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| Colorado Surface Water Supply Index (SWSI) Automation Tool  TSTool Software Guide Version 6  June 30, 2015 | PREPARED FOR  Colorado Water Conservation Board Colorado Division of Water Resources  DEVELOPED BY  Open Water Foundation |

**Table of Contents**

[Definitions 1](#_Toc430685948)

[TSTool Command Summary 5](#_Toc430685949)

[Introduction 10](#_Toc430685950)

[Colorado SWSI Methodology Overview 11](#_Toc430685951)

[Colorado SWSI Output Products 16](#_Toc430685952)

[Colorado SWSI Automation Tool Directory Structure 22](#_Toc430685953)

[Colorado SWSI Automation Tool Step-by-Step Procedures 24](#_Toc430685954)

[To modify the methodology in the control file 24](#_Toc430685955)

[To run the monthly SWSI analysis 25](#_Toc430685956)

[Set up activities 25](#_Toc430685957)

[Run the TSTool processing steps 26](#_Toc430685958)

[Review and disseminate the output products 34](#_Toc430685959)

[Compare Colorado Historical SWSI Values to NRCS Historical SWSI Values (Optional) 34](#_Toc430685960)

[To run Colorado SWSI Re-forecasts 35](#_Toc430685961)

[Compare Colorado Forecast SWSI Values to NRCS Forecast SWSI Values (Optional) 35](#_Toc430685962)

[References 36](#_Toc430685963)

[Appendix A – NRCS Native Flow Equations 37](#_Toc430685964)

[Appendix B – Station Assignments by HUC 47](#_Toc430685965)

[Appendix C – Colorado SWSI Automation Tool Workflow Details 55](#_Toc430685966)

[Control File 55](#_Toc430685967)

[TSTool Processing 55](#_Toc430685968)

[Appendix D – Historical Period Data Issues 82](#_Toc430685969)

[Appendix E – Current Water Year Data Issues 86](#_Toc430685970)

[Appendix F – Recent Period Data Issues 87](#_Toc430685971)

**Tables**

[Table 1. Colorado Revised SWSI Formulation (CWCB, 2013) 10](#_Toc430685972)

[Table 2. Forecast Period by Basin and SWSI Calculation Month 12](#_Toc430685973)

[Table 3. Example of Data Transformation from Natural Flow to Previous Month’s Streamflow Component 13](#_Toc430685974)

[Table 4. SWSI Current Summary Output - Basin Summary 16](#_Toc430685975)

[Table 5. SWSI Current Summary Output - HUC Summary 17](#_Toc430685976)

[Table 6. SWSI Current Summary Output - HUC Components 17](#_Toc430685977)

[Table 7. SWSI Summary by River Basin 18](#_Toc430685978)

[Table 8. SWSI Summary by HUC 19](#_Toc430685979)

[Table 9. Time Series by HUC (or River Basin) 19](#_Toc430685980)

[Table 10. Approximate Run Times for TSTool Processing Steps 26](#_Toc430685981)

[Table 11. Data Flags and Definitions 32](#_Toc430685982)

[Table 12. Forecast Values by Month and Location 61](#_Toc430685983)

[Table 13. Offset notation used to accumulate monthly historical natural flows over the forecast period. 68](#_Toc430685984)

[Table 14. Missing Data Values that Require Overrides 86](#_Toc430685985)

**Figures**

[Figure 1. SWSI History Graph (River Basin) 20](#_Toc430685986)

[Figure 2. SWSI History Graph for the Full Analysis Period (HUC) 21](#_Toc430685987)

[Figure 3. SWSI History Graph for the Recent and Current Periods (HUC) 21](#_Toc430685988)

[Figure 4. SWSI History Graph by Month for the Full Analysis Period (HUC) 22](#_Toc430685989)

[Figure 5. Highest level directory structure 22](#_Toc430685990)

[Figure 6. \_Documents directory 23](#_Toc430685991)

[Figure 7. YYYY-MM Directory 23](#_Toc430685992)

[Figure 8. Flowchart of the Data Download Processes 56](#_Toc430685993)

[Figure 9. Flowchart of the Data Check and Filling Processes 62](#_Toc430685994)

[Figure 10. Flowchart of the Create SWSI Component Processes 66](#_Toc430685995)

[Figure 11. Example of the Forecasted Runoff Component 69](#_Toc430685996)

[Figure 12. Flowchart of the SWSI Calculation Processes 69](#_Toc430685997)

[Figure 13. Flowchart of the Optional Processes 78](#_Toc430685998)

