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Technical Memorandum

Prepared for: Colorado Water Conservation Board and Colorado Division of Water Resources

Project Title: South Platte Decision Support System - Alluvial Groundwater Model Updates

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Technical Memorandum

Subject: Task 1: Extension of Historical Time Series Data

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Section 1: Introduction

The existing South Platte River Basin (Basin) alluvial groundwater flow model, developed as a part of the South Platte Decision Support System (SPDSS), is a planning-level groundwater model that simulates the effects of regional hydrologic drivers such as pumping and recharge on the South Platte alluvial aquifer and stream flows. The Colorado Water Conservation Board (CWCB), in coordination with the Colorado Division of Water Resources (DWR), retained Brown and Caldwell (BC) to update the model and include more recent data. BC's work was divided into a series of tasks, beginning with updating various input and calibration data sets and ending with using the updated model to simulate various water management scenarios.

The purpose of Task 1 was to extend the time series data sets used to develop model input files with the most recent available data. A number of factors were considered when determining the end date for the extension period. The availability of flow, diversion, discharge, and climate data were investigated in addition to considering the modeling periods for current consumptive use and surface water modeling efforts. To make all of the modeling efforts under SPDSS as cohesive as possible, the extended modeling period was set to align with the most recent consumptive use and surface water models, which both currently end in 2012.

In general, Task 1 was focused on gathering post-2006 data to add to the previously-developed 1950-2006 data. For some modeling input data sets, historical data were not available during the initial modeling effort but are now currently available, or major revisions to the historical data were conducted and are now available for use. In these instances, the newly acquired data were used to replace the existing times series data for the entire period of record (1950-2012).

The extension of time series data sets primarily relied on the existing tools and approaches from the initial modeling effort. For some data sets, data-centered enhancements were implemented to streamline the previous data generation workflow. In these cases, processes were modified by BC to use standard tools and data sources and remove dependence on proprietary tools, user-edited data, and data formats incompatible with standard SPDSS processes.

This memo provides a description of the data, data-processing steps, and approach used to extend time series data sets. Workflow diagrams showing the entire process to generate MODFLOW input files, including the necessary input data, were also developed. Recommendations for improving future modeling and data collection efforts are also included.

Section 2: Approach and Processes

The scope of work for Task 1 states that the existing tools and approach for collecting and processing time series data are to be used, where appropriate, for the extension effort. The tools used for the initial and current modeling efforts include standard SPDSS tools such as TSTool and StateDGI as well as other common tools such as Microsoft Access databases. In addition to those tools, the existing model package includes a number of software tools for specific modeling processes that integrate into the workflow. No new tools were introduced to the modeling process during the extension effort; however, greater emphasis was focused on using TSTool and other "data-centered" approaches where possible. The existing tools and processes are not described in detail in this memo. Instead, refer to the SPDSS Alluvial Groundwater Modeling Report and Appendices from the initial modeling effort for in-depth descriptions of the tools and processes (CDM Smith, 2013).

2.1 Data Sources and Background

The primary source for hydrologic and spatial data for the groundwater model was the HydroBase database maintained by the Colorado Division of Water Resources (DWR). The version of HydroBase used throughout the data collection process was issued on March 4, 2015. Historical data collected from HydroBase included streamflow records, diversion records, climate data, municipal and industrial pumping records, recharge deliveries, irrigated area, groundwater levels, soil types, land use, and demographic information. The groundwater model is also closely integrated with other SPDSS basin-wide modeling efforts. The current basin-wide consumptive use model (StateCU) was developed as a part of ongoing surface water model (StateMod) development efforts. For the groundwater model, output from StateCU was used to estimate irrigation recharge, canal seepage, and irrigation well pumping. The input datasets for both the groundwater and surface water models have been prepared using consistent sources and data.

Some of the time series data, such as municipal and industrial discharges and bedrock fluxes, were collected from non-decision support system data sources or models. Discharge data were collected from the Environmental Protection Agency (EPA) database and bedrock fluxes were based on output from the U.S. Geological Survey (USGS) Denver Basin groundwater model.

Data-centered enhancements were implemented during data collection and processing where possible. These enhancements include increasing the use of TSTool commands to retrieve data stored in HydroBase, eliminating reliance on data not stored in HydroBase, and developing detailed workflow diagrams to explain the processing steps for each time series.

2.2 Approach Summary

In general, the extension of time series data for each component was completed separately using individual approaches and processes. Table 2-1 below provides a summary of the approaches and processes used to generate the time series data for each component. Additional details for various components are provided in Attachments A and B.

Table 2-1. Time Series Data Set Extension Approach

TIME SERIES DATA SET	EXTENSION APPROACH
Constant time series - alluvial underflow into model	The rates of monthly alluvial groundwater inflow entering the model domain at modeled tributary branches were calculated during the initial modeling effort and are constant year-to-year. The same values were used for the extended model.
Constant time series - bedrock fluxes	Bedrock fluxes were calculated using the USGS Denver Basin Model. The USGS model period of record ended in 2003. The 2003 fluxes were repeated for subsequent years of the SPDSS model, including the extension period.
Constant time series - reservoir seepage	Reservoir seepage rates were assumed to be constant for a given soil type underlying the reservoirs. The seepage rates in the existing model were used for the extended modeling period.
Streamflow routing components - streamflow, municipal and industrial discharges, and diversions	Historical streamflows and diversion records for the extended modeling period were collected from HydroBase by the surface water model contractor and were provided to BC. Incomplete records were filled using regression or other suitable methods as described in the SPDSS Task 2 technical memorandum (Leonard Rice Engineers, 2007). Tributary inflows at the edge of the model domain were estimated using the nearest downstream gage and then adding diversions occurring between the gage and the model boundary. See Attachment B for details on the data collection efforts. Municipal and industrial discharge data were collected from the EPA database.

Precipitation	Historical monthly precipitation data from the key climate stations identified in the initial modeling effort were retrieved from HydroBase by the surface water model contractor and were provided to BC. Missing data were filled using linear regression. The climate station weights used to distribute precipitation across the model domain and the percentages used to determine the amount of precipitation that becomes recharge (based on land use and soil types) were not changed from the initial modeling effort.
Consumptive use model output - agricultural pumping, canal seepage, and irrigation recharge	Agricultural pumping, canal seepage, and irrigation recharge time series data were estimated using the StateCU model output. The consumptive use modeling was completed by the surface water model contractor and provided to BC. The model output contained monthly values for each parameter. See Attachment B for details on the data collection efforts.
Municipal and industrial pumping	The historical municipal and industrial pumping data were extended using a combination of data retrieved from HydroBase and data provided by the well users. HydroBase data were preferred to user-supplied data. Missing or incomplete records were filled using similar methods from the initial modeling effort. The availability of HydroBase data was limited during the initial modeling effort. Estimated values prior to 2006 were replaced with newly available HydroBase records when possible. See Attachment A for details on the data collection efforts and filling procedures.
Augmentation and recharge	Recharge Areas: Augmentation recharge was estimated using recharge pond delivery records. Delivery records were retrieved from HydroBase and provided to BC by the surface water model contractor. New recharge facilities came on-line during the model extension period (2007–2012) and were added to the model. Recharge and Augmentation Pumping: Historical recharge pumping records were compiled by the surface water model contractor and provided to BC. Appropriate wells were identified with the help of the Division 1 Engineer's office. Pumping records were retrieved from HydroBase. Historical augmentation pumping records were also collected from HydroBase by the surface water model contractor and provided to BC. The Division 1 Engineer's office assisted in identifying the appropriate wells. See Attachment B for details on the data collection efforts.
Lateral boundary inflow fluxes	Lateral boundary inflow fluxes represent a combination of precipitation recharge, irrigation recharge, canal seepage, and pumping that occur outside the active model domain and that generate groundwater flux along the active model domain boundary. BC used existing tools to combine the component fluxes and generate lagged boundary inflow values.
Reservoir seepage	Reservoir seepage rates were assumed to be constant for a given soil type underlying the reservoirs. The seepage rates in the existing model were used for the extended modeling period.

Table 2-2 below provides a summary of the approaches taken to extend the time series data used to develop the calibration data sets.

Table 2-2. Calibration Data Set Extension Approach

CALIBRATION DATA SET	EXTENSION APPROACH
Observation water Levels	Measurements of groundwater level elevations were retrieved from HydroBase for monitoring well sites that were identified during the initial modeling effort.
Stream Gain/Loss Estimates	Daily streamflow, diversion, and discharge data for the extension period (2007-2012) were retrieved from HydroBase and added to existing stream mass balance spreadsheets for each identified reach. The new estimates of daily gain/loss for each reach were processed using the pilot point spreadsheets developed during the initial modeling effort and documented in the Task 46.2 technical memorandum (CDM, 2008).
Streamflow at Relevant Gages	Streamflow gage data for the gages used in calibration were retrieved from HydroBase by the surface water modeling contractor and provided to BC. Missing data were filled using linear interpolation.

Section 3: Results

Extended time series data were compiled in a number of formats. Most data were uploaded to the model database and geodatabase. StateCU model output was kept in its original format because it is read directly by the MODFLOW model input file pre-processor (StatePP). Some time series consisted of monthly values that were repeated for each year of the modeling time period. Those data were extended by modifying a flag in the existing MODFLOW input files that indicated to the model that the current values are to be used for the extended modeling time periods.

3.1 Data Descriptions and Processes for Extending Data Series

The following is a brief summary of the data collected for each time series in the model. Some time series categories were lumped together because of their similarity and because similar processes were used to extend the data. Detailed workflow diagrams for each time series, or group of time series, were developed to show the entire process of creating the extended time series and developing the MODFLOW input files. The diagrams show the source data and the final MODFLOW package that receives or uses the time series data. Figure 3-1 shows a generalized overview of the workflow for generating all of the time series data. Some processing steps for certain time series are not shown to make Figure 3-1 more legible.

3.1.1 Constant Time Series Data - Alluvial Underflow, Bedrock Fluxes, and Reservoir Seepage

Data representing alluvial underflow, bedrock fluxes, and reservoir seepage are constant on a year-to-year basis, with monthly variation. These time series were updated by modifying the existing MODFLOW model input files to indicate that the previous values are to be repeated for stress periods in the extended model. The bedrock fluxes in the SPDSS groundwater model from 2003 forward use the values from the last year of output from the United States Geological Survey (USGS) Denver Basin groundwater model, which ends in 2003.

Reservoir seepage and alluvial underflow are constant (annually) for the entire modeling period. Since no new data were introduced for the extension, an individual workflow diagram was not generated for these time series. However their processes are shown in general terms on the overview workflow diagram in Figure 3-1.

The methodologies used to determine reservoir seepage and process bedrock fluxes are discussed in further detail in Appendix B of the SPDSS Alluvial Groundwater Modeling Report from the initial modeling effort. Alluvial underflow is discussed in Appendix D of the SPDSS Alluvial Groundwater Modeling Report (CDM Smith, 2013).

3.1.2 Streamflow Routing Components

The streamflow routing (SFR2) MODFLOW package is used by the model to route surface water in stream channels and estimate the discharge from the aquifer from the stream (gaining stream) or discharge from the stream to the aquifer (losing stream). The SFR2 package uses a combination of streamflow gage data, stream diversions, discharges to the stream (e.g., municipal waste water treatment effluent), and estimates of runoff from precipitation to calculate the flow and stage of the stream. A description of the data collection and time series extension efforts for the components of the SFR2 package are highlighted below. Precipitation runoff is discussed near the end of Section 3.1.3. The complete SFR2 workflow, including all components, is shown on Figure 3-2. Additional background information about the components of the SFR2 package and the components can be found in Appendix F and G of the SPDSS Alluvial Groundwater Modeling Report from the initial modeling effort (CDM Smith, 2013).

3.1.2.1 Streamflow

Streamflow data are used in the development of SFR2 package and are based on USGS gage measurements at gages located near the model boundary on the South Platte River and major tributaries. Streamflow data were also used in the development of stream gain-loss estimates applied as calibration targets and discussed in Section 3.1.8.2. These data were retrieved from HydroBase using a TSTool command file. Missing data were filled using linear regression relationships with nearby gages. The regression relationships used to fill data for the groundwater model were the same as the relationships used in the SPDSS surface water model that is currently under development. The filled data were uploaded to the model geodatabase and then processed with the SFR generator to create the MODFLOW input files. Figure 3-2 shows the complete workflow process for generating MODFLOW input files from streamflow data and the other components of the SFR2 package.

3.1.2.2 Diversions

Canal diversions are also a component in the SFR2 package. The diversion records are stored in HydroBase and were acquired and compiled using TSTool commands. Between 2006 and 2012, there were very few missing values in the records. Missing data were filled using an approach consistent with current StateCU and StateMod modeling efforts. The data filling process uses a wet-dry-average pattern based on historical flow patterns at a nearby stream gage. The pattern file assigns a wet, dry, or average attribute for each month, and then, for any given month with missing data, the average monthly value corresponding to the pattern assignment is used to fill the data gap. Final data were uploaded to the model geodatabase for SFR generator processing. The workflow for processing diversion data is a part of Figure 3-2.

3.1.2.3 Municipal and Industrial Discharges

Major municipal and industrial discharges from wastewater treatment plants and power plants to the South Platte River and major tributaries make up the third time series component of the SFR2 package. Unlike the streamflow and diversion data, discharges from municipal and industrial sources were not stored in HydroBase. Data were retrieved from the Environmental Protection Agency (EPA) database. Records were mostly complete for the extension time period; however, some sites required filling. For small, intermittent data gaps, average monthly values were used to fill missing values. When data for municipal discharges were missing for larger consecutive periods of time, the values were filled using per capita use and population data. This is the same approach used in the initial modeling effort to fill missing data prior to 2006. Missing industrial discharge data were filled with monthly average values. The processing steps for discharge data are also shown on Figure 3-2.

3.1.3 Precipitation

Precipitation data were collected from HydroBase using TSTool commands for 29 weather stations located throughout the Basin. The weather stations are operated by the National Oceanic and Atmospheric Administration (NOAA) and are the same locations used in the initial modeling effort. The precipitation data collected from the stations were distributed across the model grid based on a set of weighting files which indicated the relative weight that a particular weather station had for any given model cell. A weighting file was generated for each station using a kriging interpolation method. Generally, the further the model cell was from a particular weather station, the lower the weight for that station. The precipitation assigned to any given model cell represented the weighted sum of precipitation for multiple surrounding weather stations. The weather station weighting and precipitation distribution methods were developed during the initial modeling effort and were unchanged during the update process.

