent in Water Districts 1 and 2 based on the 2000 decadal average. This likely reflects both the increase in recharge site construction, and some higher runoff flows available to divert for recharge.
- The 2000 decadal average for Water District 64 reflects balanced augmentation supply and requirement.

IV. Augmentation Plan Requirements and Supplies

d. Summary of Depletion Patterns in Water Districts 1 and 64

The Colorado Water Institute has requested assistance with investigating the depletion patterns for irrigation wells in the South Platte Basin. For this analysis, Wilson Water Group used the depletion/return flow patterns developed for the SPDSS Lower South Platte StateMod model. The patterns were originally developed by Ray Bennett while working for the Colorado Division of Water Resources, and documented in the draft *Appendix G, Lower South Platte Surface Water Model, Return Flow and Depletion Location Development* memorandum. This memorandum, attached at the end of this summary, discusses the pattern development approach and includes the Glover parameters used to develop the patterns. In general, the following approach was used to develop the patterns:

- The *unit response* patterns are unit-less and reflect the percent of the total depletions that would deplete the river in any given month.
- A Glover analysis was performed using the AWAS modeling tool at points representing the general centroid of each irrigation district or aggregate of groundwater only lands.
- Glover parameters, including transmissivity, specific yield, distance to the aquifer boundary, and distance to the stream, were collected from individual SPDSS modeling efforts (SPDSS Task 43.3 - South Platte Alluvium Region Aquifer Property Technical Memorandum and SPDSS Task 42.3 South Platte Alluvium Region Aquifer Configuration Technical Memorandum) and through spatial mapping analyses.
- The maximum number of months for the patterns was set to 120 months or the number of months necessary to achieve 95 percent of the full depletion. The last 5 percent of depletions were normalized over the pattern to result in patterns that equal 100 percent.
- Patterns range from 9 to 120 months, with a maximum of 76.5 percent depleting the river in the first month.
- The resultant patterns were formatted in the Monthly Unit Response File (*.urm) for input into the Lower South Platte StateMod model; example patterns are shown below.

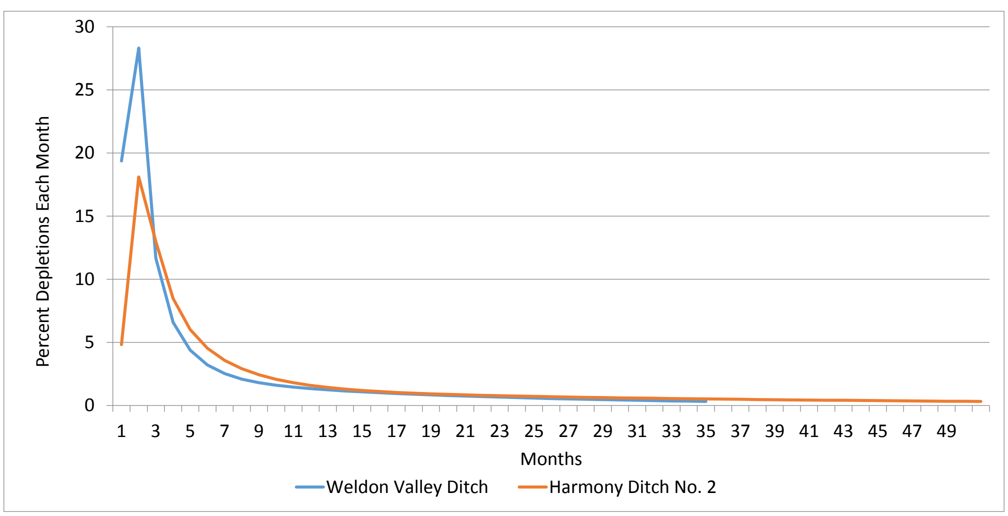

Figure 4.5. An example of patterns seen in Lower South Platte StateMod model

For this effort, the patterns were assigned to each irrigation structure found in the SPDSS modeling effort to assess how quickly the depletions from the groundwater pumping would impact the nearest live stream (i.e. the South Platte River mainstem in most instances). Irrigation structures located within Designated Groundwater Basins are not depletive of the river, and therefore excluded from this pattern analysis.