# **Definitions**

|  |  |
| --- | --- |
| **AWDB** | **The NRCS Air and Water Database makes data available to the public through web services.** |
| **CIM** | **Colorado Information Marketplace** |
| **Colorado’s Decision Support Systems (CDSS)** | **A system of databases and software tools used to help the State of Colorado make decisions about water resources.** |
| **ColoradoWaterHBGuest** | **HydroBase data are made available to the public from web services. ColoradoWaterHBGuest is the public account that is allowed accessed to the HydroBase web services.** |
| **ColoradoWaterSMS** | **The State of Colorado’s Satellite Monitoring System transmits real-time hydro-meteorological data to a central storage database. While these data are made available, they are typically considered provisional and have not been quality-controlled.** |
| **Command file** | **A text file with a .TSTool extension that is used by TSTool and contains commands for data acquisition, analysis, and visualization.** |
| **Control file** | **The Excel workbook named CO-SWSI-Control.xlsx that is used to define all configuration properties and input data needed to run the Colorado SWSI analysis.** |
| **Current Period** | **The water year that includes the current month for which the SWSI analysis is being computed.** |
| **CWCB** | **Colorado Water Conservation Board** |
| **Data Composite** | **The sum of the SWSI component volumes (reservoir storage, previous month’s streamflow, and forecasted runoff) for a HUC8 or river basin.** |
| **DWR** | **Colorado Division of Water Resources** |
| **Forecast SWSI Value** | **A SWSI value that was computed using forecasted natural flows for the forecasted runoff component.** |
| **Forecasts** | **Future runoff volumes predicted by the NRCS using regression equations and observed hydro-meteorological data as predictor variables. The NRCS issues these forecasts on the 1st of the month from January to June at locations throughout the West dominated by snowmelt-runoff. In Colorado, the forecasts represent future runoff volumes for a specified forecast period. The forecasts are presented as probabilistic ranges. For the purposes of the Colorado SWSI analysis, the 50th percent exceedance (expected value) forecast is used.** |
| **Historical Period** | **The period used to establish the distribution of SWSI and NEP values, currently defined as WY 1971-2010. In this period, historical natural flows are used for the forecasted runoff component.** |
| **Historical SWSI Value** | **A SWSI value that was computed using historical natural flows for the forecasted runoff component.** |
| **HUC** | **Hydrologic unit codes are basin boundaries established by the US Geological Survey. The length of the code indicates the relative spatial scale. For example, HUC2 represents major river basins, while HUC8 represents watersheds. In the Colorado SWSI analysis, all references to HUC refer to the 8-digit HUC.** |
| **HydroBase** | **The State of Colorado’s official database that stores water administration data and hydro-meteorological data. These data are accessible with web services.** |
| **Native flow** | **For the purposes of the Colorado SWSI analysis, native flows are approximate estimates of the streamflows that would occur at a given location in the absence of human influences and that result from natural hydrologic processes such as rainfall-runoff and snowmelt-runoff:**  **where:**  ***Qnative* = the native streamflow calculated at a given location for a given time interval**  ***Qobserved* = the streamflow observed at a given location for a given time interval**  ***∆ReservoirStorage* = ∑(*∆*reservoir storage) for all reservoirs upstream of the given location for the given time interval**  ***∆Irrigation* = ∑(diversions – return flows) for significant demands upstream of the given location for the given time interval. This term is often omitted unless observed data are available.**  ***∆Transbasin* = ∑(transbasin exports – transbasin imports) upstream of the given location for the given time interval.** |
| **Natural flow** | **For the purposes of the Colorado SWSI analysis, the terms native flow and natural flow are used interchangeably and represent an approximation of the streamflows that would be in the river at a given location if not for human influences. See definition for native flow.** |
| **NEP** | **Non-exceedance probability, or the probability of not exceeding a given value** |
| **NRCS** | **Natural Resources Conservation Service** |
| **Observed flow** | **Streamflows in a river channel measured using a stream gage and rating curve. These flows reflect human influences to the river.** |
| **OIT** | **Colorado Governor's Office of Information Technology** |
| **Override** | **An override is a value specified by the user that is manually entered and will be used even if data for that time interval already exist in a time series.** |
| **Recent Period** | **The period between the historical period and the current period.**  **In the monthly Colorado SWSI analysis, data for the recent period are not required but are helpful for comparison against current results. The recent period results are calculated the same way as the current month’s SWSI: the composite volume is assessed using the historical dataset. However, the forecasted runoff component in the recent period is calculated using historical natural flows. This means that in the monthly analysis, the SWSI results for the recent period represent “historical SWSI” values.**  **When generating historical forecasts of the Colorado SWSI (for example, because the station assignments for a HUC have been changed), the forecasted runoff component in the recent period is calculated using forecasted natural flows, same as that used in the current period. This means that in the re-forecast analysis, the SWSI results for the recent period represent “forecast SWSI” values.** |
| **RESC** | **A data type used by the NRCS AWDB web services to represent historical reservoir storage contents. For a monthly time step, the data values represent end-of-month storage.** |
| **SRVO** | **A data type used by the NRCS AWDB web services to represent historical natural flow volumes.** |
| **SRVOO** | **A data type used by the NRCS AWDB web services to represent historical observed flow volumes.** |
| **SWSI** | **The Surface Water Supply Index was developed by the NRCS and DWR for Western States that rely on snowmelt-runoff and reservoir storage for water supply (Garen, 1993).** |
| **Time series product** | **A text file with a .tsp extension that is used by TSTool as a template for plotting data and placing annotations on one or more graphs.** |
| **TSTool** | **A data acquisition, analysis, and visualization tool developed by the State of Colorado as part of the Colorado’s Decision Support Systems (CDSS). TSTool processes are used to promote transparency, repeatability, and automation for complex water resources analyses.** |
| **Water Year** | **A water year runs from October of the previous calendar year to September of the current calendar year. For example, water year 1971 begins October 1970 and ends September 1971.** |
| **WATF** | **The State of Colorado’s Water Availability Task Force (WATF) interprets available hydrologic information from across the State and takes action to mitigate drought effects when appropriate.** |

# **TSTool Command Summary**

The following TSTool commands are used in the Colorado SWSI Automation Tool. Full documentation for each command is provided with the TSTool software.