The recharge component resulting from precipitation was determined by using recharge factors that describe the percentage of precipitation that recharges the alluvial aquifer. The percentages are based on land cover types, soil classifications, and season. The recharge percentages used for the extended modeling period were the same as the percentages used in the initial model. The workflow for processing precipitation recharge data is shown in Figure 3-3. Further background information can be found in Appendix B from the SPDSS Alluvial Groundwater Modeling Report from the initial modeling effort (CDM Smith, 2013).

The runoff component of precipitation was calculated in a similar way, but using a different set of percentages. The runoff percentages used for the extended modeling period were the same as the percentages used in the initial model. The runoff percentages were based on the same land cover and soil types as the recharge percentages. Precipitation runoff is the fourth component of the SFR2 package. The workflow diagram shown in Figure 3-2 includes the runoff processing. More information about SFR2 package components can be found in Appendix G of the SPDSS Alluvial Groundwater Modeling Report from the initial modeling effort (CDM Smith, 2013).

Missing or incomplete precipitation data were filled using linear regression relationships with nearby stations. The regression relationships are consistent with the initial modeling effort as well as the current StateCU and StateMod modeling efforts.

3.1.4 Consumptive Use Model Output

A number of groundwater model input time series are based on the output from the StateCU consumptive use model. These include irrigation pumping, irrigation recharge, and canal seepage. An updated version of the basin-wide StateCU model was developed in support of SPDSS surface water modeling efforts. The model output was provided to BC by the surface water model contractor. The StateCU model uses irrigation "snapshots" (i.e. mapping) from HydroBase to determine the appropriate amount of irrigated area for each diversion structure in the model and to determine which irrigation wells correspond to the particular parcels. The snapshots provide a quantification of the irrigated area and the crop types on a parcel-by-parcel basis for a given year. Snapshots are available from HydroBase for 1956, 1976, 1987, 2001, 2005, and 2010. The 2010 snapshot was added to the StateCU model for the groundwater model extension effort. Additionally, the snapshots have been revised since completion of the previous groundwater modeling effort, with a focus on improving the well-to-parcel assignments. As a result, the current StateCU output is slightly different than the output used in the initial groundwater modeling effort. For consistency with the other modeling efforts in the Basin, the older StateCU output used in the initial groundwater modeling was replaced with the new StateCU output for the entire model period (1950 – 2012). The monthly values of irrigation pumping, irrigation recharge, and canal seepage are calculated by the StateCU model, and there are no missing or incomplete data. The data are read directly from the detailed water balance output from StateCU into the MODFLOW model pre-processor, StatePP, and converted into MODFLOW input files. The complete workflow for StateCU generated data is shown in Figure 3-4. Appendix B from The SPDSS Alluvial Groundwater Modeling Report from the previous modeling effort provides additional information methodologies and process used for recharge data collection (CDM Smith, 2013).

3.1.5 Municipal and Industrial Pumping

Municipal and industrial pumping data were gathered from both HydroBase (using TSTool commands) and from well users. Data from HydroBase was preferred when both sources were available for two reasons. One was to maintain a data-centered approach. The other was that the user-supplied data were often in annual pumping forms or were generalized, lumping pumping records from individual wells into a total pumping record for an entire well field. Mostly, the data from HydroBase and the well users were in agreement. Larger discrepancies were investigated and addressed on a case-by-case basis. A detailed overview of the data collection and the approach for filling missing or incomplete data is provided in Attachment A. Because of the variation in the quality and completeness of available data, missing values were filled on a case-by-case basis for each well user. Pumping data were uploaded to the model geodatabase and read by StatePP. The workflow for extending municipal and industrial pumping data is relatively straightforward and shown with sufficient detail on the workflow overview in Figure 3-1. Additional background information about the collection of municipal and industrial pumping can be found in Appendix C of the SPDSS Alluvial Groundwater Modeling Report from the initial modeling effort (CDM Smith, 2013) and the Task 41.3 technical memorandum (CDM, 2006).

3.1.6 Augmentation and Recharge

3.1.6.1 Recharge Areas

Intentional recharge of the alluvial aquifer for augmentation purposes occurs in recharge ponds and in canals throughout the Basin. The time series data reflecting augmentation recharge were collected from HydroBase using TSTool commands. The data were compiled by the surface water model contractor and are consistent with current SPDSS consumptive use and surface water modeling efforts. The number of recharge areas included in the extended version of the groundwater model has increased since the initial model. This is primarily a result of the rapid development of recharge areas that occurred in the Basin since 2006.

The data collection efforts for recharge areas during the initial modeling effort relied on data that were either never in HydroBase (for example, data from augmentation plan accounting forms) or data that has since been removed from HydroBase. The current augmentation recharge time series rely exclusively on data found in HydroBase. A comparison of historical augmentation recharge data from both the initial groundwater model and the current surface water model revealed discrepancies at nearly all recharge sites. Most of the data discrepancies were small and were likely a result of rounding of the delivery record values. Some differences were much larger and could not be easily explained. However, the sum of augmentation recharge at all sites in the model was very similar. After consultation with the surface water model contractor and a thorough review of the data, BC used the augmentation recharge data set from the surface water model and replaced the existing data from the initial modeling effort for the entire modeling period. This approach offers two advantages. First, it is data-centered and easily repeatable. Second, the augmentation recharge data set is consistent with the current surface water model.

The workflow for extending the augmentation recharge time series is shown Figure 3-5. Appendix M of the SPDSS Alluvial Groundwater Modeling Report from the initial modeling effort provides more details on the process used to generate the augmentation recharge time series data (CDM Smith, 2013).

3.1.6.2 Recharge and Augmentation Pumping

Recharge pumping represents water pumped from the alluvial aquifer that is delivered to recharge ponds. Augmentation pumping is water periodically pumped from the alluvial aquifer and delivered directly to the river to replace streamflow depletions from well pumping associated with augmentation plans. The time series for both types of pumping were retrieved from HydroBase using TSTool commands. The list of wells used for recharge or augmentation purposes was provided to BC by the surface water model contractor. The surface water model contractor consulted with the DWR to determine the proper list of wells for each type of use.

The new list of wells was different from the list of wells used in the initial modeling effort, which was a result of the different approach taken to identify recharge or augmentation wells. The initial effort considered all wells with a decreed use of either recharge or augmentation and collected any records corresponding to the pumping under those uses. This resulted in a number of wells being identified that were used for recharge or augmentation pumping for a brief period of time and then never operated under that use again. The majority of the pumping from these wells was in very small quantities and the pumping records were not always available in HydroBase. The new approach identified wells that are used for augmentation or recharge on a regular or semi-regular basis. The goal was to create a dataset that represents both past and potential future use of augmentation or recharge wells. After consultation with the surface water model contractor, BC adopted the new data collection approach and replaced the data from the initial model for the entire period of record. The new approach is more data-centered and is consistent with the other modeling efforts in the Basin.

The workflow for recharge and augmentation pumping time series extension is also shown on Figure 3-5. Additional information about the methodology used to collect augmentation and recharge pumping data can be found in Appendix M of the SPDSS Alluvial Groundwater Modeling Report from the initial modeling effort (CDM Smith, 2013).

3.1.7 Lateral Boundary Inflow Fluxes

The lateral boundary fluxes are a composite of a number of individual time series that represent groundwater flux at the boundary of the active model domain. The fluxes at the model boundary are a result of irrigation, canal seepage, precipitation, augmentation recharge, and pumping that occurs outside of the active model domain. The net flux from these inputs at the boundary is estimated with a software tool developed in the initial modeling effort. This tool uses output from StatePP (for irrigation recharge, irrigation pumping, municipal and industrial well pumping, and canal seepage), precipitation, augmentation recharge, and augmentation/recharge pumping occurring outside the active model domain. The locations of the inputs listed above are used to determine the shortest distances between individual inputs and the active model boundary. The distances are used to identify the boundary model cells that will receive the lateral inflow fluxes and to derive parameters for estimating the timing of the fluxes. The analytical Glover Equation is used to generate the lag timing of the fluxes. The tool uses this information to generate MODFLOW input files reflecting lateral boundary inflow fluxes. A detailed workflow diagram for the lateral boundary fluxes is shown on Figure 3-6. Further information regarding lateral boundary inflows can be found in Appendix D of the SPDSS Alluvial Groundwater Modeling Report from the initial modeling effort (CDM Smith, 2013).

3.1.8 Calibration Data

The primary data used for model calibration include groundwater level observations, estimates of stream gain or loss on a reach-by-reach basis, and streamflow measurements. A description of the methods and approach used to generate each data set is below. Additional background information regarding the calibration data can be found in Appendix K of the SPDSS Alluvial Groundwater Modeling Report from the initial modeling effort (CDM Smith, 2013).

3.1.8.1 Observation Water Levels

Groundwater level elevation data were retrieved from HydroBase using TSTool commands for 552 wells located throughout the Basin. The same 513 wells used for calibration during the initial modeling effort were used in addition to 39 new sites where groundwater elevation data were available after 2006. A comparison of the groundwater elevation data obtained from the most recent version of HydroBase and the groundwater elevation data collected during the initial modeling effort indicated that the measuring point elevation has been updated for a number of the wells. The update in measuring point elevations resulted in changes to observed groundwater elevations for these wells. For these wells, groundwater elevation data for the entire modeling period were obtained to ensure that the data reference a consistent measuring point elevation.

3.1.8.2 Stream Gain/Loss Estimates

Estimates of stream gain and loss were calculated on a reach-by-reach basis using a mass balance approach developed during the initial modeling effort. Streamflow gage data is used along with measured diversions and municipal/industrial discharges to determine the net unmeasured gain or loss of flow along a particular stream reach on a daily time scale. The streamflow and diversion data were retrieved from HydroBase and the discharge data were collected from the EPA (see section 3.1.2 for more detail). The reaches are defined by the location of the stream gages. The daily net gain or loss value computed with the mass balance approach is constrained by a number of factors using the pilot point process developed in previous modeling efforts. The process for quantifying gains/losses includes an initial constraint that limits the daily gain/loss by the capacity of the aquifer to transmit water to and from the stream. The constrained daily values are then averaged over a multi-day period to account for the expected travel time in the reach. A longer moving average is then derived from the daily data to account for runoff events that can produce rapid but temporary one or two day increases in stream gains. The cumulative monthly constrained and averaged values are then used as the calibration targets for the stream gain/loss calculated by the model in the SFR2 package. A more detailed description of the methodology and approach for estimating stream gain or loss is provided in Appendix E of the SPDSS Alluvial Groundwater Model Report from the initial modeling effort (CDM Smith, 2013).

3.1.8.3 Streamflow at Relevant Gages

Streamflow data used for calibration was collected by the surface water model contractor and provided by to BC using the same procedures outlined in Section 3.1.2.1 above. The gage locations used for calibration are within the model domain and are used to check simulations of streamflow generated by the SFR2 package. The same 13 sites identified during the initial modeling effort will be used for calibration of the updated model.

3.2 QA/QC Procedures

The procedures for quality assurance and quality control (QA/QC) were tailored to the individual datasets being reviewed. The following is an overview of the QA/QC that was conducted on the various types of data.

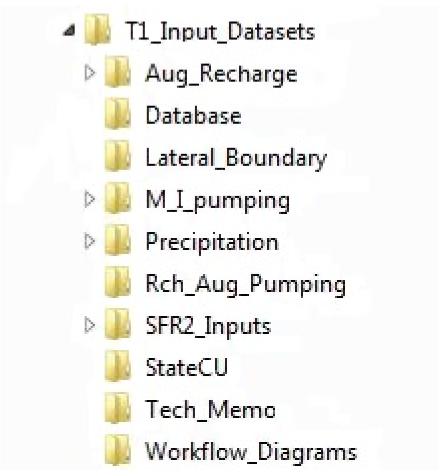
- **Data received from the surface water model contractor.** Data provided by the surface water model contractor included StateCU modeling output, precipitation time series, streamflow measurements, canal diversions, augmentation deliveries, and augmentation and recharge pumping. Excluding the StateCU output, these data were provided in the form of TSTool command files and TSTool output and had undergone a level of QA/QC by the other contractor prior to being delivered to BC. BC tested each TSTool command file to make sure they ran without errors. All of the StateCU and TSTool outputs were examined for outliers and inconsistent trends.
- **Constant time series data.** Time series components that were constant year-to-year were not changed during the extension effort. BC conducted a brief review of the existing data and did not find values that appeared to be unreasonable.
- **Municipal and industrial pumping.** The majority of the municipal and industrial pumping data for the extended time period were collected from HydroBase using TSTool commands. The command files were reviewed by senior staff and checked for consistency. The extended data were compared to the data from the initial period of record to check for consistency and continuity. Unreasonably large increases or decreases in pumping were investigated on a case-by-case basis.
- **Augmentation and recharge.** Augmentation recharge in ponds and augmentation and recharge pumping data were retrieved from HydroBase using TSTool commands provided by the surface water model contractor. BC reviewed the commands and TSTool output for consistency.
- **Lateral boundary fluxes.** The lateral boundary fluxes are represented by a combination of input sources including data from StateCU. QA/QC will be conducted for the individual components prior to processing the lateral boundary fluxes as described in this section. The computed lateral boundary fluxes will be spot-checked for consistency after processing.
- **Processing tool output.** The workflow to convert time series data into MODFLOW model input files involves using processing tools developed by the previous groundwater modeling

contractor. BC conducted an evaluation of each tool, which included a review of the source code and a review of the output files focusing on consistency and verifying expected results.

The methods described above represent the first round of QA/QC for the time series data. Additional QA/QC will be conducted after the MODFLOW input files are generated and model testing can begin. The testing process will provide an opportunity to discover data inconsistencies that were previously undetected.

3.3 Data Management

The data generated during the time series extension process was organized by type or source. A sample of the file directory is shown below.



In general, each time series is separated into its own directory. The components of the SFR2 package (streamflow, diversion, discharges, and precipitation runoff) are grouped in the same directory, and organized into sub-directories. StateCU model output is located in a separate directory.

Depending on the approach for collecting and processing data, each directory contains the TSTool commands (if applicable), the specific processing tool input and output files, and relevant background data.

MODFLOW input files will be stored in a separate directory from the time series data.