Of the 356,246 acres of irrigated land in Water Districts 1 and 64 (CDSS 2001 Irrigated Acreage Assessment), approximately 17 percent is located in Designated Groundwater Basins. The remaining 296,606 acres of irrigated land receive either a sole or supplemental supply of groundwater that can be considered depletive to the river.

Although statistical analysis could be performed on all of the patterns to determine the average, maximum, minimum patterns in the basin, this analysis would not reflect the fact that some patterns are associated with very little acreage. For example, the pattern for North Sterling Irrigation District can be applied to the depletions from supplemental pumping on over 36,000 acres, whereas the pattern for Harmony Irrigation District can be applied to the depletions from supplemental pumping on only 11,000 acres. To "weight" the patterns, two thresholds (50 percent and 75 percent) were selected to reflect the sum of the depletions that occur in a given time frame (i.e. three months, six months, one year and three years) within each threshold. For example, 75 percent of the depletions associated with 17,869 acres of irrigated land impact the river in the first three months. This acreage amount corresponds to 6 percent of the total acreage in the South Platte Basin outside of Designated Groundwater Basins. If a 50 percent threshold is applied, 50 percent of the depletions associated with 43,881 acres of irrigated land impact the river in the first three months.

The following tables summarize the information in the example above and expand the assessment into further time frames.

Table 4.2. Timing and Acreage for 75 Percent of the Depletions to Impact the River

Timing	3 Months	6 Months	1 Year	3 Years
Acres	17,869 acres	28,939 acres	66,121 acres	285,056 acres
Percent of WD 1+64 Acreage not in Design. Basins	6%	10%	22%	96%

Timing and Acreage for 55 Percent of the Depletions to Impact the River

Timing	3 Months	6 Months	1 Year	3 Years
Acres	43,881 acres	99,681 acres	256,571 acres	285,056 acres
Percent of WD 1+64 Acreage not in Design. Basins	15%	34%	87%	96%

Timing of depletions is an important component when analyzing streamflow in the South Platte River. **The conclusion that can be drawn from this assessment is that for much of the acreage in the basin, the depletions do not fully reach the river within the irrigation season or even in the same year. A large majority of the depletions, however, do impact the river within 3 years, which supports the HB 1278 5-year average assessment period.**
Another analysis was performed to investigate the use of recharge pits that have the same lagged return flow pattern as well depletions. The following graph provides an illustration of the following:

1) Users pump 100 acre-feet each irrigation season based on a typical pumping pattern; causing an unlagged depletions = 60 acre-feet (equal to Crop Consumptive use, example assumes flood irrigation at 60 percent efficiency).
2) The lagged depletion pattern used for this example returns less than 1 percent in the first month of pumping. This pattern is representative of approximately 59 percent of the acreage irrigated in Water Districts 1 and 64.
3) Recharge sites with the same depletion pattern require junior diversions totally 80 acre-feet during the runoff months (assume water is available only in May and June) to meet the winter depletions obligations once a steady-state pattern has been reached (approximately 4 years).

This example assumes ALL depletions will be covered by recharge pits in the same vicinity as the irrigated lands and that there is ALWAYS a call on the river. It ignores the other important “direct augmentation” options including augmentation wells and surface reservoir releases.