| **TSTool Command** | **Description** |
| --- | --- |
| Add | Add one or more time series to a time series. |
| AddConstant | Add a constant or monthly constants to one or more time series. |
| AdjustExtremes | Adjust the extreme values in a time series while conserving mass, for example to adjust for negative streamflow. |
| AnalyzePattern | Analyze time series for wet/average/dry conditions. |
| AppendTable | Append a table to another. |
| CalculateTimeSeriesStatistic | Calculate a statistic for time series. |
| ChangeInterval | Change the interval for time series to create new interval time series. |
| ChangePeriod | Change the period of time series, for example to extend and fill. |
| CheckTimeSeries | Check time series values for specific criteria and output to a table and warnings. |
| CheckTimeSeriesStatistic | Calculate a time series statistic and then check the statistic against criteria. |
| CloseExcelWorkbook | Close an Excel workbook that is being written to. |
| Comment | A single line #-comment to provide explanatory information. |
| CommentBlockEnd | Multi-line \*/ comment block end. |
| CommentBlockStart | Single line /\* comment block start. |
| ConvertDataUnits | Convert time series data units. |
| Copy | Create new time series by copying a time series. |
| CopyFile | Create a new file by copying a file. |
| CopyPropertiesToTable | Copy processor properties to a table. |
| CopyTable | Create a new table by copying a table, with options to copy specific columns, rename columns, and filter rows. |
| CopyTimeSeriesPropertiesToTable | Copy time series properties to a table. |
| DeselectTimeSeries | Deselect time series, used to create lists of time series used with TSList=SelectedTS command parameter. |
| Disaggregate | Disaggregate time series from lonter interval to shorter interval data. |
| Divide | Divide time series by another time series. |
| Empty | Blank command line. |
| EndFor | End of For() command block. |
| EndIf | End of If() command block. |
| Exit | Exit processing, useful when testing a partial command file. |
| ExpandTemplateFile | Expand a FreeMarker syntax template text file into an expanded file, useful for repeating common processing. |
| FillConstant | Fill missing data in time series with a constant value. |
| FillFromTS | Fill missing data using values in a time series from another time series' data values. |
| FillHistMonthAverage | Fill missing data in monthly time series using the monthly averages from the same time series. |
| FillHistYearAverage | Fill missing data in yearly time series using the yearly averages from the same time series. |
| FillInterpolate | Fill missing data in time series by interpolating between non-missing values. |
| FillPattern | Fill missing data in time series by using wet/average/dry values for the same time series. |
| FillRegression | Fill missing data in time series using ordinary least squares regression. |
| FillRepeat | Fill missing data in time series by repeating values forward or backward. |
| For | For-loop start. |
| FormatDateTimeProperty | Format date/time property into a new processor string property given a format specifier, useful when a specific string version of date/time is needed. |
| FormatStringProperty | Format a new string processor property given other properties as input. |
| FormatTableDateTime | Format a date/time column in a table, for example to output a specific date/time format for output. |
| FormatTableString | Format a table string column using other table columns as input. |
| Free | Free a time series - it will no longer be available for further processing, useful when using temporary time series for processing. |
| FreeTable | Free a table - it will no longer be available for further processing, useful when using temporary tables for processing. |
| If | If block start. |
| InsertTableColumn | Insert a column into a table. |
| InsertTableRow | Insert a row into a table. |
| JoinTables | Join tables horizontally using one or more common columns. |
| ListFiles | List files in a folder. |
| LookupTimeSeriesFromTable | Create a new time series by looking up time series values from a table. |
| ManipulateTableString | Manipulate a table string in a table - see also FormatTableString() command. |
| Message | Generate a message for logging and user. |
| Multiply | Multiply one time series by another. |
| NewEndOfMonthTSFromDayTS | Create a new end of month time series from a daily time series, useful for determining reservoir end or month time series. |
| NewExcelWorkbook | Create a new Excel workbook that can be written to by other commands. |
| NewPatternTimeSeries | Create a new time series filled with an initial pattern of values and flags, useful for automated testing. |
| NewStatisticTimeSeries | Create a new time series containing a statistic of all similar date/times, for example average of all January 1 daily values. |
| NewStatisticYearTS | Create a new Time series containing a statistic of all annual values, useful to create an annual time series to compare to other time series. |
| NewTable | Create a new empty table. |
| NewTimeSeries | Create a new time series to receive results from other commands. |
| ProcessTSProduct | Process a time series product into views and image files. |
| ReadDateValue | Read time series from a "DateValue" format file, one of the primary formats used by TSTool. |
| ReadDelimitedFile | Read time series from a delimited file, for example a comma-separated-value (CSV) file. |
| ReadHydroBase | Read time series from the State of Colorado's HydroBase database. |
| ReadNrcsAwdb | Read time series from Natural Resources Conservation Service (NRCS) Air and Water Database web services. |
| ReadPatternFile | Read time series from wet/average/dry pattern file produced by AnalyzePattern() command. |
| ReadPropertiesFromExcel | Read processor properties from an Excel worksheet. |
| ReadPropertiesFromFile | Read processor properties from a text file. |
| ReadStateMod | Read time series from the State of Colorado's StateMod water allocation model text input files. |
| ReadTableCellsFromExcel | Read table cells from specific cells in an Excel worksheet, useful for transferring form input into a flat data table. |
| ReadTableFromDataStore | Read a table from a database datastore. |
| ReadTableFromExcel | Read a table from an Excel worksheet. |
| ReadTimeSeriesFromDataStore | Read time series from a datastore. |
| ReadTimeSeriesList | Read time series using a table with list of identifiers. |
| RemoveFile | Remove a file. |
| ReplaceValue | Replace values in a time series with alternate values. |
| RunCommands | Run a command file, used to create master command files to run larger workflows. |
| RunningStatisticTimeSeries | Create a running statistic time series using various methods to determine the sample size. |
| Scale | Scale time series by a constant value. |
| SelectTimeSeries | Select time series for processing, used with the TSList=SelectedTS parameter. |
| SetConstant | Set time series data values to a constant. |
| SetFromTS | Set time series data values using values from another time series. |
| SetInputPeriod | Set the global input period default when reading time series, useful for datastores that have an inconvenient default input period. |
| SetOutputPeriod | Set the global output period default when writing time series, useful to standardize all output to a consistent period. |
| SetOutputYearType | Set the global output year type (e.g., calendar, water year). |
| SetProperty | Set a processor property. |
| SetPropertyFromTable | Set a processor property from a table. |
| SetTableValues | Set table values based on filters. |
| SetTimeSeriesPropertiesFromTable | Set time series properties from a table, useful to cross-reference data from different data sources. |
| SetTimeSeriesProperty | Set a single time series property. |
| SetTimeSeriesValuesFromLookupTable | Set time series values from a lookup table, for example to set values based on a distribution. |
| SetTimeSeriesValuesFromTable | Set time series values from a table, similar to other commands that set time series values. |
| SetWorkingDir | Set the working directory for processing - generally not used given newer features to access processor ${WorkingDir} property. |
| ShiftTimeByInterval | Shift time series values by an interval, useful to handle time zone changes, routing, and use of previous timestep(s) as input. |
| SortTable | Sort a table based on one or more columns. |
| SortTimeSeries | Sort a list of time series based on identifier or other time series properties. |
| StartLog | Start a new log file for logging. |
| Subtract | Subtract time series from another time series. |
| TableMath | Calculate table column values using input table column(s) and/or constant values. |
| TableTimeSeriesMath | Manipulate time series values using data from a table. |
| TableToTimeSeries | Create new time series using values from a table. |
| TimeSeriesToTable | Create a table using values from time series. |
| WriteDateValue | Write time series to a DateValue format file. |
| WriteDelimitedFile | Write time series to a delimited (e.g., CSV) file. |
| WritePropertiesToFile | Write processor properties to a text file. |
| WriteTableCellsToExcel | Write table cells to cells in an Excel worksheet, useful for transferring "flat" table data into Excel forms. |
| WriteTableToDataStore | Write a table to a database datastore. |
| WriteTableToDelimitedFile | Write a table to a delimited (e.g., CSV) file. |
| WriteTableToExcel | Write a table to an Excel worksheet. |
| WriteTableToHTML | Write a table to an HTML file. |
| WriteTimeSeriesPropertiesToFile | Write time series properties to a file, useful for automated tests. |
| WriteTimeSeriesProperty | Write time series property to a file, replaced by WriteTimeSeriesProperiesToFile(). |
| WriteTimeSeriesToDataStore | Write time series to a database datastore, useful for generic database designs. |
| WriteTimeSeriesToExcel | Write time series to an Excel worksheet, with formatting based on data values. |

# **Introduction**

The State of Colorado monitors conditions that affect water supply, including snowpack, precipitation, reservoir storage, and streamflows. The Governor of Colorado established the Water Availability Task Force (WATF) to interpret available information and to take actions to mitigate drought effects when appropriate. The WATF has the authority to activate the Colorado Drought Mitigation and Response Plan (CWCB, 2013) when drought conditions reach significant levels.

The WATF makes drought projections based on a variety of hydro-meteorological data types (i.e., snowpack, soil moisture, streamflow, reservoir levels, ground water levels, precipitation, and temperature) and drought indices (i.e., Surface Water Supply Index, Standardized Precipitation Index, and Modified Palmer Drought Index). More information about the WATF is available on the CWCB website (CWCB, 2015).

The Surface Water Supply Index (SWSI) is an index used to describe drought in mountainous areas that rely primarily on surface water supplies such as snowpack and reservoir storage. The SWSI was developed by the Soil Conservation Service (now Natural Resources Conservation Service or NRCS) and the Colorado Division of Water Resources (DWR) in 1981 for the Colorado Drought Plan. DWR has produced the original SWSI in accordance with the Colorado Drought Plan since 1981. In 1993, Dave Garen from NRCS proposed a revised SWSI calculation to improve upon the known deficiencies of the original SWSI calculation methodology (Garen, 1993). Other Western States have adopted their own version of the SWSI as well.

The Colorado Water Conservation Board (CWCB) completed a major revision to the Colorado Drought Plan in 2010. At that time, Colorado adopted a revised SWSI analysis that is calculated on a smaller geographic scale and that uses streamflow forecasts instead of the weighted precipitation, streamflow, snowpack, and reservoir storage factors used in the original SWSI. This approach is similar to what Garen proposed in 1993. The revised Colorado SWSI is computed on a monthly time step and considers three components depending on the time of year (**Table 1**).

Table . Colorado Revised SWSI Formulation (CWCB, 2013)

|  |  |
| --- | --- |
| **Time Period** | **Components** |
| January - June | Forecasted Runoff + Reservoir Storage |
| July - September | Previous Month's Streamflow + Reservoir Storage |
| October - December | Reservoir Storage |

Since 2011, the NRCS has been producing a SWSI product for the WATF similar to the revised SWSI called for in the 2010 Drought Plan. The NRCS SWSI process relies on Excel spreadsheets to compute values for selected eight-digit Hydrologic Unit Codes (HUC).