The naming convention for TSTool command files, TSTool output, and StateCU model output uses the common prefix of “SP2015_GW” followed by an identifier for the time series. For example, the augmentation recharge output is named “SP2015_GW_RechargeArea.stm.” If separate versions of the same file are maintained, “_v01,”” _v02,” etc. is appended to the file name. A detailed filename matrix will be developed as a part of the model documentation task (Task 4) that will clearly identify all the command files, tool output files, and model package files for each input component.

Section 4: Conclusions

4.1 Task 1 Overview

The time series data sets for the SPDSS groundwater model were extended from the initial period of 1950 to 2006 to include data through 2012. The majority of the effort was focused on developing the data for the extension period (2007-2012); however, some time series were updated for the entire modeling period because of improvements to the available data and approach. Task 1 also included the extension of time series data to be used for model calibration.

In general, the approach and tools used to extend the time series relied on concepts and tools from the initial modeling effort. The intent of the project approach was to streamline the extension effort using previous methods; however, this proved to be more difficult than originally anticipated. A large amount of time was committed to understanding the existing tools and processes, which resulted in the development of the detailed workflow diagrams that are attached to this memorandum. The goal in creating the diagrams was to clarify the overall workflows, identify necessary input files and tools, and provide guidance for future users to develop time series datasets. The refinement and clarification of the workflows and approaches used to develop time series data for the groundwater model are intended to improve the quality and accuracy of the data used in the model and to reduce the effort required to generate time series data in the future.

4.2 Recommendations for Future Modeling

The following items are recommendations that could be implemented during future modeling efforts to improve the overall process and approach to creating time series data. These items were not addressed because of limitations to the scope and budget of the time series extension effort.

- **Data-Centered Approach Enhancements.** BC recommends a continued effort to update the approach to generating time series data in a data-centered manner. This could include eliminating spreadsheet or database files used to modify time series data and integrating their functionality into TSTool commands. Additionally, the existing, function-specific processing tools needed to develop groundwater model data sets could be streamlined by integrating them into StatePP. Examples include integrating the “recharge stitcher” and “well stitcher” tools, which are used to combine multiple recharge and well outputs files into single files, into the StatePP code. Several tools used to format data, such as “DDH_Import” and “Proc_Stream” could be eliminated by utilizing updated output functionality in TSTool. Other recommendations include potentially merging functionality of StatePP and StateDGI to eliminate some processing steps when creating model data sets.
- **Utilize Improved Resources.** As improvements are made to HydroBase, such as the recent update to the irrigation snapshots and well-to-parcel assignments, the model should be updated to take advantage of those improvements. Updates and improvements to HydroBase can be incorporated into new time series data and model files efficiently with the increased reliance on TSTool and other data-centered processes. Additional future updates to HydroBase could include municipal and industrial discharge data and improved pumping records. TSTool is also under active development and gaining functionality that could be leveraged to streamline time series processing and model input generation.
- **Database Management and Data QA/QC.** Throughout the process of extending time series data, BC found that the model database used to store the time series data and structure information contained a large amount of non-relevant structures and data. Including structures outside of the rectangular model domain and the corresponding time series data created unnecessary processing steps, led to errors during StateDGI/StatePP processing, and increased file sizes. BC recommends generating a new database with only structures and data relevant to the model. Additionally, a number of queries seemed to duplicate the functions of other queries, possibly as a result of multiple database revisions during the initial modeling effort. BC recommends cleaning up the queries such that only relevant and non-duplicative versions remain.

References

CDM Smith. 2013. South Platte Decision Support System Alluvial Groundwater Model Report.

CDM. 2008. SPDSS Groundwater Component Phase 4 Task 46.2 Final Stream Gain/Loss Estimated Technical Memorandum.

CDM. 2006. SPDSS Phase 3 Task 41.3 Estimation of Municipal and Industrial Pumping in the South Platte Alluvium Region.

Colorado Division of Water Resources' HydroBase database (includes data for diversions, streamflows, climate, ground water levels and river calls), available at: http://cdss.state.co.us/onlineTools/Pages/OnlineToolsHome.aspx.

Colorado Division of Water Resources' GIS coverages for Division 1, available at: http://cdss.state.co.us/GIS/Pages/Division1SouthPlatte.aspx.

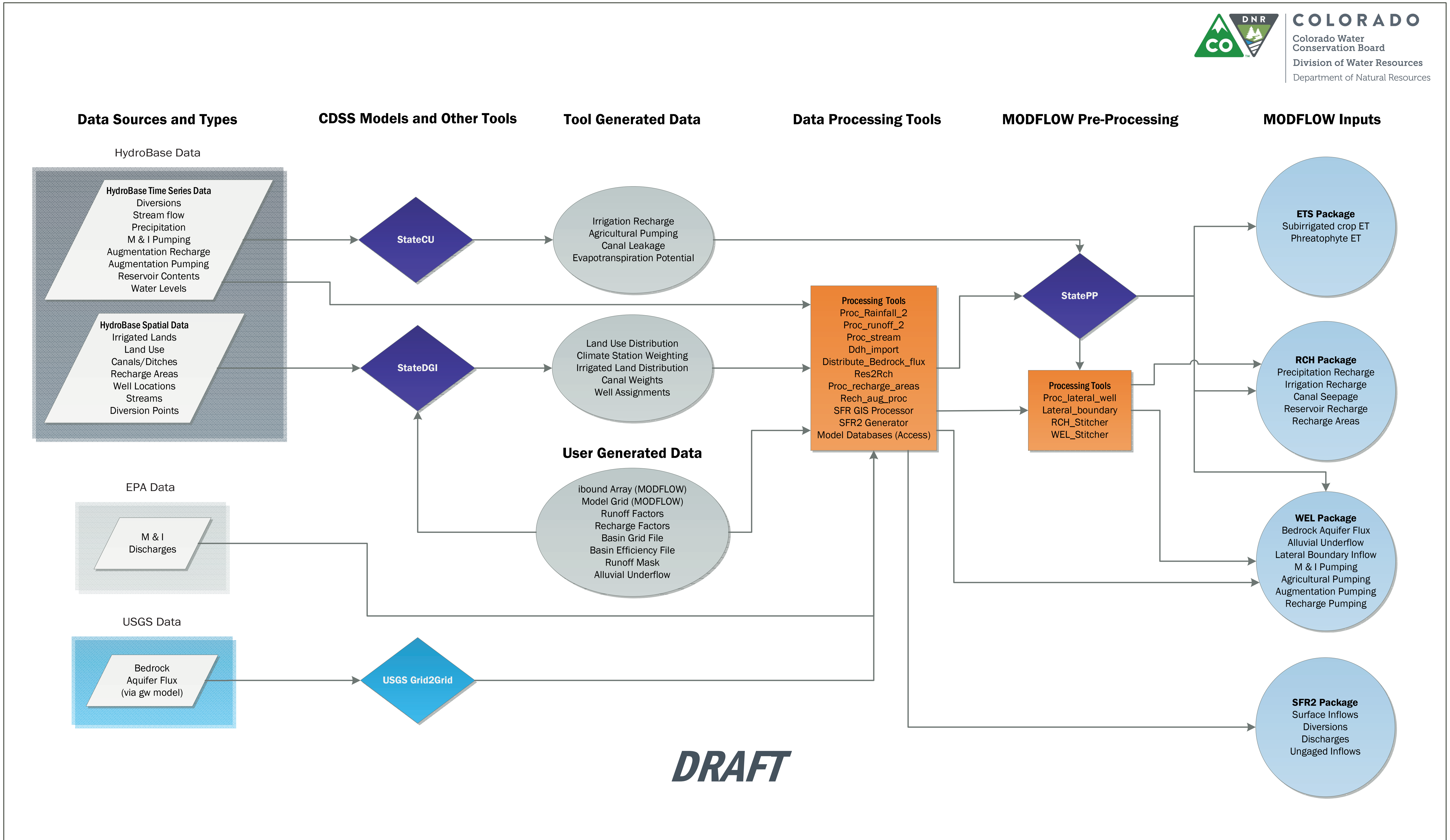
Leonard Rice Engineers. 2007. SPDSS Memorandum Task 2 – Identify Streamflow Gages and Estimate Streamflows for Missing Records.

United States Environmental Protection Agency discharge data access, available at: http://echo.epa.gov/.

Waskom, R.M. 2013. Report to the Colorado Legislature Concerning: HB12-1278 Study of the South Platte River Alluvial Aquifer. Colorado Sate University.

Attachment A: Municipal and industrial pumping data collection details

Attachment B: StateCU, precipitation, and recharge data collection details



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CWCB and DWR

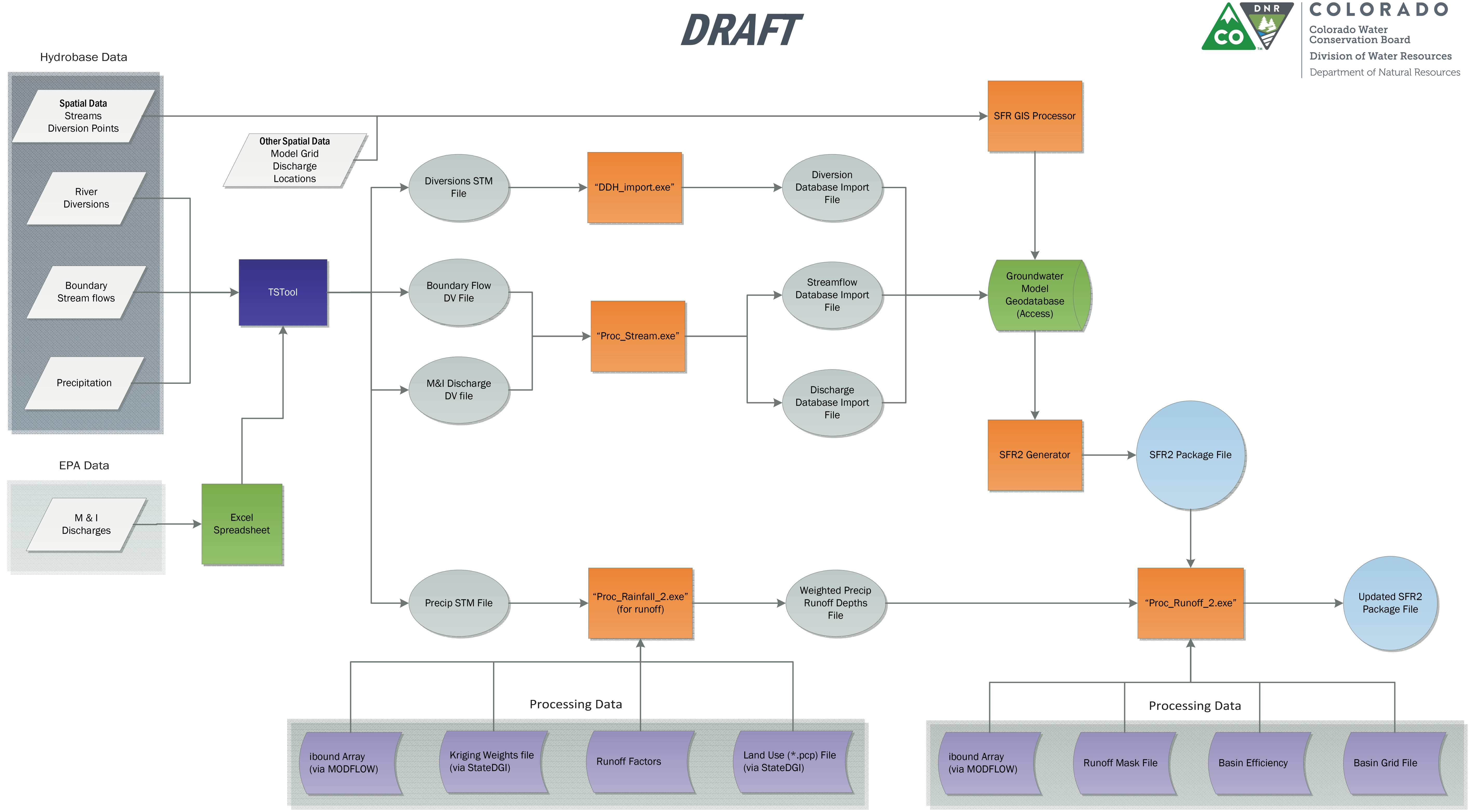
SPDSS Groundwater Model Update

Date: August 2015
Project: 146767

Notes: 1) See Figures 3-2 through 3-6 for detailed workflows for individual tools and processes.

Figure 3-1

SPDSS Alluvial Groundwater Model Overview Workflow



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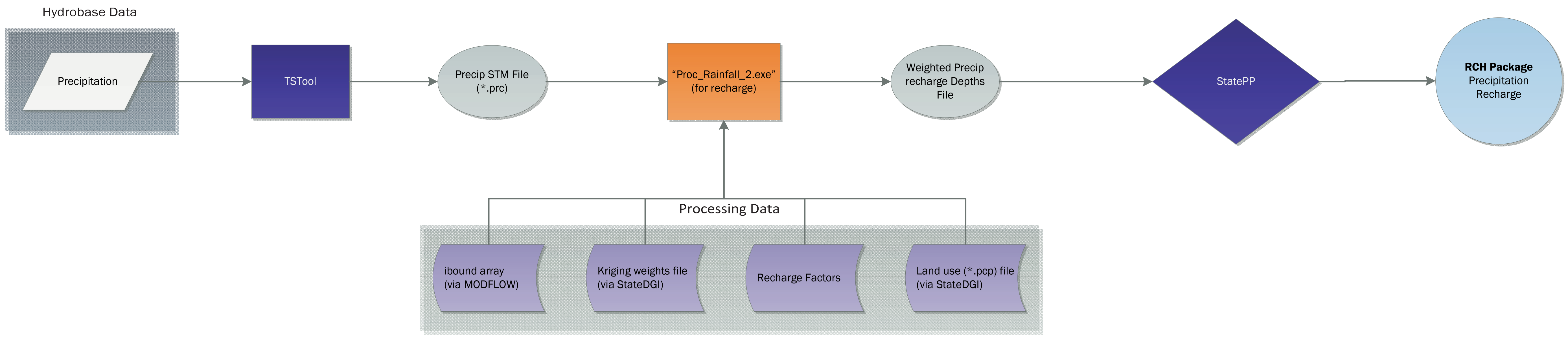
Notes: 1) Proc_rainfall_2.exe generates either weighted runoff depths or weights precipitation recharge depths, depending on what type of factors are read as inputs. For SFR2 purposes, runoff depths were generated.