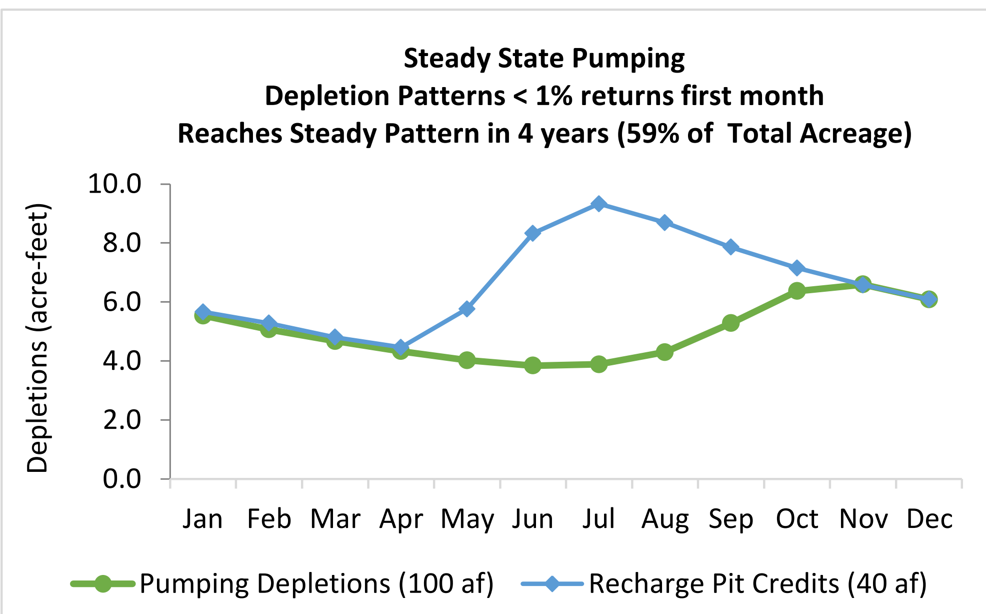

Figure 4.6. Steady state pumping depletion patterns <1% returns first month reaches steady pattern in 4 years (59% total acreage)

The following similar graph provides an illustration of the following:

1) Users pump 100 acre-feet each irrigation season based on a typical pumping pattern; causing an unlagged depletions = 60 acre-feet (equal to Crop Consumptive use, example assumes flood irrigation at 60 percent efficiency).
2) The lagged depletion pattern used for this example returns between 1 and 10 percent in the first month of pumping. This pattern is representative of approximately 23 percent of the acreage irrigated in Water Districts 1 and 64.
3) Recharge sites with the same depletion pattern require junior diversions totally 110 acre-feet during the runoff months (assume water is available only in May and June) to meet the winter depletions obligations once a steady-state pattern has been reached (approximately 3 years).

As with the previous example, this example assumes ALL depletions will be covered by recharge pits in the same vicinity as the irrigated lands and that there is ALWAYS a call on the river. It ignores the other important "direct augmentation" options including augmentation wells and surface reservoir releases.

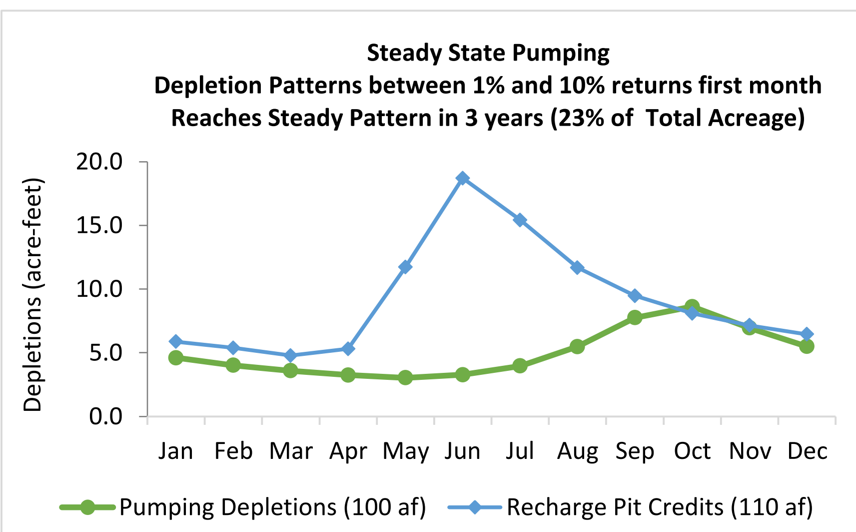

Figure 4.7. Steady state pumping depletion patterns between 1% and 10% returns first month reaches steady pattern in 3 years (23% of total acreage)

IV. Augmentation Plan Requirements and Supplies

d. District Figures

Table 4.3. Groundwater Diversions by Water District, 1950-2012.