In 2015, the State of Colorado undertook the SWSI Automation Tool Enhancement project, which resulted in the development of an automated SWSI calculation tool based on the criteria set forth in the 2010 Drought Plan. The automated tool produces results that can be incorporated into DWR’s HydroBase database and made available to the public using the CDSS Platform (DNR, 2015) and the Colorado Information Marketplace. Open Water Foundation collaborated with DWR and CWCB in developing the Colorado SWSI Automation Tool. Riverside Technology, inc, provided input on the forecast data source and reviewed the implementation of the Colorado SWSI Automation Tool.

The TSTool software tool has been developed as part of the CDSS. TSTool has the advantages of being able to access many data sources, of automating data processing and visualization, and of using workflow commands that provide transparency and repeatability to the computation process.

This **Colorado Surface Water Supply Index (SWSI) Automation Tool - TSTool Software Guide** provides an overview of the concepts and procedures necessary for a practitioner to use the Colorado SWSI Automation Tool.

# **Colorado SWSI Methodology Overview**

The Colorado SWSI is calculated for each month of the year, typically within the first ten days of the month. As noted previously in **Table 1**, the Colorado SWSI is computed using three components depending on the time of year:

* **Forecasted Runoff:** Forecasted runoff volumes are issued monthly from January through June by the NRCS. The forecasts represent probabilistic estimates of natural flow volumes for the upcoming season. They are generated using regression models and hydro-meteorological data as predictor variables (i.e., snowpack, precipitation, and streamflow). The Colorado SWSI computations use the 50th percent exceedance (expected value) forecast volumes. Complete information about the NRCS forecasts can be obtained from the NRCS website (NRCS, 2015).

The forecasts are generated for fixed forecast periods defined by location that were selected to represent high runoff months. The Colorado SWSI Automation Tool was developed assuming the forecast period starts in April. This assumption is true for all locations except the Purgatoire River at Trinidad. At this location, from January through June, the NRCS issues a March-July forecast. Starting in April, the NRCS also issues a current month-July forecast. Until the Colorado SWSI Automation Tool can be updated to handle this case, when running the SWSI analysis in January-March, the DWR will use a regression equation that relates March-July runoff volumes with April-July runoff volumes for Purgatoire River at Trinidad.

For the Colorado SWSI analysis, forecasts that end in September are used for locations in the Rio Grande Basin and forecasts that end in July are used for locations in other river basins. The forecasts used in May and June represent expected runoff from the current month until the end of the forecast period. See **Table 2** for a summary of the forecast period used by river basin and SWSI calculation month.

Table . Forecast Period by Basin and SWSI Calculation Month

|  |  |  |
| --- | --- | --- |
| **SWSI Calculation Months** | **Forecast Period (Rio Grande Basin)** | **Forecast Period (Non-Rio Grande Basins)** |
| January-April | April-September | April-July |
| May | May-September | May-July |
| June | June-September | June-July |
| July-December | Not used | Not used |

The Colorado SWSI Automation Tool is configured to obtain forecasted streamflow data from the NRCS AWDB web services.

When the Colorado SWSI is calculated for the months of January through June, the analysis incorporates the forecasted runoff component as an indicator of future surface water supply. For the current water year’s forecasted runoff values, the NRCS forecasts are used. For recent and historical water years, when the actual runoff is known, the forecasted runoff component is calculated from historical natural flow data.

* **Reservoir Storage:** The Colorado SWSI always incorporates observed reservoir storage data as an indicator of the current state of the surface water supply. For a given month’s analysis, the SWSI incorporates beginning-of-month storage values. For inclusion in the Colorado SWSI analysis, DWR has selected reservoirs that are used as active storage in a HUC and that increase the available water supply volume in a HUC. Therefore, the reservoirs that are included are typically municipal and irrigation reservoirs, not reservoirs used for augmentation.

The Colorado SWSI Automation Tool is set up to obtain observed reservoir storage data from the NRCS and the State of Colorado.

* + The NRCS AWDB web services provide access to end-of-month storage values using the RESC data type.
  + The State of Colorado has two sets of web services:
    - ColoradoWaterHBGuest services access daily reservoir storage data from HydroBase that have been quality controlled and are considered published.
    - ColoradoWaterSMS services access daily reservoir storage data for the recent period that have not been quality-controlled and are considered provisional.
    - The daily reservoir storage data from ColoradoWaterHBGuest and ColoradoWaterSMS are merged to make a continuous record, with ColoradoWaterHBGuest data taking precedence.
    - To be consistent with the NRCS AWDB data, end-of-month storage time series are computed from the daily storage values.
  + Before calculating the SWSI values, the end-of-month storage values are shifted forward by one month to represent beginning-of-month storage values for the current month’s analysis.
* **Previous Month’s Streamflow:** Per the State Drought Plan, in the months of July-September, the Colorado SWSI procedure incorporates a component representing the previous month’s native flow volume (CWCB, 2013).

The Colorado SWSI Automation Tool is set up to obtain monthly native flow volumes from the NRCS AWDB web services. **Appendix A – NRCS Native Flow Equations** contains the equations used by the NRCS to compute native flow volumes in Colorado.

Before calculating the Colorado SWSI values, the monthly native flow volumes are shifted forward by one month to represent previous month’s streamflow for the current month’s analysis (see **Table 3** for an example demonstrating the data manipulation).

Table . Example of Data Transformation from Natural Flow to Previous Month’s Streamflow Component

|  |  |  |  |
| --- | --- | --- | --- |
| **Date** | **Natural Flow (ac-ft)** | **SWSI Component (ac-ft)** | **Explanation** |
| 2015-06 | 3,000 | 0 | Previous month’s streamflow component is not used in June |
| 2015-07 | 2,000 | 3,000 | July SWSI analysis uses June volume to represent previous month’s streamflow volume |
| 2015-08 | 1,000 | 2,000 | August SWSI analysis uses July volume to represent previous month’s streamflow volume |
| 2015-09 | 800 | 1,000 | September SWSI analysis uses August volume to represent previous month’s streamflow volume |
| 2015-10 | 500 | 0 | Previous month’s streamflow component is not used in October |

If the required native flow data are not available for the current month’s analysis, the Colorado SWSI Automation Tool has been set up to use observed flows rather than native flows for the previous month’s streamflow component. This option is discussed in more detail in the **Colorado SWSI Automation Tool Step-by-Step Procedure** and in **Appendix C – Colorado SWSI Automation Tool Workflow Details**.

The Colorado SWSI analysis is performed on 41 HUC8 watersheds. DWR selected natural flow locations, water supply reservoirs, and forecast locations that represent the surface water supply for each HUC8 included in the Colorado SWSI analysis (see **Appendix B – Station Assignments by HUC**). In general, all significant water supply reservoirs with storage data available in real-time are included. The natural flow and forecast locations were selected to most closely represent total flow in the HUC, whether at a single location at the HUC outlet or as multiple locations on individual tributaries.

As part of the current project, Open Water Foundation reviewed the input data being used in the Colorado SWSI analysis. Issues that were identified, solutions that were implemented, and unresolved issues are documented in the following appendices:

* **Appendix D – Historical Period Data Issues**
* **Appendix E – Current Water Year Data Issues**
* **Appendix F – Recent Period Data Issues**

After development of the Colorado SWSI Automation Tool, Riverside Technology, inc reviewed sections of the TSTool process to confirm that the implemented command logic is consistent with the calculation methodology. The review notes are included in .