Figure 3-2

SFR2 Package Development Workflow



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Notes: 1) Proc_rainfall_2.exe can be run with recharge factors to generate weighted recharge arrays or with "runoff" factors to generate weighted runoff arrays. Recharge arrays are used in the recharge package workflow.

Figure 3-3

Recharge Package Development Workflow – Precipitation Recharge

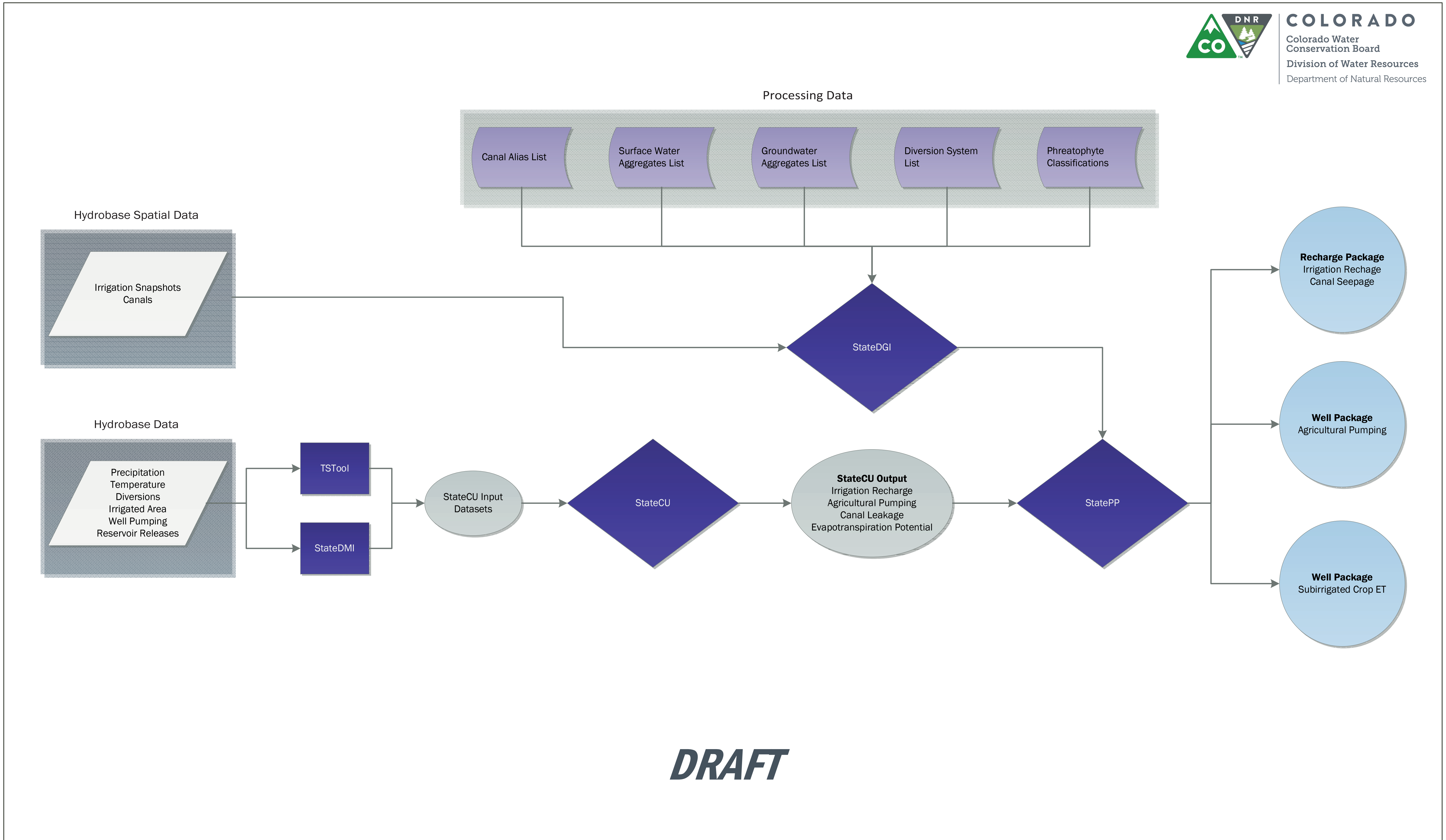

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Figure 3-4

MODFLOW Package Development Workflow – Consumptive Use Model Components

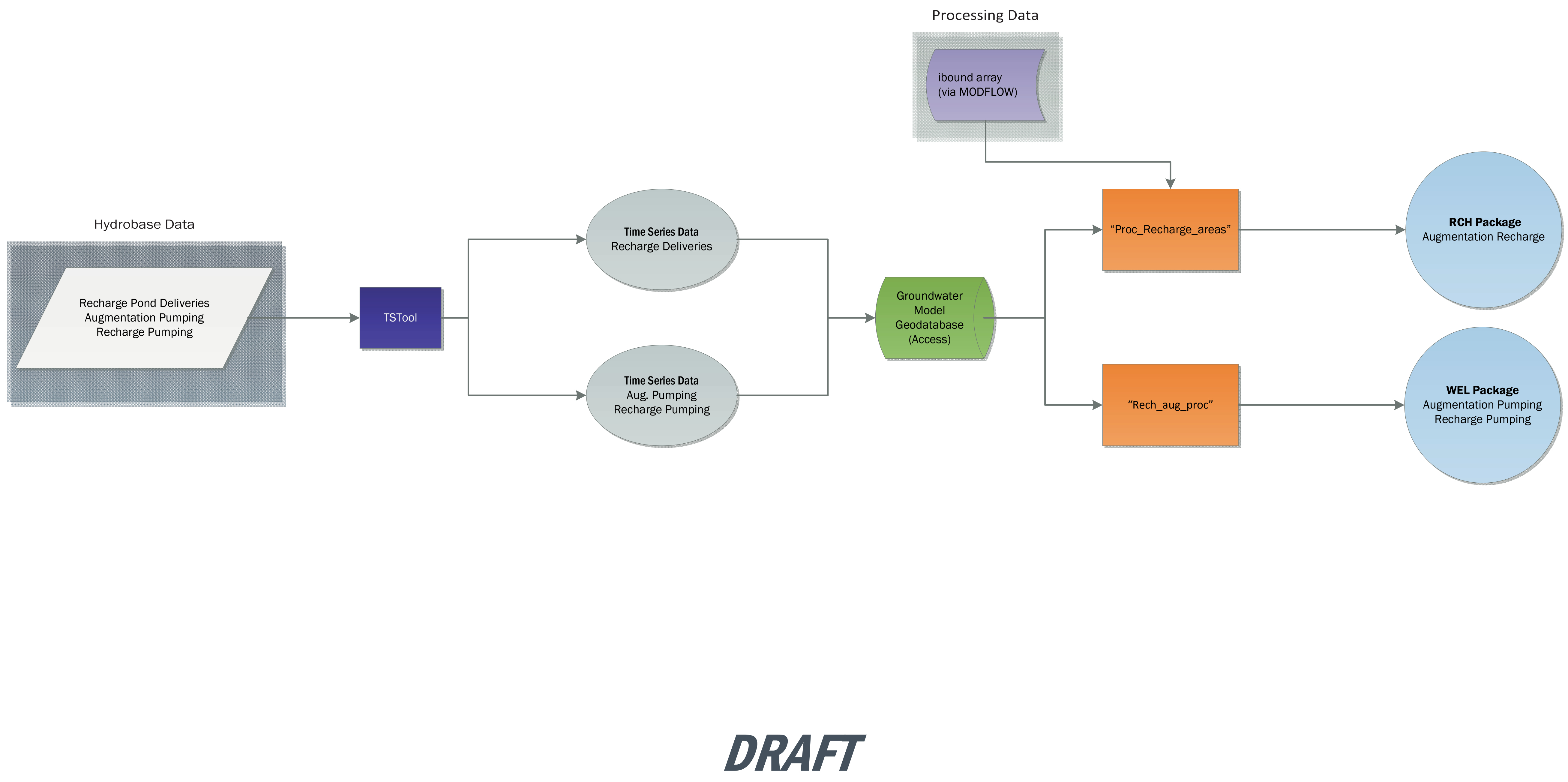

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Figure 3-5

MODFLOW Package Development Workflow – Augmentation Components

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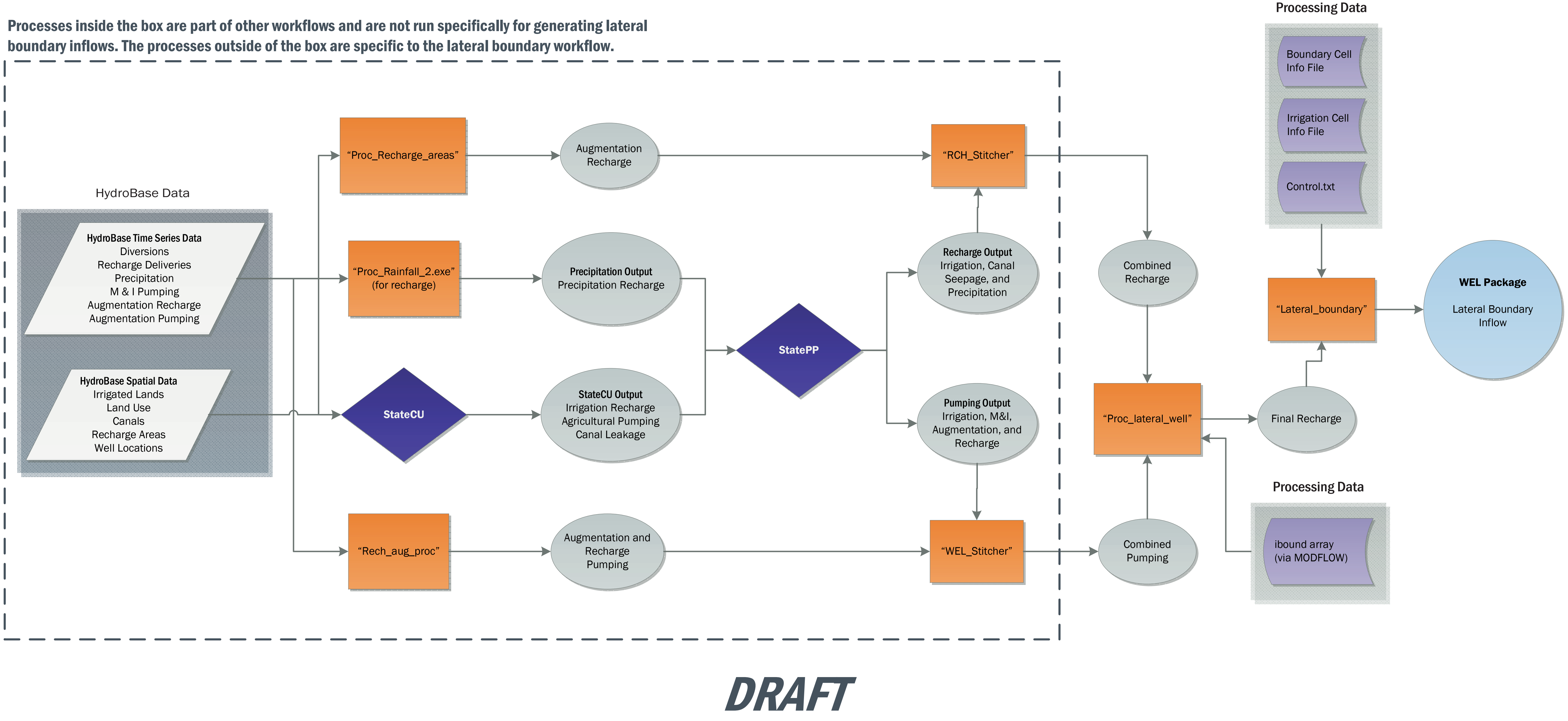

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Notes:
1) See Figure 3-3 for complete precipitation workflow.
2) See Figure 3-4 for complete StateCU workflow.
3) See Figure 3-5 for complete augmentation recharge, augmentation pumping, and recharge pumping workflow.

Figure 3-6

Lateral Boundary Inflow Workflow

Attachment A: Municipal and industrial pumping data collection details

Procedures Used to Estimate Pumping Data

Summary

Data were collected from various sources to extend the time series to December, 2012. The Groundwater Model Access database contains the previously determined pumping values[1] for January, 1950 to December, 2006. Data were also collected from some of the owners/operators of the wells and HydroBase records, when available.

First, HydroBase data were inserted where applicable to fill in the data for all years available. Then, M&I records obtained from the entities were filled in. For dates that have both sets of data, HydroBase data were applied. Next, the Access databases values were inserted to fill the time series to 12/2006 or when the earliest HydroBase record was available.

Lastly, data were filled in using the procedures described in the *Phase 3 Task 41.3 Estimation of Municipal and Industrial Pumping in the South Platte Alluvium Region Final** when applicable. For wells with no data available, the maximum estimated pumping will be set equal to the decreed pumping rate for each entity.

In the complete set of pumping data, from January, 1950 to December, 2003, the monthly pumping amounts are labeled according to their source. The pumping labels (sources) include:

- "Access" - Data previously used through 2006 in the Access database
- "Measured" - Data measured by owners/operators of well
- "HydroBase" - Data taken from HydroBase

See the following section for more detail on how the data were filled in for each well.

Detailed descriptions of procedures

The wells with pumping data in the Access database* (MI_Pumping) had their pumping time series extended until December, 2013. The procedures described below show in the detail how all dates were filled. The wells are organized according to their Well ID.

Aurora

- For all wells
    - 1/1950 to 10/2006 - Based on data in Access database
- For Aurora_Well_1, Aurora_Well_2, Aurora_Well_4, Aurora_Well_5 & Aurora_Well_6
    - 11/2006 to 10/2010 – Based on data provided by Aurora
    - 11/2010 to 12/2013 – Based on HydroBase data
        - Missing months filled in with zeros (no pumping) or measured pumping value.
        - Verified by looking at Aurora's measured data
- For Aurora_Well_3 &Aurora_Well_7
    - 11/2006 to 10/2013 – Based on data provided by Aurora

Brighton

- For all wells
    - 1/1950 to 12/2006 - Based on data in Access database
- For Brighton_Well_11, Brighton_Well_3, Brighton_Well_4, Brighton_Well_7, Brighton_Well_8 & Brighton_Well_9
    - 1/2007 to 10/2011 – Based on average of 2006 and 2013Assumed pumping in the last two years of record is the most representative of pumping records.