Groundwater Diversions by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1950	137,373	47,681	30,858	215,912
1951	109,915	31,393	26,782	168,090
1952	176,075	49,004	45,073	270,152
1953	158,420	53,691	38,934	251,045
1954	245,330	132,689	79,364	457,383
1955	241,122	94,834	74,977	410,933
1956	261,242	113,181	70,073	444,496
1957	161,432	53,656	61,740	276,828
1958	192,291	70,054	71,040	333,385
1959	243,505	78,533	90,561	412,599
1960	271,427	90,396	93,321	455,144
1961	178,828	43,729	76,294	298,851
1962	210,336	70,302	70,455	351,093
1963	297,247	113,800	107,148	518,195
1964	319,326	111,853	132,662	563,841
1965	179,452	50,461	86,205	316,118
1966	296,476	93,681	110,702	500,859
1967	195,947	59,997	101,438	357,382
1968	265,739	84,981	113,277	463,997
1969	272,505	74,395	126,610	473,510
1970	297,576	68,993	133,739	500,308
1971	276,295	76,955	121,960	475,210
1972	259,738	88,516	120,607	468,861
1973	225,560	82,165	120,286	428,011
1974	285,525	95,942	158,852	540,319
1975	245,755	65,127	130,412	441,294
1976	276,726	72,544	159,493	508,763
1977	331,729	108,807	162,478	603,014
1978	274,250	92,280	151,852	518,382
1979	222,479	67,277	107,569	397,325
1980	263,798	85,704	135,184	484,686
1981	266,359	100,932	124,449	491,740
1982	215,785	63,862	97,945	377,592
1983	190,973	59,444	111,708	362,125
1984	235,010	67,074	133,957	436,041
1985	231,301	71,120	116,652	419,073
1986	250,767	77,341	122,531	450,639
1987	234,085	69,512	113,635	417,232
1988	282,131	79,854	137,253	499,238
1989	230,054	62,830	119,845	412,729

Groundwater Diversions by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1990	225,227	80,600	112,131	417,958
1991	233,487	69,853	129,287	432,627
1992	228,667	77,173	98,448	404,288
1993	209,758	64,793	103,890	378,441
1994	310,292	97,858	154,984	563,134
1995	188,295	55,078	110,334	353,707
1996	220,359	74,634	106,535	401,528
1997	216,355	64,515	114,278	395,148
1998	250,841	79,259	112,723	442,823
1999	226,589	71,863	106,091	404,543
2000	313,971	100,974	175,724	590,669
2001	282,741	79,207	150,712	512,660
2002	380,603	119,611	178,402	678,616
2003	247,948	91,714	148,580	488,242
2004	214,260	75,671	111,058	400,989
2005	179,040	35,469	117,559	332,068
2006	216,341	43,523	150,073	409,937
2007	180,739	19,495	112,984	313,218
2008	156,648	21,935	93,299	271,882
2009	141,590	19,285	73,476	234,351
2010	174,147	28,384	113,917	316,448
2011	174,181	42,258	101,077	317,516
2012	240,884	44,114	171,293	456,291

Source: HydroBase Version 20130710.

Table 4.4. Total Goundwater Crop Consumptive Use by Water District, 1950-2012.

Total Groundwater Crop Consumptive Use by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1950	82,424	28,609	18,515	129,547
1951	65,949	18,836	16,069	100,854
1952	105,645	29,402	27,044	162,091
1953	95,052	32,215	23,360	150,627
1954	147,198	79,613	47,618	274,430
1955	144,673	56,900	44,986	246,560
1956	156,745	67,909	42,044	266,698
1957	96,859	32,194	37,044	166,097
1958	115,375	42,032	42,624	200,031
1959	146,103	47,120	54,337	247,559
1960	162,856	54,238	55,993	273,086
1961	107,297	26,237	45,776	179,311
1962	126,202	42,181	42,273	210,656
1963	178,348	68,280	64,289	310,917
1964	191,596	67,112	79,597	338,305
1965	107,671	30,277	51,723	189,671
1966	177,886	56,209	66,421	300,515
1967	117,568	35,998	60,863	214,429
1968	159,443	50,989	67,966	278,398
1969	163,503	44,637	75,966	284,106
1970	181,863	41,858	81,338	305,058
1971	172,125	47,116	75,024	294,265
1972	164,951	54,681	75,117	294,749
1973	146,216	51,275	75,757	273,248
1974	187,943	60,360	101,050	349,352
1975	165,399	41,705	84,433	291,537
1976	188,503	46,778	103,718	338,999
1977	225,932	70,036	105,464	401,432
1978	188,904	59,727	99,695	348,325
1979	154,477	44,070	71,450	269,998
1980	184,583	56,120	89,824	330,527
1981	185,904	66,129	83,251	335,285
1982	151,899	42,578	66,196	260,672
1983	135,316	39,705	75,036	250,057
1984	166,994	45,044	90,488	302,526
1985	165,062	48,006	79,637	292,704
1986	179,253	52,487	83,826	315,566
1987	167,687	47,574	77,943	293,203
1988	201,638	54,494	93,949	350,081
1989	165,614	43,164	82,536	291,315