The Colorado SWSI methodology includes the following steps:

* The natural flow, reservoir storage, and forecast data are downloaded for all specified stations and reservoirs.
* The raw data are analyzed for missing values.
* Missing values can be filled using automated techniques (such as regression analysis or interpolation) and/or the user can manually specify values to be used. Automated techniques can be used to fill missing values in the raw data obtained from source agencies. Manually-specified values are applied to any data value (missing or not) in the auto-filled dataset.
  + For natural flows, missing values can be filled automatically using monthly regression analysis. The user should specify a filling station that is close to the station being filled, that has data for the periods that require filling, and that has a correlation coefficient of at least 0.7 for the overlapping data with the station being filled. Filled values are denoted using a data flag of “R” for regression.
  + For reservoir storage, missing values are filled in multiple ways.
    - If the values are missing because the reservoir was not yet storing water, the storage values are set to 0. Filled values are denoted using a data flag of “Z” for zeroes.
    - If values are missing after the reservoir began storing water, the user can elect to fill based on linear interpolation between surrounding values or with historical average monthly values. Filled values are denoted using data flags of “I” for interpolation or “H” for historical monthly averages.
    - If a reservoir is decommissioned, the user can elect to fill the storage data with zeroes to the current month. Filled values are denoted using a data flag of “Z” for zeroes.
  + No automated filling options are implemented for the forecast data.
  + The user may elect to apply overrides (i.e., values determined by the user) for any time series value. Filled values are denoted using a data flag that starts with “MO” for manual overrides.
  + Any missing data in the historical period that are not filled will reduce the number of years used to establish the distribution of SWSI and NEP values.
  + Any missing data in the recent and current periods that are not filled will produce missing values in the output products.
* The filled input data are transformed to represent the SWSI components. This step includes time shifts, data accumulations, and setting component values to zero in months when the component is not used for the SWSI analysis.
* Results are computed for each station and reservoir. The results include the following values:
  + Component Volume (ac-ft)
  + Component Non-Exceedance Probability by Month (%)
* Results are computed for each HUC. The results include the following values:
  + Data Composite (ac-ft)
  + Data Composite Percent of Average (%)
  + Data Composite Non-Exceedance Probability (%)
  + Data Composite SWSI (--)
  + Reservoir Storage (ac-ft)
  + Reservoir Storage Percent of Average (%)
  + Reservoir Storage Non-Exceedance Probability (%)
  + Reservoir Storage SWSI (--)
  + Previous Month’s Streamflow (ac-ft)
  + Previous Month’s Streamflow Percent of Average (%)
  + Previous Month’s Streamflow Non-Exceedance Probability (%)
  + Previous Month’s Streamflow SWSI (--)
  + Forecasted Runoff (ac-ft)
  + Forecasted Runoff Percent of Average (%)
  + Forecasted Runoff Non-Exceedance Probability (%)
  + Forecasted Runoff SWSI (--)
  + Composite SWSI for the same month last year
  + Change in Composite SWSI from last year to this year
* Results are calculated for each major river basin in Colorado. The results include all of the results listed by HUC as well as the following values:
  + Composite SWSI for the previous month
  + Change in Composite SWSI from the previous month to the current month

For each SWSI component and the sum of the components (i.e., the data composite), the results are computed using the same methodology:

* For a given month, the component’s water supply volumes are ranked over the historical period, currently defined as WY 1971-2010, to determine the Gringorten plotting position. The plotting position values range from 0.00-1.00.
  + In using the Gringorten plotting position, the analysis assumes an empirical distribution, which is to say the historical data are used without fitting a distribution to the dataset.
  + If there are ties in the water supply volumes, they receive the same plotting position value.
  + DWR expects that the historical period will be moved forward periodically in accordance with the NRCS.
* The Gringorten plotting position is multiplied by 100 to determine the non-exceedance probabilities (NEP) over the historical period. The non-exceedance probabilities range from 0% (driest in the historical record) to 100% (wettest in the historical period).
* The non-exceedance probability values are transformed to a scale of -4.16 (extreme drought conditions) to +4.16 (abundant water supply) to determine the SWSI values over the historical period. The conversion formula is shown in **Equation 1**. This range of SWSI values is consistent with that used for the Palmer Drought Index and allows users to view familiar values.

Equation . Converting NEP Value to SWSI Values

* For months in the recent and current periods, the component’s water supply volumes are used to look up corresponding NEP and SWSI values based on the historical dataset.

# Colorado SWSI Output Products

The results from the Colorado SWSI Automation Tool are produced as both tabular and graphical outputs. Tabular outputs are typically written to two file formats: DateValue files are used by TSTool to run the processing steps, while Excel files are provided to facilitate user review. HTML files can also be written to implement a website, though these commands are currently disabled in the process.

**SWSI Current Summary**

The main output used by DWR to import results into HydroBase and the Colorado Information Marketplace and to display results in the CDSS Map Viewer is an Excel workbook named **SWSI-Current-Summary.xlsx**, which contains three worksheets: Basin Summary, HUC Summary, and HUC Components. These worksheets can be written to HTML files to implement a website that facilitates user review or product sharing though the commands are currently disabled.

The Basin Summary results worksheet (shown in **Table 4**) includes:

* Basin name (Basin)
* Analysis date (Date)
* Composite SWSI value for the analysis date (SWSI)
* Composite NEP value for the analysis date (NEP)
* Composite SWSI value for the month prior to the analysis date (SWSI Prev Mo)
* The change in Composite SWSI values from the previous month to the current month (Chg SWSI Prev Mo)
* Composite SWSI value for the same month for the year prior to the analysis date (SWSI Prev Yr)
* The change in Composite SWSI values from the previous year to the current year (Chg SWSI Prev Yr)

Table . SWSI Current Summary Output - Basin Summary

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Basin** | **Date** | **SWSI** | **NEP** | **SWSI Prev Mo** | **Chg SWSI Prev Mo** | **SWSI Prev Yr** | **Chg SWSI Prev Yr** |
| Arkansas | 2015-05 | -0.07 | 49.18 | -0.08 | 0.01 | -0.22 | 0.15 |
| Colorado | 2015-05 | -1.80 | 28.34 | -1.67 | -0.13 | 2.21 | -4.01 |
| Gunnison | 2015-05 | -2.33 | 22.07 | -2.01 | -0.32 | 1.57 | -3.90 |
| Rio Grande | 2015-05 |  |  |  |  | -0.66 |  |
| San Juan-Dolores | 2015-05 | -3.66 | 6.05 | -3.29 | -0.37 | -1.53 | -2.13 |
| South Platte | 2015-05 | 2.26 | 77.14 | 1.28 | 0.98 | 2.50 | -0.24 |
| Yampa-White | 2015-05 | -2.11 | 24.67 | -2.65 | 0.54 | 0.12 | -2.23 |

The HUC Summary results worksheet (shown in **Table 5**) includes:

* Basin name (Basin)
* HUC identifier (HUC\_ID)
* HUC name (HUC\_Name)
* Analysis date (Date)
* Composite SWSI value for the analysis date (SWSI)
* Composite NEP value for the analysis date (NEP)
* Composite SWSI value for the same month for the year prior to the analysis date (SWSI Prev Yr)
* The change in Composite SWSI values from the previous year to the current year (Chg SWSI Prev Yr)
* NEP value for the reservoir storage component (ReservoirStorageNEP)
* NEP value for the previous month’s streamflow component (PrevMoStreamflowNEP)
* NEP value for the forecasted runoff component (ForecastedRunoffNEP)