1. See *SPDSS Phase 3 Task 41.3 Estimation of Municipal and Industrial Pumping in the South Platte Alluvium Region Final* (2006) for more details on the methodology used to determine values in the Access database.

    - 11/2011 to 10/2013 – Based on HydroBase data
    - 11/2013 to 12/2013 –Based on average of 2006 and 2013
        - Assumed pumping in the last two years of record is the most representative of pumping records
- For rest of wells,
    - 1/2007 to 12/2013 – Based on 2006 data. Assumed pumping records most representative of current use.

Brush

- For all wells,
    - 1/1950 to 12/1965 - Based on data in Access database
    - 1/1966 to 10/2007 - Based on data provided by Brush
    - 11/2007 to 12/2013 - Based on HydroBase data
        - Missing months filled in with zeros or measured pumping value.
        - Verified by looking at Brush's data.

Carey Wells

- For all wells
    - 1/1950 to 12/2006- Based on Access database
    - 1/2007 to 12/2013
        - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Cherry Creek (CCC) Wells

- For CCC_Well_1
    - 1/1950 to 12/2006 - Based on Access database
    - 12/2006 to 10/2007 - Based on average of 2004 & 2005 pumping
        - 2004 & 2005 years with measured data (Access database)
    - 11/2007 to 6/2011 - Based on HydroBase data
        - Blank values filled in with zeros, assumed zero pumping to reflect measured pumping trends
    - 7/2011to 12/2013 - Based on average of HydroBase data
- For CCC_Well_4 and CCC_Well_5,
    - 1/1950 to 12/2006 - Based on Access database
    - 12/2006 to 10/2007 - Based on average of 2004 & 2005 pumping
        - 2004 & 2005 years with measured data (Access database)
    - 11/2007 to 12/2013 - Based on HydroBase data
        - Blank values filled in with zeros, assumed zero pumping to reflect measured pumping trends

City Ice Wells

- For all wells,
    - 1/1950 to 12/2006 – Based on Access database
    - 12/2006 to 12/2013
        - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

CO State Wells

- For all wells
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to0 12/2013
        - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Continental (Suncor) Wells

- For all wells
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 12/2013
        - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

CWSD Wells (Centennial)

- For all wells
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 12/2013 - Based on data provided by Centennial Surf Club/Highlands Ranch

Dekalb Wells (Grand Mesa Eggs)

- For all wells
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 12/2013
        - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

ECCV Wells (East Cherry Creek Water and Sanitation District)

- For all wells,
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 3/2008 - Based on average years 2004-2006 (complete years of measured data)
    - 4/2008 to 10/2013 Based on HydroBase Data
        - Blank values filled in with zeros, assumed zero pumping to reflect measured pumping trends

Englewood Wells

- For Englewood_Well_1
    - 1/1950 to 03/2005 - Based on Access database
    - 04/2005 to 02/2009 - Based on data provided by Englewood
        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
    - 03/2009 to 10/2013 - Based on HydroBase records
        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
    - 11/2013 to 12/2014 - Based on data provided by Englewood
        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
- For Englewood_Well_2
    - 1/1950 to 06/2004 - Based on Access database
    - 7/2004 to 02/2009 Based on data provided by Englewood
        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
    - 3/2009 to 10/2013 Based on HydroBase records
        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
    - 11/2013 to 12/2014 - Based on data provided by Englewood
        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
- For Englewood_Well_3
    - 1/1950 to 2/2004 - Based on Access database
    - 3/2004 to 2/2009- Based on data provided by Englewood

        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
    - 3/2009 to 10/2013 - Based on HydroBase records
        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
    - 11/2013 to 12/2014 - Based on data provided by Englewood
        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
- For Englewood_Well_6
    - 1/1950 to 3/2001 - Based on Access database
    - 4/2001 to 3/2009 - Based on data provided by Englewood
        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
    - 4/2009 to 9/2013 - Based on HydroBase records
        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
    - 10/2013 to 12/2014 - Based on data provided by Englewood
        - Missing values filled in with zeros. Pumping is for irrigation thus has no pumping during winter months.
- For Englewood_Well_7
    - 1/1950 to 12/2006 - Based on Access database
    - 12/2006 to 12/2014 filled in with zeros – no more pumping with this well since 1999 per Englewood's information

Fort Lupton –

- For all Fort_Luption_Well_1, Fort_Lupton_Well_2, Fort_Lupton_Well_3 and Fort_Lupton_Well_4
    - 1/1950 to 12/2006 - Based on Access database
    - 12/2006 to 10/2011
        - Fill in data with calculated average from 1980-2005 since those are measured pumping records
    - 11/2011 to 10/2013 - Based on HydroBase records
        - Fill in missing with calculated average from 1980-2005
- For Fort_Lupton_Well_5 and Fort_Lupton_Well_6
    - 1/1950 to 12/2006 - Based on Access database
    - 12/2006 to 12/2013
        - Fill in data with calculated average from 1980-2005

Fort Morgan

- For Fort_Morgan_Well_1, Fort_Morgan_Well_15, Fort_Morgan_Well_16, Fort _Morgan_Well_3, Fort_Morgan_Well_4 and Fort_Morgan_Well_5
    - 1/1950 to 12/2006 - Based on Access database
    - 12/2006 to 12/213- Based on HydroBase records when available
        - Missing values filled in with data provided by Fort Morgan
- For rest of wells,
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 12/2013 - Based on data provided by Fort Morgan

Great Western Wells

- For all wells,
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 12/2013
        - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Greeley Wells

- For Greeley_Well_1, Greeley_Well_3, Greeley_Well_4 and Greeley_Well_5
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2006 to 12/2013 - Based on data provided by Greeley
        - Missing values for Jan and Feb 2007, assumed zero pumping to reflect measured pumping trends
- For remaining wells,
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 12/2013
        - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Hibbs Well

- 1/1950 to 12/2006 - Based on Access database
- 1/2007 to 12/2013
    - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Hillrose Well

- 1/1950 to 12/2006 - Based on Access database
- 1/2007 to 12/2013
    - Based on average of 2002-2005 measured monthly pumping records

Julesburg Wells

- For Julesburg_Well_3
    - 1/1950 to 10/1995 - Based on Access database
    - 10-1995 to 12/2006 - Based on hydro base
        - Missing values filled in with Access database values
    - 1/2007 to 10/2007
        - Filled in with a percentage of pumping according to the yearly totals provided by Julesburg
        -

Jan	3.5%
Feb	3.6%
March	4.3%
April	6.9%
May	11.1%
June	13.6%
July	16.7%
August	14.1%
September	11.2%
October	6.9%
November	4.3%
December	3.8%

        - Have monthly records from 1998 to 2005, so calculated pumping % of yearly total average across years
    - 11/2007 to 12/2013 - Based on HydroBase records
        - Missing values filled in with a percentage of pumping according to the yearly totals provided by Julesburg
- For rest of wells,
    - 1/1950 to 12/2006- Based on Access database
    - 1/2007 to 12/2013
        - Based on HydroBase data

- Filled in with a percentage of pumping according to the yearly totals provided by Julesburg
- Average monthly percentages from 1998 -2005 data
-

Jan	3.5%
Feb	3.6%
March	4.3%
April	6.9%
May	11.1%
June	13.6%
July	16.7%
August	14.1%
September	11.2%
October	6.9%
November	4.3%
December	3.8%

KB Packing Wells

- For all wells
  - 1/1950 to 12/2006 Based on Access database
  - 1/2007 to 12/2013
    - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Kersey Wells –

- For all wells
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Access data shows trend of yearly pumping increases by 4.727 AF. (% increase = 2.56%). Continue this projection forward.

Klausner Wells

- For all wells
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Krueger Well

- For well
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013 – Based on HydroBase records
    - Missing data filled in with maximum estimated pumping equal to decreed rate (as previously done for the Access database)
    - HydroBase records are sporadic and do not have complete years, so cannot use its average

La Salle Wells

- For all Lasalle_Well_1 and LaSalle_Well_2
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Access estimated data shows trend of total yearly AF increases by 0.3051 AF. (% increase = 0.3507%). Continue this projection forward.
- For all Lasalle_Well_3, LaSalle_Well_4 and LaSalle_Well_5

- 1/1950 to 12/2006 Based on Access database
  - 1/2007 to 12/2013- Based on HydroBase records
    - Missing data filled in
      - Access estimated data shows trend of total yearly AF increases by 0.3051 AF. (% increase = 0.3507%). Continue this projection forward.

Lauck Wells

- For all wells
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Log Lane Well

- For all wells
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Based on 2004, year of measured data
    - 5/2010 well abandoned so zero pumping afterwards

Lousberg

- For all wells
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Mathews Wells

- For all Mathews_Well_2
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)
- For Mathews_Well_1
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 10/2011
    - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)
  - 11/2011 to 12/2013 -Based on HydroBase data
    - Missing data filled in with maximum estimated pumping equal to decreed rate

McAtee Wells

- For McAtee_Well_3, McAtee_Well_4, McAtee_Well_8
  - 1/1950 to 10/2006 - Based on Access database
  - 11/2006 to 12/2013 -Based on HydroBase data
    - Missing data filled in with maximum estimated pumping equal to decreed rate
- For rest of wells,
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

MCQWC Wells

- MCQWC_Well_2, MCQWC_Well_3, MCQWC_Well4 and MCQWC_Well_5
  - 1/1950 to 10/2006 - Based on Access database

- 11/2006 to 12/2013- Based on HydroBase records
  - Filled in with pumping average 2005-2006 because based on actual monthly data for individual wells

- MCQWC_Well_1
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Filled in with pumping average 2005-2006 because based on actual monthly data for individual wells

Merino Well

- 1/1950 – 12/2006- Based on Access database
- 1/2007 – 12/2013 - Based on HydroBase records
  - Missing data November and December, 2013 filled in with HydroBase values for pumping in 2012

Milliken Well

- 1/1950 to 12/2006 - Based on Access database
- 1/2007 to 12/2013
  - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Montfort Wells

- For Monfort_Well_6
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)
- For rest of wells
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Based on HydroBase records
    - Filled in missing data with maximum estimated pumping equal to decreed rate

Ovid Well

- 1/1950 to 12/2006 Based on Access database
- 1/2007 to 12/2013
  - Used years 2004-2005 to determine monthly percentage of pumping because these years are actual monthly measurements, then applied that to the yearly totals provided by Ovid

Jan	6.4%
Feb	5.5%
March	7.3%
April	8.5%
May	11.5%
June	12.7%
July	14.8%
August	12.4%
Sept	12.1%
Oct	7.6%
Nov	2.3%
Dec	2.3%

Pack Corp Wells

- For all wells

- 1/1950 to 12/2006 - Based on Access database
- 1/2007 to 12/2013
  - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Platteville Wells

- For all wells
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Access estimated data shows trend of total yearly AF increases by 6.59 AF. (% increase = 3.056%). Continue this projection forward.

PWSD Well

- 1/1950 to 12/2006 Based on Access database
- 1/2007 to 12/2013
  - Based on pumping trend 1983-2005; same pumping each month. Continue forward.

SACWSD (South Adams County Water and Sanitation District) Wells

- For SACWSD_Well_1
  - 1/1950 to 10/1995 - Based on Access database
  - 11/1995 to 12/2013 - Based on HydroBase data
    - Missing data filled in with average 1996-2000, 2003-2006, 2008 (full years of HydroBase data)
- SACSWD_Well_10
  - 1/1950 to 10/2001 - Based on Access database
  - 11/2001 to 12/2013 - Based on HydroBase data
    - Missing data filled in with pumping from 2003 (only full year of measured data)
- SACWSD_Well_2
  - 1/1950 to 10/1995 - Based on Access database
  - 11/1995 to 12/2013 - Based on HydroBase data
    - Missing data filled in with average 1998-2001, 2005 (full years of HydroBase data)
- SACWSD_Well_3
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Filled in with zeros because database shows no pumping from 1988-2006. Assume continues with no pumping.
- SACWSD_Well_4
  - 1/1950 to 10/1995 - Based on Access database
  - 11/1995 to 12/2013 - Based on HydroBase data
    - Missing values filled in with average 1996-2000, 2003, 2005 – 2006, 2012 (full years of HydroBase data)
- SACWSD_Well_5
  - 1/1950 to 12/2006 - Based on Access database
  - 1/2007 to 12/2013
    - Filled in with average of years 2000-2005 (measured data)
- SACWSD_Well_6
  - 1/1950 to 1/1996 - Based on Access database
  - 2/1996 to 12/2013 - Based on hydro base data
    - Missing data filled in with average of 1998-2000, 2003, 2012 (full years of HydroBase data)
- SACWSD_Well_7

    - 1/1950 to 1/1996 - Based on Access database
    - 2/1996 to 12/2013 - Based on hydro base data
        - Missing data filled in with average of 1998-2005, 2008(full years of HydroBase data)
- SACWSD_Well_8
    - 1/1950 to 1/1996 - Based on Access database
    - 2/1996 to 12/2013 - Based on hydro base data
        - Missing data filled in with average of 1998-2001, 2003-2006 (full years of HydroBase data)
- SACWSD_Well_9
    - 1/1950 to 1/1996 - Based on Access database
    - 2/1996 to 12/2013 - Based on hydro base data
        - Missing data filled in with average of 1996-2008 (full years of HydroBase data)

Sedgwick

- For Sedgwick_Well_2,
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 11/2007
        - Filled in with Monthly Average 2010-2012 (complete years with measured data)
    - 1/2007 to 12/2013- Based on HydroBase data
        - Missing data filled in with monthly Average 2010-2012 (complete years with measured data)
- For rest of wells,
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 12/2013
        - Access estimated data shows trend of total yearly AF increases by 0.046 AF. (% increase = 0.41025%). Continue this projection forward.