Total Groundwater Crop Consumptive Use by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1990	163,355	55,170	78,037	296,562
1991	169,726	48,093	89,719	307,537
1992	166,644	53,027	68,797	288,468
1993	153,729	44,688	72,607	271,024
1994	226,936	67,144	107,751	401,831
1995	138,981	38,119	76,552	253,652
1996	163,061	51,669	74,740	289,469
1997	160,249	44,546	80,115	284,910
1998	186,841	54,877	79,162	320,879
1999	168,354	49,862	74,673	292,888
2000	231,994	69,813	123,011	424,817
2001	208,674	54,848	106,078	369,600
2002	279,334	82,160	125,316	486,809
2003	185,774	64,110	105,839	355,723
2004	161,313	53,713	80,862	295,888
2005	136,553	26,732	85,331	248,616
2006	163,657	32,770	108,600	305,027
2007	137,320	14,711	82,735	234,765
2008	119,525	16,616	68,791	204,932
2009	107,959	14,470	54,313	176,742
2010	132,441	21,490	83,239	237,171
2011	132,695	30,520	74,004	237,219
2012	181,739	32,595	123,557	337,891

Source: HydroBase Version 20130710.

Table 4.5. Augmentation Requirement by Water District, 1950-2012.

Augmentation Requirement by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1950	54,211	26,228	18,179	98,618
1951	38,273	16,178	15,801	70,252
1952	67,850	26,501	26,594	120,945
1953	62,669	27,724	22,984	113,376
1954	109,891	69,279	47,179	226,348
1955	107,678	48,082	44,653	200,413
1956	108,586	57,869	42,401	208,856
1957	55,094	28,635	36,731	120,459
1958	67,854	38,710	42,287	148,851
1959	90,941	43,023	53,962	187,925
1960	102,658	50,660	55,555	208,873
1961	59,366	25,667	45,386	130,420
1962	69,759	40,888	41,757	152,404
1963	115,151	63,289	63,932	242,372
1964	130,409	61,675	79,070	271,154
1965	64,610	26,576	51,009	142,195
1966	118,338	52,905	65,196	236,439
1967	71,630	33,381	59,252	164,262
1968	94,990	46,855	67,472	209,318
1969	103,938	42,046	75,076	221,060
1970	111,372	40,029	80,516	231,916
1971	101,321	44,284	73,780	219,385
1972	99,976	50,111	73,904	223,991
1973	81,519	48,369	74,756	204,643
1974	107,228	56,264	100,361	263,854
1975	88,172	39,168	83,599	210,939
1976	106,373	43,781	102,808	252,963
1977	132,402	65,905	104,917	303,224
1978	102,637	54,846	99,054	256,537
1979	80,506	42,566	70,423	193,496
1980	95,204	52,649	89,430	237,283
1981	98,668	63,212	82,866	244,745
1982	77,349	39,766	65,749	182,863
1983	72,309	37,678	73,346	183,333
1984	86,296	42,071	89,834	218,201
1985	88,495	45,827	78,549	212,871
1986	95,980	50,034	82,231	228,246
1987	90,083	46,554	76,334	212,971
1988	110,333	50,826	92,231	253,390
1989	86,991	41,417	81,058	209,466

Augmentation Requirement by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1990	83,517	50,561	76,757	210,835
1991	91,945	43,895	88,656	224,496
1992	88,947	47,901	67,210	204,057
1993	81,979	41,916	71,177	195,072
1994	123,953	61,468	107,097	292,518
1995	70,440	36,499	75,537	182,476
1996	85,891	48,426	72,933	207,250
1997	85,118	40,909	79,309	205,335
1998	97,525	49,181	77,764	224,470
1999	94,633	44,714	73,324	212,671
2000	140,806	62,002	123,320	326,128
2001	125,744	49,072	105,642	280,457
2002	175,538	73,507	126,142	375,188
2003	98,895	57,378	106,955	263,229
2004	87,146	47,460	81,731	216,337
2005	56,415	22,605	86,133	165,152
2006	78,652	25,801	109,534	213,986
2007	57,694	11,158	83,085	151,936
2008	46,936	12,702	68,500	128,137
2009	42,819	10,861	54,699	108,379
2010	54,983	17,549	83,939	156,471
2011	57,161	22,209	74,467	153,837
2012	86,564	24,576	126,387	237,527

Source: HydroBase Version 20130710.