Table . SWSI Current Summary Output - HUC Summary

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Basin** | **HUC\_ID** | **HUC\_Name** | **Date** | **SWSI** | **NEP** | **SWSI Prev Yr** | **Chg SWSI Prev Yr** | **Reservoir Storage NEP** | **Prev Mo Streamflow NEP** | **Forecasted Runoff NEP** |
| Arkansas | 11020001 | Arkansas Headwaters | 2015-05 | -0.66 | 42.05 | 0.91 | -1.58 | 57.64 |  | 37.80 |
| Arkansas | 11020002 | Upper Arkansas | 2015-05 | 0.77 | 59.25 | 1.49 | -0.72 | 76.99 |  | 43.93 |
| Arkansas | 11020005 | Upper Arkansas-Lake Meredith | 2015-05 | -0.39 | 45.32 | 0.60 | -0.99 | 78.03 |  | 39.53 |
| Arkansas | 11020006 | Huerfano | 2015-05 | -2.91 | 15.08 | -2.44 | -0.47 | 12.69 |  | 25.91 |
| … | … | … | … | … | … | … | … | … | … | … |

The HUC Components results worksheet (shown in **Table 6**) includes:

* Basin name (Basin)
* HUC identifier (HUC\_ID)
* HUC name (HUC\_Name)
* Analysis date (Date)
* Component (reservoir storage, previous month’s streamflow, or forecasted runoff) for which the station was used (Component Type)
* Station or reservoir identifier (Component ID)
* Station or reservoir name (Component Name)
* Monthly component volume in ac-ft (Component Volume)
* Monthly component NEP computed by month (Component NEP by Month)

Table . SWSI Current Summary Output - HUC Components

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Basin** | **HUC\_ID** | **HUC\_Name** | **Date** | **Component Type** | **Component ID** | **Component Name** | **Component Volume** | **Component NEP by Month** |
| Arkansas | 11020001 | Arkansas Headwaters | 2015-05 | Forecasted Runoff | 07091500 | ARKANSAS RIVER AT SALIDA | 194000.00 | 38.00 |
| Arkansas | 11020001 | Arkansas Headwaters | 2015-05 | Reservoir Storage | 07007020 | CLEAR CREEK RESERVOIR | 8700.00 | 74.00 |
| Arkansas | 11020001 | Arkansas Headwaters | 2015-05 | Reservoir Storage | 07007110 | TURQUOISE LAKE | 62900.00 | 53.00 |
| … | … | … | … | … | … | … | … | … |

**SWSI Summary by Basin**

All of the component and result time series are written to an Excel workbook ({BasinName}-SWSI.xlsx) for each river basin. These workbooks can also be written to HTML files to implement a website that facilitates user review or product sharing though the commands are currently disabled.

The SWSI Summary by Basin results worksheet (shown in **Table 7**) includes:

* Analysis date (Date)
* Monthly component volume in ac-ft (Data Composite, Reservoir Storage, Previous Month’s Streamflow and Forecasted Runoff)
* Monthly component percent of historical average computed by month (PctOfAverage for Data Composite, Reservoir Storage, Previous Month’s Streamflow and Forecasted Runoff)
* Monthly component plotting position (Plotting Position for Data Composite, Reservoir Storage, Previous Month’s Streamflow and Forecasted Runoff)
* Monthly component NEP value (NEP for Data Composite, Reservoir Storage, Previous Month’s Streamflow and Forecasted Runoff)
* Monthly component SWSI value (SWSI for Data Composite, Reservoir Storage, Previous Month’s Streamflow and Forecasted Runoff)

Table . SWSI Summary by River Basin

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Date** | **Data Composite** | **Data Composite**  **PctOfAverage** | **Data Composite**  **Plotting Position** | **Data Composite**  **NEP** | **Data Composite**  **SWSI** | **…** |
| 1999-10 | 975655 | 229 | 0.99 | 98.51 | 4.04 | … |
| 1995-10 | 894473 | 210 | 0.96 | 96.02 | 3.83 | … |
| 1985-10 | 872295 | 205 | 0.94 | 93.53 | 3.63 | … |
| 1997-10 | 840187 | 197 | 0.91 | 91.04 | 3.42 | … |
| 1986-10 | 836559 | 196 | 0.89 | 88.56 | 3.21 | … |
| … | … | … | … | … | … | … |

**SWSI Summary by HUC**

All of the component and results time series are written to an Excel workbook ({HUC\_ID}-SWSI.xlsx) for each HUC. These workbooks can also be written to HTML files to implement a website that facilitates user review or product sharing though the commands are currently disabled.

The SWSI Summary by HUC results worksheet (shown in **Table 8**) includes:

* Analysis date (Date)
* Monthly component volume in ac-ft (Data Composite, Reservoir Storage, Previous Month’s Streamflow and Forecasted Runoff)
* Monthly component percent of historical average computed by month (PctOfAverage for Data Composite, Reservoir Storage, Previous Month’s Streamflow and Forecasted Runoff)
* Monthly component plotting position (Plotting Position for Data Composite, Reservoir Storage, Previous Month’s Streamflow and Forecasted Runoff)
* Monthly component NEP value (NEP for Data Composite, Reservoir Storage, Previous Month’s Streamflow and Forecasted Runoff)
* Monthly component SWSI value (SWSI for Data Composite, Reservoir Storage, Previous Month’s Streamflow and Forecasted Runoff)

Table . SWSI Summary by HUC

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Date** | **Data Composite** | **Data Composite**  **PctOfAverage** | **Data Composite**  **Plotting Position** | **Data Composite**  **NEP** | **Data Composite**  **SWSI** | **…** |
| 1985-10 | 65519 | 291 | 0.99 | 98.51 | 4.04 | … |
| 1995-10 | 61046 | 271 | 0.96 | 96.02 | 3.83 | … |
| 1979-10 | 52800 | 235 | 0.94 | 93.53 | 3.63 | … |
| 1984-10 | 41448 | 184 | 0.91 | 91.04 | 3.42 | … |
| … | … | … | … | … | … | … |

**Time Series by HUC (or Basin)**

All of the input, component, and results time series are written to an Excel workbook ({HUC\_ID}-TimeSeries.xlsx or ({BasinName}-TimeSeries.xlsx) for each HUC and River Basin. The Time Series summaries by HUC (or Basin) include the same time series as the SWSI summaries, with the addition of monthly volumes in ac-ft for each individual station used in the analysis (as shown in **Table 9**). These workbooks can also be written out to HTML files to implement a website that facilitates user review or product sharing though the commands are currently disabled.

In the HUC time series summaries, the term “HUC:” is prepended before the HUC identifier to make it clear where results are being presented by station identifier versus HUC identifier.

Table . Time Series by HUC (or River Basin)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Date** | **06620000**  **Component**  **PrevMoStreamflow** | **06620000**  **Component**  **ForecastedRunoff** | **HUC:10180001**  **Component**  **ReservoirStorage** | **HUC:10180001**  **ReservoirStorage**  **PctOfAverage** | **…** |
| 1970-10 | 0 | 0 | 0 | Null | … |
| 1970-11 | 0 | 0 | 0 | Null | … |
| 1970-12 | 0 | 0 | 0 | Null | … |
| 1971-01 | 0 | 310163 | 0 | Null | … |
| 1971-02 | 0 | 310163 | 0 | Null | … |
| 1971-03 | 0 | 310163 | 0 | Null | … |
| 1971-04 | 0 | 310163 | 0 | Null | … |
| … | … | … | … | … | … |

**SWSI History Graphs by River Basin**

Graphs are created for each river basin (Basin-{BasinName}-SWSI-history-graph.png) that show the time series of SWSI values since the beginning of the historical period through the current month’s analysis (**Figure 1**). Red vertical lines are used on the graphs to distinguish the historical, recent, and current periods used in the analysis.