Sterling Beef Wells

- For all wells,
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 12/2013
        - Based on HydroBase records
        - Missing data filled in average from years 2007-2011 (full years of HydroBase records)

Sterling EW Wells

- 1/1950 to 12/2006 - Based on Access database
- 1/2007 to 12/2013
    - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Sterling Wells

- For Sterling_Well_1, Sterling_Well_2, Sterling Well_3
    - 1/1950 to 10/1999 - Based on Access database
    - 10/1999 to 10/2006 - Based on HydroBase data
        - Missing data filled in with access data base (based on actual pumping records)
    - 11/2009 to 12/2013 - Based on HydroBase data
        - Missing data filled in with average of years (full years of measured data)
            - Well 1 average 2000-2003, 2007-2009, 2012
            - Well 2 average 2001-2002, 2005, 2007
            - Well 3 average 2000-2002, 2007-2009, 2012

- Sterling_Well_10, Sterling_Well_4
    - 1/1950 to 12/2006 - Based on access data base
    - 1/2007 to 12/2013- Based on HydroBase data
        - Filled in with average from years (full years measured data)
            - Well 10 average 2001-2003, 2005, 2007
            - Well 4 average 2001-2005
- Sterling_Well_5
    - 1/1950 to 5/2000 Based on Access database
    - 6/2000 to 12/2006 Based on HydroBase data
        - Missing data filled in with Access database values because Based on measured pumping for those years
    - 1/2007 to 12/2013
        - Based on HydroBase
        - Missing values filled in with 2005 pumping (full year measured data)
- Sterling_Well_6
    - 1/1950 to 10/1995 - Based on Access database
    - 11/1995 to 12/2006 - Based on HydroBase records
        - Missing records filled in with Access database
    - 1/2007 to 12/2013 - Based on HydroBase records
        - Missing values filled in with pumping from 2005 (year full data).
        - No pumping November - April, fill in with zeros to reflect pumping trends
        -
- Sterling_Well_7
    - 1/1950 to 12/1995 - Based on access
    - 1/1996 to 12/2006 - Based on HydroBase
        - Missing data filled in with Access database
    - 1/2007 to 12/2013 - Based on HydroBase
        - Missing values filled in with average 2001-2002, 2005
- Sterling_Well_8, Sterling_Well_9
    - 1/1950 to 12/2006 - Based on access data base
    - 1/2007 to 12/2013
        - Filled in with HydroBase data
        - Missing data filled in with average from years 2001-2005 (full years measured data)
        - No pumping November - April, fill in with zeros to reflect pumping trends

Swift Wells

- For all wells,
    - 1/1950 to 12/2006 - Based on hydro base
    - 1/2007 to 12/2013
        - Fill in with average from 2004, 2005 because actual pumping records

Thornton Wells

- For all wells,
    - 1/1950 to 12/2006 - Based on hydro base
    - 1/2007 to 12/2013
        - Fill in with average from 2002-2005 because actual measured pumping records

Valencia Wells

- For all wells
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 12/2013

        - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Walker Wells

- For all wells
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 12/2013
        - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

Wiggins

- For all wells
    - 1/1950 to 12/2006 - Based on Access database
    - 1/2007 to 12/2013
        - Maximum estimated pumping equal to decreed rate (as previously done for the Access database)

XCEL Public Service Wells

- Xcel_well_1
    - 1/1950 to 10/2001 - Based on Access database
    - 11/2001 to 12/2006 - Based on HydroBase
            - Missing data filled in with access database
    - 1/2007 to 12/2013- Based on HydroBase
        - Missing data filled in with measured data given to us by XCEL
- Xcel_Well_3
    - 1/1950 to 10/2005 Based on access
    - 11/2005 to 12/2013 - Based on HydroBase records
        - Missing data filled in with measured data by XCEL
- Xcel_Well_2, Xcel_Well_4 and Xcel_Well_5
    - 1/1950 to 10/2005- Based on access
    - 11/2005 to 12/2013 - Based on measured data by XCEL

Additional Observations:

There were some discrepancies in the Access database. Various wells included in the MI_Pumping_Wells_wGridLocation sheet but not included in MI_Pumping sheet. Those wells are shown in the table below.

Only wells with pumping records in the access data base (MI_Pumping) had their time series extended.

Well ID	CCCC_Well_2	CCCC_Well_3	Lasalle_Well_6	NCWA_Well_1	NCWA_Well_2	NCWA_Well_3	Walker_Well_3
Permit Number	15447	15450	3673	4862	13429	60767	2498
Well name	HOLLAND MARCUS W 2-15447	HOLLAND MARCUS W 3-15450	LASALLE TOWN OF 3673-F	N COLO W ASSN W 1-04862F	N COLO W ASSN W 2-13429F	60767-F	WALKER WELL 4-2498-F
X coordinate	510013.3	510013.3	525243	503077.6	503077.8	504056.3	582009
Y coordinate	4391564	4391564	4467052	4529678	4529476	4528865	4460598

Also, various wells were missing permit numbers. Those wells include:

- Brighton_Well_10
- Brighton_Well_12
- Brighton_Well_13
- Brighton_Well_14
- Brighton_Well_15
- Brighton_Well_16
- Brighton_Well_17
- Brighton_Well_18
- Brighton_Well_19
- CO_State_Well_2
- CO_State_Well_3
- Continental_Well_10
- Continental_Well_9
- Mathews_Well_2
- McAtee_Well_1
- McAtee_Well_2
- SACWSD_Well_1
- SACWSD_Well_3
- SACWSD_Well_5
- Thornton_Well_1
- Thornton_Well_5
- Walker_Well_2

Attachment B: StateCU, precipitation, and recharge data collection details

Transmittal Memo

To: Matt Lindburg, Zach Wengrovius, Brown & Caldwell
From: Kara Sobieski
Date: November 17, 2015
Re: SPDSS Model Information – Basin-wide Scenario, Burlington System Overview, Summary of Model Changes

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This transmittal reflects the following deliverables:

- **South Platte River Basin-wide Consumptive Use Analysis**: This dataset includes consumptive use, irrigation return flows, and canal recharge information for irrigation and carrier structures in the entire South Platte Basin. This deliverable provides information on structures that are outside of the active ground water model boundary, but within the inactive boundary where they may have an impact on boundary conditions or lateral inflows. The dataset deliverable includes the basin-wide model input and output files; however, similar to the previously delivered ground water area subset scenario (sp2015GW_WCarriers), the detailed water budget output file (*.dwb) contains the bulk of information used for the ground water model. Note that other files previously developed based on information from the ground water area subset scenario (e.g. alias lists) and delivered have not been reproduced using the full scenario.

- **Burlington Ditch, FRICO-Barr, Henrylyn System Overview:** The Burlington, FRICO-Barr and Henrylyn Systems are represented in StateCU with several carriers and irrigation demands. A detailed overview of the system is provided *Task 5 - Key Structure Operating Memorandum – Burlington, FRICO–Barr, and Henrylyn Systems*; this summary provides specific information as to which structures reflect canal recharge and/or irrigation return flows and spatially where these return flows should be represented in the ground water model. Due to the complexity of these operations, the irrigation return flows are summarized in the first table, **Operations and Irrigation Recharge Approach,** and the canal recharge is summarized in the second table, **Canal Recharge Approach**. Refer to the figure at the end of this memo to assist with identification of canals and structures.

  As many of the demands (irrigation and reservoirs) included in these systems have a different conveyance loss, the total diversions through the Burlington Canal/O'Brian Canal Headgate (0200802) have been disaggregated and represented under three different model IDs: Denver-Hudson Canal (0200805), Little Burlington Canal (0200918), and Barr Lake Carrier (0203837_C). Therefore, no diversions, conveyance loss, or irrigation return flows associated to the primary Burlington Canal headgate (0200802) in the StateCU model. It is recommended the canal recharge assigned to this structure be calculated by summing portions of the canal recharge estimated under these three different model IDs; see the **Canal Recharge Approach** table and the simplified figure below for the recommended calculations.

Operations and Irrigation Recharge Approach

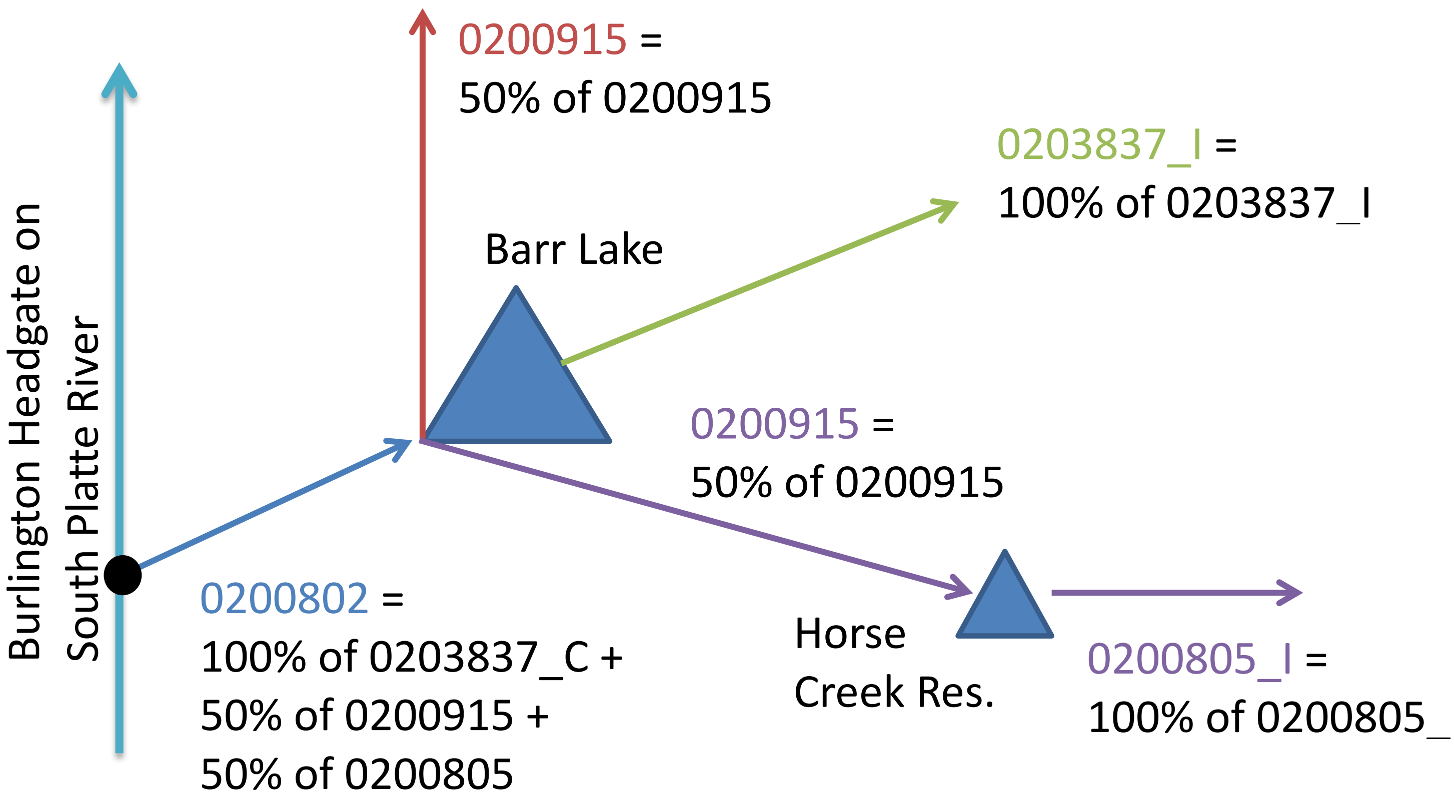
Model ID	Name	Operations	Irrigation Recharge
0200802	Burlington Canal	Carries direct diversions to Denver-Hudson Canal, Barr Lake, and Little Burlington system demands	N/A
0200805	Denver-Hudson Canal	Reflects total river diversions to Henrylyn Irrigation District (0200805_I) and Reservoirs (Horse Creek and Prospect Reservoirs)	N/A
0200805_I	Denver-Hudson Canal (Henrylyn) Irrigation Demand	Reflects portion of direct diversions to irrigation (after losses) and releases from reservoir to irrigation demand	Total return flows (recharge & overland) from irrigated lands assigned to 0200805 & 0200902
0200915	Little Burlington Canal	Reflects total river diversions to Little Burlington Canal irrigated lands	Total return flows from irrigated lands assigned to 0200915
0203837_C	Barr Lake Carrier	Reflects total diversion to storage in Barr Lake	N/A
0203837_I	Barr Lake Irrigation Demand	Reflects releases from Barr Lake to irrigation demand	Total return flows from irrigated lands assigned to 0203837

Canal Recharge Approach

Model ID	Name	Canal Length Reach in GIS	Canal Recharge Calculation
0200802	Burlington Canal	Burlington Canal headgate to Barr Lake	100% of conveyance loss in StateCU under 0203837_C + 50% of conveyance loss in StateCU under 0200805 + 50% of conveyance loss in StateCU under 0200915
0200805	Denver-Hudson Canal	Denver-Hudson Canal from Barr Lake to Horse Creek Reservoir	50% of conveyance loss in StateCU under 0200805 model ID
0200805_I	Denver-Hudson Canal (Henrylyn) Irrigation Demand	Denver-Hudson Canal from Horse Creek Reservoir to end of canal, including Box Elder Lateral	100% of conveyance loss in StateCU under 0200805_I model ID
0200915	Little Burlington Canal	Little Burlington Canal from Bar Lake to end of canal, including Brighton Lateral	50% of conveyance loss in StateCU under 0200915 model ID
0203837_C	Barr Lake Carrier	N/A – all conveyance loss included under 0200802 ID	N/A – all conveyance loss included under 0200802 ID
0203837_I	Barr Lake Irrigation Demand	Conveyance loss from Barr Lake to end of following outlet canals: Neres Canal East Neres Canal Beebe Canal E. Burlington Ext. Ditch Speer Canal	100% of conveyance loss in StateCU under 0203837_I model ID