Table 4.6. Annual Surface Augmentation Supplies by Water District, 1950-2012.

Annual Surface Augmentation Supplies by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1950	-	-	-	-
1951	-	-	-	-
1952	-	-	-	-
1953	-	-	-	-
1954	-	-	-	-
1955	-	-	-	-
1956	-	-	-	-
1957	-	-	-	-
1958	-	-	-	-
1959	-	-	-	-
1960	-	-	-	-
1961	-	-	-	-
1962	-	-	-	-
1963	-	-	-	-
1964	-	-	-	-
1965	-	-	-	-
1966	-	-	-	-
1967	-	-	-	-
1968	-	-	-	-
1969	-	-	-	-
1970	-	-	-	-
1971	-	-	-	-
1972	-	-	-	-
1973	-	-	-	-
1974	-	-	-	-
1975	-	-	-	-
1976	-	-	-	-
1977	-	-	-	-
1978	-	-	-	-
1979	-	-	-	-
1980	-	-	-	-
1981	-	-	-	-
1982	-	-	-	-
1983	-	665	3,372	4,037
1984	1,821	67	4,845	6,734
1985	8,482	1,950	14,929	25,361
1986	2,994	4,767	3,539	11,300
1987	759	4,644	10,480	15,884
1988	6,689	2,652	10,807	20,148

Annual Surface Augmentation Supplies by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1989	8,110	3,966	15,133	27,208
1990	9,855	4,113	14,077	28,046
1991	29,334	4,589	17,859	51,783
1992	19,402	4,425	7,180	31,006
1993	21,058	3,740	7,193	31,991
1994	23,602	3,600	8,107	35,310
1995	33,334	1,045	1,964	36,343
1996	30,426	3,116	3,963	37,504
1997	2,555	633	79	3,267
1998	4,324	1,204	1,832	7,361
1999	4,650	495	194	5,339
2000	24,328	4,297	17,275	45,900
2001	20,838	4,238	18,754	43,830
2002	36,424	9,494	45,766	91,683
2003	46,345	17,355	34,032	97,731
2004	53,184	18,751	39,145	111,080
2005	73,338	18,278	48,801	140,416
2006	51,764	11,680	59,733	123,177
2007	42,412	20,854	34,286	97,552
2008	11,627	29,798	12,524	53,949
2009	4,850	22,322	387	27,560
2010	11,089	22,229	511	33,829
2011	1,864	2,702	17	4,583
2012	906	15,382	14,026	30,313

Source: HydroBase Version 20130710.

Table 4.7. Annual Recharge Augmentation Supplies by Water District, 1950-2012.

Annual Recharge Augmentation Supplies by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1950	-	-	-	-
1951	-	-	-	-
1952	-	-	-	-
1953	-	-	-	-
1954	-	-	-	-
1955	-	-	-	-
1956	-	-	-	-
1957	-	-	-	-
1958	-	-	-	-
1959	-	-	-	-
1960	-	-	-	-
1961	-	-	-	-
1962	-	-	-	-
1963	-	-	-	-
1964	-	-	-	-
1965	-	-	-	-
1966	-	-	-	-
1967	-	-	-	-
1968	-	-	-	-
1969	-	-	-	-
1970	-	-	-	-
1971	-	-	-	-
1972	-	-	-	-
1973	-	-	-	-
1974	-	-	-	-
1975	-	-	-	-
1976	-	-	-	-
1977	-	-	-	-
1978	-	-	-	-
1979	9,033	381	1,688	11,101
1980	4,422	204	2,516	7,142
1981	20,361	-	5,265	25,626
1982	14,672	285	5,844	20,801
1983	38,786	3,179	7,624	49,588
1984	35,921	924	8,146	44,991
1985	46,056	1,284	5,611	52,951
1986	47,256	1,817	6,300	55,372
1987	48,729	4,564	6,596	59,889
1988	33,213	2,814	6,438	42,465