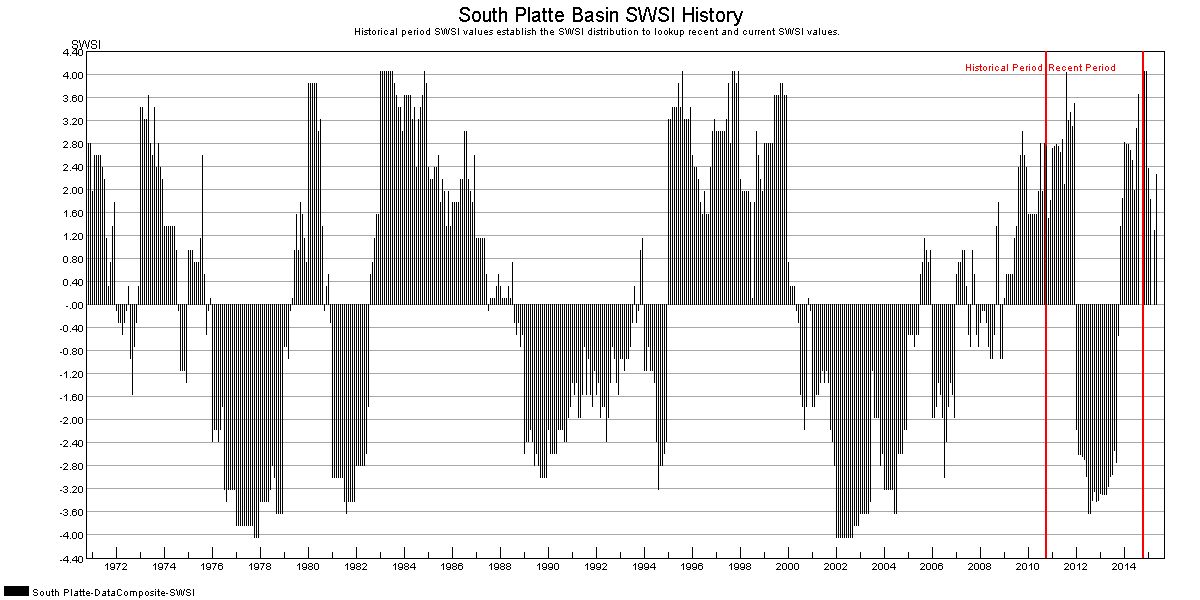


Figure . SWSI History Graph (River Basin)

**SWSI History Graphs by HUC**

Graphs are created for each HUC that show the time series of component volumes and SWSI values for the full analysis period for all months (HUC-{HUC\_ID}-SWSI-history-graph.png; **Figure 2**) and for all months for the recent and current periods only (HUC-{HUC\_ID}-SWSI-recent-graph.png; **Figure 3**). To change the period displayed in the recent graph, the user may change the **RecentPeriodGraphStartDate** property in the control file.

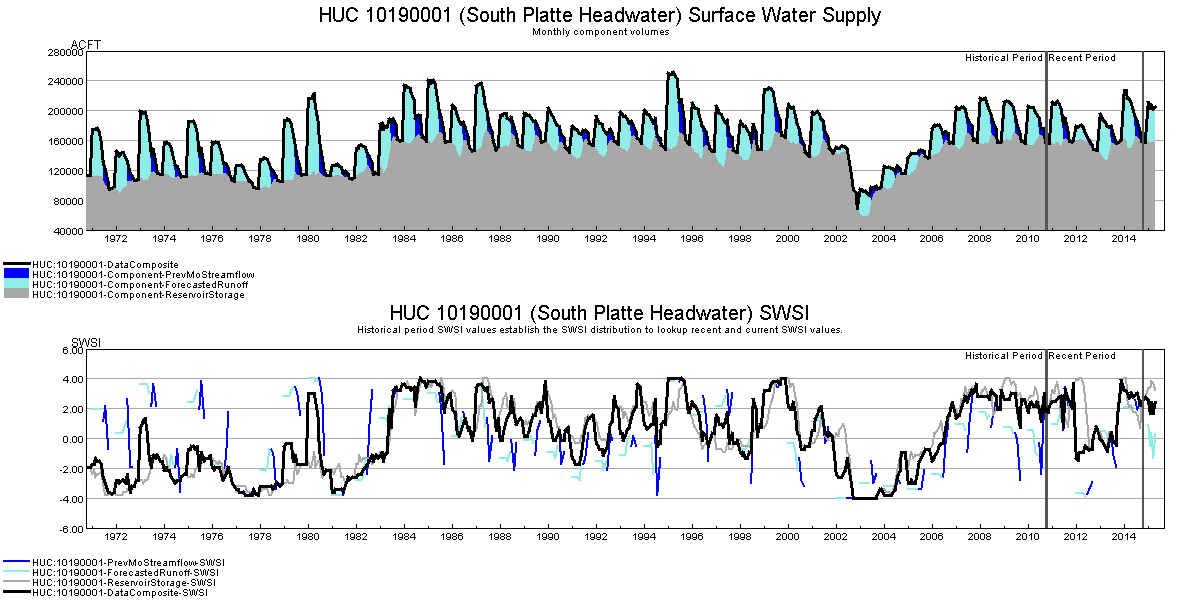


Figure . SWSI History Graph for the Full Analysis Period (HUC)

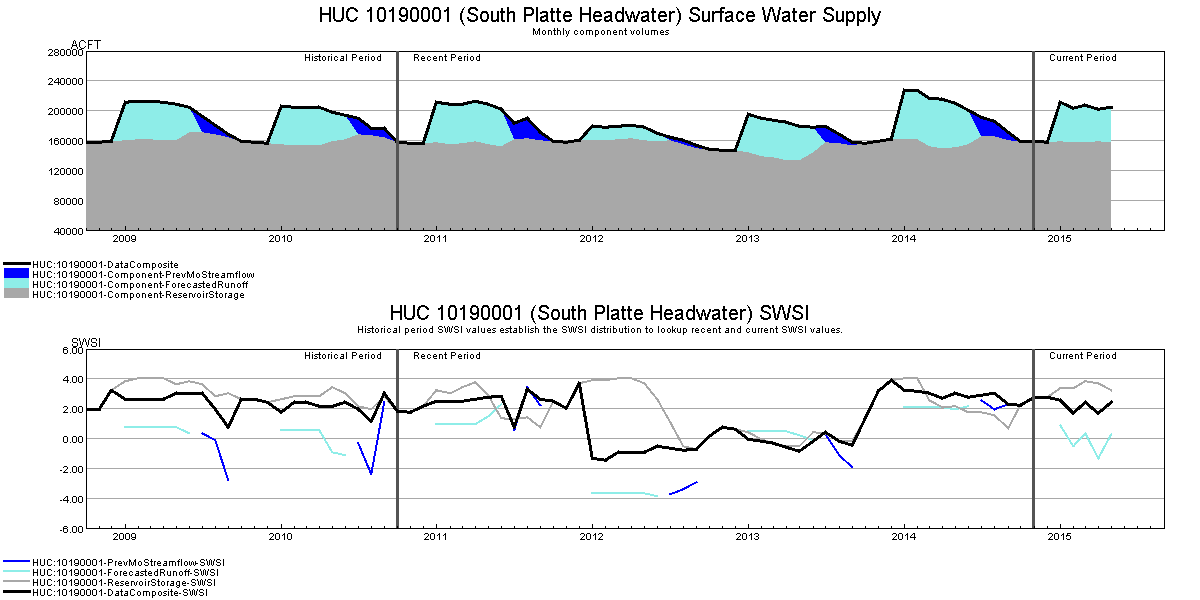


Figure . SWSI History Graph for the Recent and Current Periods (HUC)

**SWSI History Graphs by HUC and Month**

Graphs are created for each HUC and month (HUC-{HUC\_ID}-SWSI-history-{Month}-graph.png) that show the time series of component volumes and SWSI values for the full analysis period (**Figure 4**).