W. Burlington Ext. Ditch

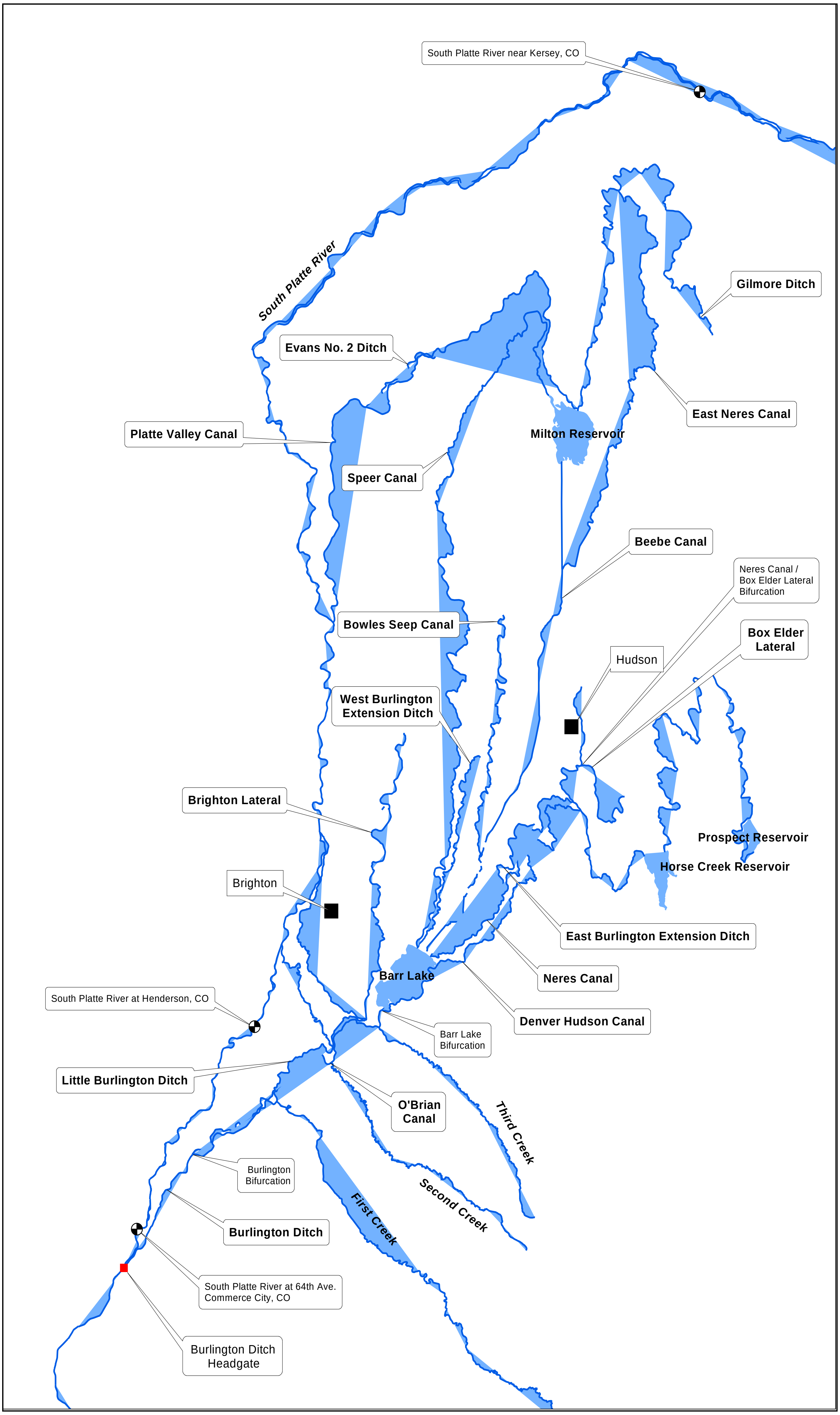
* The primary canals that carry water to irrigation demands have been included; other canals that carry multi-source water or may not be primary carriers have been excluded.



- **2008 to 2015 Model Changes**: The following table provides a summary of the model IDs that have changed or have been added/removed from the 2008 South Platte modeling effort to the 2015 modeling effort. There have been other changes (e.g. revised efficiencies, capacities, diversion amounts) implemented by the sub-basin modelers that are reflected in the 2015 model results but not explicitly listed below.

Model ID	Revision
01_ADP037	Disaggregated in 2015 Model, 0100643, 0100644, 0100835, and 0104486 modeled explicitly now
0200991 - 0200994	Added to the 2015 Model to reflect Standley deliveries to “Standley Lake Cities”; no irrigation or conveyance loss
0400502_D	Diversion system disaggregated in 2015 Model, 0400502 and 0400587 modeled explicitly
0500603_D & 0500603_I	Diversion system disaggregated in 2015 Model, 0500603, 0500564, 0500565, 0500568, 0500569, 0500570, 0500571, 0500572,

	0500573, 0500574, 0500575, 0500648 modeled explicitly
0600557	Added to the 2015 Model
05_ADP001	Divided up into two aggregate systems in 2015 Model, 05_ADP001 and 05_ADP002
0600597	Municipal structure, removed from 2015 Model
0600598	Municipal structure, removed from 2015 Model
0600599	Municipal structure, removed from 2015 Model
0600767	Municipal structure, removed from 2015 Model
0600800	Municipal structure, removed from 2015 Model
0600878	Municipal structure, removed from 2015 Model
0600889	Municipal structure, removed from 2015 Model
0600902	Municipal structure, removed from 2015 Model
0600943	Municipal structure, removed from 2015 Model
0700678	Added to the 2015 Model
0801*	Several municipal structures added/removed by sub-basin modeler, no irrigation or conveyance loss
2302*	Administrative gages in South Park revised model IDs from gage ID name (e.g. SFKANTCO) to HydroBase IDs (2302900)
AWP	Groundwater aggregates added/removed based on revised assignment of wells by DWR
0400521_I	Added as off-channel demand in 2015 Model
0400530_I	Added as off-channel demand in 2015 Model
0400532_I	Added as off-channel demand in 2015 Model
0400543_I	Added as off-channel demand in 2015 Model
0500563_I	Added as off-channel demand in 2015 Model
0500564_I	Added as off-channel demand in 2015 Model
0600501_C & 0600501_I	Added as off-channel demand in 2015 Model
0600516_I	Added as off-channel demand in 2015 Model
0600537_C & 0600537_I	Added as off-channel demand in 2015 Model
0600565_C & 0600565_I	Added as off-channel demand in 2015 Model
0700569_C	Added as off-channel demand in 2015 Model
0700570_C	Added as off-channel demand in 2015 Model
0801004_D	Removed diversion system designation (_D) in 2015 Model


South Platte River near Kersey, CO
South Platte River
Gilmore Ditch
Evans No. 2 Ditch
East Neres Canal
Platte Valley Canal
Milton Reservoir
Speer Canal
Beebe Canal
Neres Canal / Box Elder Lateral Bifurcation
Box Elder Lateral
Bowles Seep Canal
Hudson
West Burlington Extension Ditch
Brighton Lateral
Prospect Reservoir
Horse Creek Reservoir
Brighton
East Burlington Extension Ditch
Neres Canal
Barr Lake
South Platte River at Henderson, CO
Denver Hudson Canal
Barr Lake Bifurcation
Little Burlington Ditch
O'Brian Canal
Third Creek
Burlington Bifurcation
Second Creek
First Creek
Burlington Ditch
South Platte River at 64th Ave. Commerce City, CO
Burlington Ditch Headgate

Transmittal Memo

To: Matt Lindburg
From: Erin Wilson
Date: 12/12/2015
Re: SPDSS Model Interactions – Precipitation Recharge Files

This transmittal includes files required to develop the precipitation recharge input into the SPDSS ground water model. This deliverable meets the requirements outlined in item 1 of the Model Interactions memo (GW_Inflow_Outflow_12-12-2014.docx, updated and included in this transmittal).

1) Spreadsheet matching previous climate station IDs with new climate station IDs adopted by NOAA (HydroBaseClimateStation_newIDs). Note that the new climate station IDs are now stored in HydroBase and have been adopted for SPDSS consumptive use and surface water efforts.
2) Precipitation Recharge Grids for ArcMap (CDSSToolBox_climate_grids.zip). Note that these grids have not been revised to reflect the new climate station IDs adopted by NOAA.
3) Time series file with monthly total precipitation for each climate station, in standard StateMod format (SP2015.prc).
4) File previously submitted to CDM with GridID (row_column), climate station ID, and climate station weight (Grid_Precip_Wts.csv). This file was originally developed using StateDGI. We have replaced the previous NOAA climate station IDs with the new climate station IDs – this may allow you not to have to recreate the file or worry about the updating the gridded climate dataset at this time.

The climate station weight file (Grid_Precip_Wts.csv) is used in conjunction with the monthly precipitation by climate station file (SP2015.prc) and land use by category file (not included in this submittal) to estimate precipitation recharge in each ground water model cell. **Table 1** defines the initial recommended precipitation recharge by land use category, as a percent of total weighted precipitation, for the ground water model area as recommended in Task 64.

Table 1
Precipitation Recharge as Percentage of Total Precipitation

Land Use Category	Irrigation Season % April through October	Non-Irrigation Season November through March
ALFALFA_SOILA	23%	1%
ALFALFA_SOILB	14%	1%
ALFALFA_SOILC	4%	1%
ALFALFA_SOILD	2%	1%
CORN_SOILA	23%	1%
CORN_SOILB	14%	1%

CORN_SOILC	4%	1%
CORN_SOILD	2%	1%
DRY_BEANS_SOILA	23%	1%
DRY_BEANS_SOILB	14%	1%
DRY_BEANS_SOILC	4%	1%
DRY_BEANS_SOILD	2%	1%
FOREST_SOILA	1%	1%
FOREST_SOILB	1%	1%
FOREST_SOILC	1%	1%
FOREST_SOILD	1%	1%
GRASS_PASTURE_SOILA	23%	1%
GRASS_PASTURE_SOILB	14%	1%
GRASS_PASTURE_SOILC	4%	1%
GRASS_PASTURE_SOILD	2%	1%
NATIVE_VEGETATION_SOILA	1%	1%
NATIVE_VEGETATION_SOILB	1%	1%
NATIVE_VEGETATION_SOILC	1%	1%
NATIVE_VEGETATION_SOILD	1%	1%
ORCHARD_WO_COVER_SOILB	14%	1%
ORCHARD_WO_COVER_SOILC	4%	1%
ORCHARD_WO_COVER_SOILD	2%	1%
PHREATOPHYTE_SOILA	1%	1%
PHREATOPHYTE_SOILB	1%	1%
PHREATOPHYTE_SOILC	1%	1%
PHREATOPHYTE_SOILD	1%	1%
SMALL_GRAINS_SOILA	23%	1%
SMALL_GRAINS_SOILB	14%	1%
SMALL_GRAINS_SOILC	4%	1%
SMALL_GRAINS_SOILD	2%	1%
SOD_FARM_SOILA	23%	1%
SOD_FARM_SOILB	14%	1%
SOD_FARM_SOILC	4%	1%
SUGAR_BEETS_SOILA	23%	1%
SUGAR_BEETS_SOILB	14%	1%
SUGAR_BEETS_SOILC	4%	1%
URBAN_SOILA	1%	1%
URBAN_SOILB	1%	1%
URBAN_SOILC	1%	1%
URBAN_SOILD	1%	1%
VEGETABLES_SOILA	23%	1%
VEGETABLES_SOILB	14%	1%
VEGETABLES_SOILC	4%	1%
WATER_SOILA	0%	0%
WATER_SOILB	0%	0%
WATER_SOILC	0%	0%

WATER_SOILD	0%	0%
WATER_*ResWDID*_SOILA	0%	0%
WATER_*ResWDID*_SOILB	0%	0%
WATER_*ResWDID*_SOILC	0%	0%
WATER_*ResWDID*_SOILD	0%	0%

Memo

To: Brown & Caldwell
From: Kara Sobieski and Logan Callihan
Date: 3/17/2015
Re: Streamflow, Import and Export Data

The following summarizes the approach taken to determine the surface water flows within the ground water model boundary, the surface water inflows into the ground water model boundary, and the import and export components to/from the ground water model. The original data for this effort was developed in SPDSS Task 2, which identified key streamflow gages for both the SPDSS surface and ground water models. Streamflow data and import and export data has been reviewed, modified if necessary, and extended through 2013. Four separate StateMod formatted files are included with the deliverable as described below.

Surface Water Streamflow within the Ground Water Model

The file SP2015_SFwithinGW_032015.stm provides the time-series of historical streamflows at gages within the active ground water model boundary. Surface water flows within the ground water model are gaged streamflows located *within* the boundary of the ground water model. These gages were initially identified as key streamflow gages for the ground water model in SPDSS Task 2 based on the following criteria: key streamflow gages must have good or excellent records based on USGS ratings; have at least 70% of the records complete throughout the SPDSS study period (1950-2002 at the time); or have the best available data at an important location.

As part of the model extension, key streamflow gages within the ground water boundary were extended and filled through 2013. In general, the dataset was created by pulling monthly surface water flow records from HydroBase using TSTool and filling missing data based on the techniques outlined in the SPDSS Task 2 memoranda on stream gages and stream flow records. **Table 1** lists the surface water streamflow gages modeled *within* the SPDSS ground water model boundary.

Table 1. Surface Water Streamflows within the SPDSS Ground Water Model Boundary.

Water District	Structure ID[1]	Streamflow Gage
1	06754000	South Platte River near Kersey
1	06758500	South Platte River near Weldona
1	06759910 & 06760000	South Platte River at Cooper Bridge near Balzac & South Platte River at Balzac
2	06720500	South Platte River at Henderson
2	06721000	South Platte River at Fort Lupton
3	06752500	Cache La Poudre near Greeley
4	06744000	Big Thompson River at mouth near La Salle

Water District	Structure ID[1]	Streamflow Gage
5	06731000	St. Vrain Creek at mouth near Platteville
7	06720000	Clear Creek at Derby
8	06708000	South Platte River at Waterton
8	06709530 & 06709500	Plum Creek at Titan Road near Louviers & Plum Creek near Louviers
8	06710247, 06710245 & 06710000[2]	South Platte River below Union Ave at Englewood, South Platte River at Union Ave at Englewood & South Platte River at Littleton
8	06713500	Cherry Creek at Denver
8	06714000	South Platte River at Denver
9	06711500	Bear Creek at Sheridan
64	06764000	South Platte River at Julesburg

Source: HydroBase & SPDSS Task 2

Notes:
[1] Multiple IDs indicate two gages were combined
[2] South Platte River at Littleton (06710000) is combined with South Platte River at Union (06710245). The Englewood Intake (0801013) is subtracted from the combined record, which is filled and then combined with South Platte River below Union (06710247).

Note, SPDSS Task 2 Figure 3 indicates the Cherry Creek at Denver gage (06713500) is also located within the groundwater model boundary. This gage, however, was identified only as a calibration gage and not filled.

Surface Water Inflows

The file SP2015_SWInflowToGW_032015.stm provides the time-series of historical river inflows to the active ground water model boundary. Surface water inflows, as recorded at streamflow gages, occur at the top of the main stem South Platte River and tributary basins upstream of the ground water model area. Missing data was filled based on techniques outlined in Task 2.