Annual Recharge Augmentation Supplies by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1989	29,108	6,015	7,328	42,451
1990	51,304	5,311	7,528	64,143
1991	58,227	4,804	9,020	72,051
1992	69,179	5,460	9,559	84,198
1993	55,010	7,174	9,028	71,213
1994	35,400	5,011	9,339	49,750
1995	79,307	4,873	13,041	97,220
1996	67,456	7,084	11,129	85,669
1997	68,449	6,872	16,362	91,684
1998	77,881	6,684	23,620	108,185
1999	86,570	4,478	22,009	113,058
2000	36,359	3,922	21,326	61,606
2001	101,046	11,189	43,191	155,426
2002	21,333	1,019	23,434	45,786
2003	18,891	1,397	46,053	66,342
2004	14,394	708	63,906	79,007
2005	86,007	3,978	86,240	176,225
2006	33,562	986	32,841	67,389
2007	121,018	19,041	98,899	238,958
2008	87,171	8,243	72,323	167,737
2009	237,556	16,326	116,422	370,304
2010	136,135	15,555	111,119	262,809
2011	157,631	5,817	96,852	260,299
2012	37,940	9,887	62,381	110,208

Source: HydroBase Version 20130710.

Table 4.8. Total Augmentation (Groundwater & Recharge) Supply by Water District, 1950-2012.

Total Augmentation (Groundwater & Recharge) Supply by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1950	-	-	-	-
1951	-	-	-	-
1952	-	-	-	-
1953	-	-	-	-
1954	-	-	-	-
1955	-	-	-	-
1956	-	-	-	-
1957	-	-	-	-
1958	-	-	-	-
1959	-	-	-	-
1960	-	-	-	-
1961	-	-	-	-
1962	-	-	-	-
1963	-	-	-	-
1964	-	-	-	-
1965	-	-	-	-
1966	-	-	-	-
1967	-	-	-	-
1968	-	-	-	-
1969	-	-	-	-
1970	-	-	-	-
1971	-	-	-	-
1972	-	-	-	-
1973	-	-	-	-
1974	-	-	-	-
1975	-	-	-	-
1976	-	-	-	-
1977	-	-	-	-
1978	-	-	-	-
1979	9,033	381	1,688	11,101
1980	4,422	204	2,516	7,142
1981	20,361	-	5,265	25,626
1982	14,672	285	5,844	20,801
1983	38,786	3,843	10,996	53,625
1984	37,742	992	12,991	51,725
1985	54,538	3,234	20,540	78,312
1986	50,250	6,584	9,839	66,673
1987	49,489	9,209	17,076	75,773
1988	39,902	5,466	17,245	62,614

Total Augmentation (Groundwater & Recharge) Supply by Water District, 1950-2012.

Irrigation Year (Nov-Oct)	District 1	District 2	District 64	District 2, 1 & 64
	Acre-Feet			
1989	37,218	9,981	22,461	69,660
1990	61,159	9,425	21,605	92,189
1991	87,561	9,393	26,879	123,833
1992	88,580	9,885	16,739	115,204
1993	76,069	10,914	16,221	103,204
1994	59,002	8,612	17,447	85,060
1995	112,642	5,918	15,004	133,564
1996	97,882	10,199	15,092	123,173
1997	71,004	7,505	16,442	94,951
1998	82,206	7,888	25,452	115,546
1999	91,221	4,973	22,204	118,397
2000	60,687	8,218	38,601	107,506
2001	121,883	15,427	61,946	199,256
2002	57,757	10,513	69,200	137,469
2003	65,236	18,752	80,085	164,072
2004	67,577	19,459	103,051	190,088
2005	159,345	22,256	135,041	316,642
2006	85,326	12,667	92,574	190,566
2007	163,431	39,895	133,185	336,510
2008	98,798	38,041	84,846	221,686
2009	242,406	38,648	116,809	397,863
2010	147,224	37,784	111,630	296,638
2011	159,494	8,518	96,869	264,882
2012	38,846	25,269	76,407	140,521

Source: HydroBase Version 20130710.