The ground water model boundary was spatially reviewed to identify streamflow gages that most represent the streamflow conditions at the ground water model boundary. In some instances, the streamflow gages have been adjusted to match the location of the boundary. For example, if the streamflow gage is located downstream of the ground water boundary, diversions located in between the actual location of the gage and groundwater boundary have been added to the gaged streamflow such that the gage reflects the inflow at the boundary. If the streamflow gage is located upstream of the groundwater boundary, diversions located between the actual location of the gage and the ground water boundary have been subtracted from the recorded streamflow resulting in the inflow at the boundary. **Table 2** lists the surface water inflows modeled in the SPDSS ground water model area by Water District and any diversions used to adjust the streamflow to the boundary.

Table 2. SPDSS Ground Water Model Area Surface Water Inflows.

Water District	Structure ID[1]	Streamflow Gage	Adjusted Streamflow by Adding (+) or Subtracting (-) Diversions
1	06753500	Lonetree Creek near Nunn	-
2	06720820	Big Dry Creek at Westminster	-
3	06752260	Cache La Poudre at Fort Collins	0300918, 0300919, 0300921, 0300922, 0300923 (+)
4	06741510	Big Thompson at Loveland	0400519, 0400503 0400541, 0400534, 0400532 (+)
4	06743500	Little Thompson River at Milliken	0400601, 0400599, 0400587 (+)
5	06725450	St. Vrain Creek below Longmont	-
6	06730200	Boulder Creek at North 75th	-
6	06730300	Coal Creek near Plainview	0600608, 0600605, 0600606, 0600609, 0600621, 0600615 (-)
7	06719505 & 06719500[2]	Clear Creek at Golden & Clear Creek near Golden	0700725, 0700502, 0700569, 0700698, 0700601 (-)
8	06712000	Cherry Creek near Franktown	0801362 (-)
8	06709530 & 06709500	Plum Creek at Titan Rd. near Louviers & Plum Creek near Louviers	-
8	PLACHACO[3]	South Platte River below Chatfield	0801007, 0801008, 0801009 (+)
9	06711500	Bear Creek at Sheridan	0900816 (+)

Source: HydroBase & SPDSS Task 2

Notes: [1] Multiple IDs indicate two gages were combined

[2] Church Ditch (0700540) diverts between the locations of these two gages therefore the diversions were subtracted before the gages were combined

[3] The PLACHACO gage is filled with South Platte River at Littleton (06710000). See comment below Table 1 for how the South Platte River at Littleton gage is combined/filled, as the same methodology is applied for combining the Littleton gage with the PLACHACO gage.

Imports

The file SP2015_GW_IMP_032015.stm provides the time-series of imports into the active ground water model boundary. Imports into the ground water model represent any inflows that are diverted outside of the ground water model boundary but consumed within the active ground water model area. The imports can be characterized into two types, either imports used to meet municipal demands in the active ground water boundary or imports used to meet irrigation demands in the active ground water boundary. Below is a list of imports into the ground water model by type.

Municipal Imports. The following municipal imports divert water from outside the active ground water model boundary; however the consumptive use, the outdoor use return flows, and the waste water treatment return flows occur within the ground water model boundary.

- The following ditches divert above the active ground water model boundary for municipal use located within the active ground water model boundary:
  - Greeley Filters Pipeline (0300908)
  - Fort Collins Pipeline (0300906)

    - Loveland Pipeline (0400511)
- Denver Conduit No. 2 (0801002) – The Denver Conduit No. 2 is an underground pipeline that takes water from the Denver Intake (above the active ground water model boundary) to both the Platte Canyon and Marston Reservoirs for eventual treatment at the Marston Wastewater Treatment Plant and use within the Denver Water service area.
- Denver Foothills Pipeline No. 26 (0801017) – Denver Foothills Pipeline No. 6 delivers water from Strontia Spring Reservoir (above the active ground water model boundary) to the Foothills Water Treatment Plant and use within the Denver Water service area.
- Aurora Intake (0801001) – The Aurora Intake carries water from Strontia Springs Reservoir to regulate diversions to meet municipal demands.
- South Boulder Diversion Canal (0600590) – Denver Water's Northern System diverts transbasin and native water supplies from outside the ground water boundary to serve approximately 15 percent of Denver Water's demands in the ground water model. South Boulder Diversion Canal diverts from South Boulder Creek and conveys water to Ralston Reservoir and Moffat Treatment Plant.
- Diversions for the Cities of Thornton, Westminster and Northglenn – A majority of the Standley Lake Cities' supply is piped from Standley Lake (outside the active ground water model boundary) directly to the water treatment plant to serve these cities. The releases to the cities are available on a limited basis, generally from 1995 through 2006, in HydroBase under Standley Lake PL structures (IDs 0200991, 992, 993, 994). There is insufficient data in the records to utilize accurate filling techniques through TSTool to complete the records through the 1950 to 2012 study period. Therefore, the municipal demands for the Cities of Thornton, Westminster and Northglenn developed in SPDSS Task 66 are provided as an import to the ground water model.

Irrigation Imports. The following irrigation imports divert water from outside the active ground water model boundary; however the consumptive use and irrigation return flows occur within the ground water model boundary.

- North Poudre Canal (ID 0300994) - The North Poudre Canal diverts above the Cache La Poudre at Canyon near Ft. Collins streamflow gage to serve irrigated acreage under the North Poudre Irrigation Company (NPIC) within the ground water model. Additionally, NPIC acreage receives direct irrigation deliveries from Munroe Canal (0300905), also located outside the ground water model boundary. The diversions were combined and provided under ID 0300994.
- "South Side" Ditches (0300910, 0300913, 0300914) – The South Side ditch system is comprised of Pleasant Valley Canal (0300910), New Mercer Ditch (0300913), Larimer County No. 2 Ditch (0300914), and Arthur Ditch (0300918). Owned by the City of Fort Collins, the South Side ditch system is used primarily to irrigate parks and open space. All of these ditches, except for Arthur Ditch (0300918), divert outside of the groundwater boundary; however the consumptive use occurs within the boundary. Arthur Ditch (0300918) is not considered an import because it diverts within the ground water model boundary.
- The following ditches are part of off-channel reservoir systems that deliver water for irrigation within the ground water model boundary from both direct diversions outside the model boundary and off-channel storage within the model boundary. The irrigation

supply for each ditch is provided and does not only reflect total diversions at the ditch headgate.

- Larimer County Ditch (0300911)
- Cache La Poudre Ditch (0300915)
- Handy Ditch (0400521)
- Home Supply Ditch (0400524)
- South Side Ditch (0400543)
- Boulder Larimer Ditch (0400588)
- Boulder White Rock Ditch (0600516)
- Leyner Cottonwood Ditch (0600565)

- The following ditches divert outside the ground water model boundary to irrigated lands located within or on the edge of the ground water model boundary:
    - Dry Creek Ditch (0300912)
    - Taylor Gill Ditch (0301029)
    - Barnes Ditch (0400501)
    - George Rist Ditch (0400520)
    - Jim Eglin Ditch (0400596)
    - Osborne Caywood Ditch (0400600)
    - Green Ditch (0600528)
    - Church Ditch (0700540)
    - Farmers Highline Canal (0700569)
    - Wannamaker Ditch (0700698)
    - Lee Stewart Eskins Ditch (0700601)

Exports

The file SP2015_GW_EXP_032015.stm provides the time-series of exports from the active ground water model boundary. Exports from the ground water model boundary represent diversions that are used to meet demands and resulting consumptive use outside of the active ground water model area. Typically, the diversions are made below a surface water inflow stream gage but the consumptive use and returns occur outside outside of the ground water model area. The exports from the ground water model are summarized below.

Municipal Exports:

- Croke Canal (ID 0700553) – Croke Canal diverts below the Clear Creek near Golden streamflow gage and is the primary source of water stored in Standley Lake. Therefore the diversions take place within the ground water model area, but the storage and evaporative consumptive use takes place outside of the ground water model area. Standley Lake water is then released to serve the demands of the Standley Lake Cities (see the Municipal Imports section).

Transmittal Memo

To: Matt Lindburg, Brown & Caldwell
From: Kara Sobieski
Date: 7/16/2015
Re: SPDSS Model Interactions – Augmentation Plan Pumping and Recharge

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This transmittal reflects the following deliverables:

- **Canal Alias List (SP2015_GW_CanalAliasList.csv)**: This file contains a list of structures that are represented in the consumptive use and surface water model by an identifier other than their WDID (e.g. off-channel irrigation demands, diversion systems). This file was updated to reflect the new identifiers used by individual sub-basin surface water modelers. This file can be used to "translate" the canal assignments in the spatial coverage to match the structure identifiers used in the modeling effort. The file can be read directly into the StateDGI database and the "translations" are made before creating the final canal recharge file (*.can) read by StatePP.

- **Augmentation Well and Recharge Well Pumping (SP2015_GW_AugRch.gwp)**. This file contains a time series of historical pumping for the 1950 – 2013 period for each augmentation well and recharge well in the model. The list of augmentation and recharge wells used in the surface water modeling effort (shown below) was developed through discussions with Louis Flink at DWR in order to reflect only those wells that have been used recently for augmentation or recharge purposes. Note that these wells may also pump for irrigation or other uses, however this time series only reflects the augmentation or recharge pumping.

Modeled Augmentation Wells				Modeled Recharge Wells			
6405042	6405864	6406245	6406628	0109884	6405887	6406656	6406752
6405043	6405868	6406276	6406639	0109886	6406316	6406657	
6405071	6405901	6406279	6406664	0109887	6406330	6406658	
6405552	6406008	6406305	6406704	0110291	6406332	6406659	
6405556	6406073	6406337	6406705	6405031	6406475	6406666	
6405557	6406140	6406385	6406706	6405064	6406627	6406667	
6405604	6406164	6406527	6406707	6405084	6406649	6406685	
6405626	6406166	6406553		6405309	6406650	6406703	
6405857	6406180	6406554		6405310	6406654	6406709	
6405862	6406242	6406556		6405629	6406655	6406727	

- **Recharge Estimates by Recharge Area (SP2015_GW_RechargeArea.stm)**: This file contains a time series of historical recharge for the 1950 – 2012 period for each recharge area that has recharge records in HydroBase (at the time of the query). The list of recharge areas included in this deliverable was originally developed during the House Bill 1278 modeling effort, and reflects 616 recharge areas. Of this total, 176 recharge areas are not currently reflected in the GW model and would need to be added. These recharge areas likely reflect those constructed after the development of the original GW modeling effort. Additionally, of the 671 recharge areas currently modeled in the GW model, 231 of those recharge areas do not have records in this deliverable. Reconciliation of this difference in records and recharge areas will need to be completed prior to incorporating this updated information.

Transmittal Memo

To: Matt Lindburg, Brown & Caldwell
From: Kara Sobieski
Date: 12/16/2014, revised 2/13/2015
Re: SPDSS Model Interactions – Pilot Point Diversion Records

This transmittal reflects a revised time series of monthly historical diversions to support the development of the Pilot Point analysis. This deliverable meets the requirements outlined in Item 2 of the Model Interactions memo (GW_Inflow_Outflow_02-13-2015.docx, updated and included in this transmittal). The revisions reflect a simplified naming convention which eliminated the inclusion of many of the "non-typical structures" listed previously in Table 2.

The monthly historical diversion file (SP2015_GW_draft.ddh) contains monthly historical diversion data in acre-feet for the structures that are either located within or carry water through the active GW model area. Note that some structures with diversions in the SP2015_GW_draft.ddh file do not represent river headgate diversions and should not be treated as such. These "special" structures, shown in the **Table 1**, represent irrigation to land either downstream of off-channel reservoirs, lands irrigated from canals that deliver to more than one use, or reflect ground water only aggregate structures. These structures may have canal losses, non-consumed irrigation water, and pumping estimates in the final water budget output (*.dwb) from StateCU, and should be treated like any other structure when extracting information from the water budget output in StatePP. However, their headgate diversions represented in (SP2015_GW_draft.ddh) should be excluded in your efforts to estimate river gains and losses.

With the exception of the structures listed in Table 1, the remaining structures should be included in the Pilot Point method as they reflect actual river diversions. Note that the total diversions for some structures have been divided with portions assigned to a separate structure identifier; therefore it is the sum of these structures that reflect the total diversions. This applies to the following structures:

- Burlington Canal (0200802) = 0200805 + 023837_C
- Farmers Highline Canal (0700569) = 0700569 + 0700569_C
- Fisher Ditch (0700570) = 0700570 + 0700507_C

Additional notes:

- As denoted in the file name, the diversion data is draft and may change as SPDSS surface and consumptive use modeling efforts continue.
- WWG understands this initial Pilot Point effort does not require all the additional irrigation demand and ground water only structures, we have provided all of the structures in an effort to introduce the nomenclature and modeling identifiers for future deliverables.

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Table 1
Structures to be Excluded for River Gains/Losses in SP2015_GW_draft.ddh file

StateCU Structure ID	Description
*WD*_AWP###	Aggregate Well Structure, designated by Water District and aggregate number
0100503_I	Riverside Canal Irrigation Demand
0100507_I	Bijou Canal Irrigation Demand
0100687_I	North Sterling Irrigation Demand
0103817_I	Jackson Lake Irrigation Demand
0200805_I	Denver-Hudson Canal Irrigation Demand
0200817_I	Evans No 2 Ditch Demand
0200828_I	Union Ditch Irrigation Demand
0200834_I	Lower Latham Ditch Irrigation Demand
0203837_I	FRICO-Barr Reservoir Irrigation Demand
0203876_I	Milton Reservoir Irrigation Demand
0300911_I	Larimer County Ditch Irrigation Demand
0300915_I	Cache La Poudre Ditch Irrigation Demand
0300919_I	Larimer Weld Canal Irrigation Demand
0300929_I	New Cache La Poudre Ditch Irrigation Demand
0300994_I	North Poudre Canal Irrigation Demand
0400521_I	Handy Ditch Irrigation Demand
0400524_I	Home Supply Ditch Irrigation Demand
0400530_I	Louden Ditch Irrigation Demand
0400532_I	Loveland Greeley Canal Irrigation Demand
0400588_I	Boulder Larimer County Irrigation Demand
0600537_C	Leggett Carrier to Panama Reservoir
0600537_I	Leggett Ditch Irrigation Demand
0600565_C	Leyner Cottonwood Carrier
0600565_I	Leyner Cottonwood Irrigation Demand
6400511_I	Harmony Ditch 1 Irrigation Demand