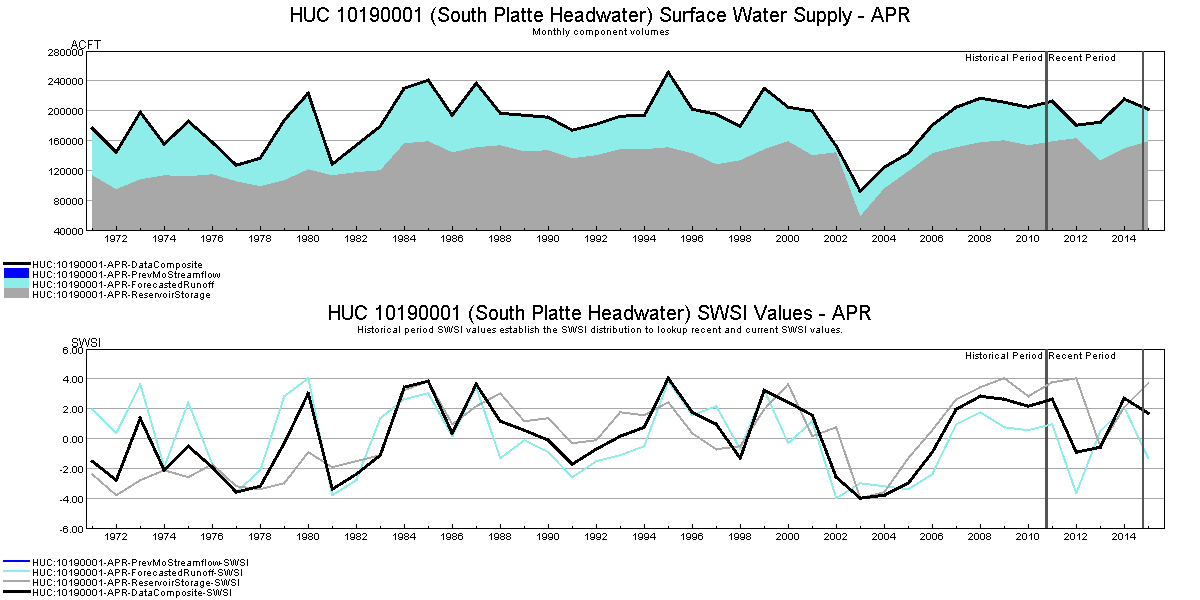


Figure . SWSI History Graph by Month for the Full Analysis Period (HUC)

# **Colorado SWSI Automation Tool Directory Structure**

The files for the Colorado SWSI Automation Tool are organized into two directories: one that contains helpful documents (\_Documents) and one that contains all files for one month’s analysis (\_2015-05). The \_2015-05 directory was provided by Open Water Foundation to DWR as a master copy and a starting point for subsequent monthly analyses.

To conduct an analysis for a new month, the most recent directory should be copied and renamed to the current month and year as YYYY-MM (or something similar). As an example, the data in a 2015-05 folder would include data relevant for a May 1, 2015 SWSI analysis, including all historical, recent, and current data, as well as all intermediate files and output files generated from the TSTool process.

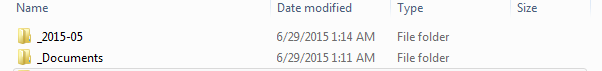


Figure . Highest level directory structure

The \_Documents directory contains this guide to running the Colorado SWSI Automation Tool (\_SWSI-TSTool-Guide), helpful background documents, and documents from the first project phase (**Figure 6**).



Figure . \_Documents directory

The Colorado SWSI Automation Tool uses an Excel workbook (named CO-SWSI-Control.xlsx and referred to in this document as the control file) and TSTool command files and time series products to perform the necessary processing. All input data, intermediate data and computation artifacts, and output data and graphs are saved within the YYYY\_MM folder to help the user review and archive the results.

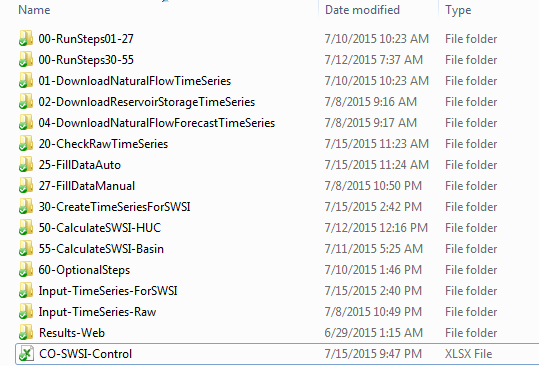


Figure . YYYY-MM Directory

**Figure 7** shows the contents of a YYYY\_MM folder, which include:

* The control file (CO-SWSI-Control.xlsx), that controls the analysis by defining the configuration properties and the stations needed to run the analysis.
* Folders whose name starts with a number (e.g., 01-DownloadNaturalFlowTimeSeries) represent TSTool processing steps. The numbers in the folder names indicate the order of the processing steps, with gaps in the numbering to allow future additions, if necessary. The folders at a minimum contain a TSTool command file with the same name as the folder.
* The Input-TimeSeries-Raw folder contains the time series data for stations and reservoirs before the data are transformed into SWSI Components. The data are available in DateValue and Excel format for three processing stages: raw data, auto-filled data, and manual-filled data.
  + The final input data are written to an Excel workbook named Final-Input-Data.xlsx that contains all data flags from the data download and filling processes. The data flags indicate data sources, data quality issues, and data manipulation, and are written to help DWR understand where the data values came from.
* The Input-TimeSeries-ForSWSI folder contains the time series data for stations and reservoirs after the data are transformed into SWSI Components.
  + The final component data are written to an Excel workbook named SWSI-Components-Data.xlsx that contains most data flags from the data download and filling processes. The exception to this is the Forecasted Runoff component, which does not include the data flags where historical natural flow data were used.
* The Results-Web directory contains all tabular and graphical output products described in **Colorado SWSI Output Products**.

# **Colorado SWSI Automation Tool Step-by-Step Procedures**

This section presents step-by-step procedures for a practitioner running the Colorado SWSI Automation Tool. Additional details of the process are documented in **Appendix C – Colorado SWSI Automation Tool Workflow Details**.

## To modify the methodology in the control file

1. Open the master version of the Excel file named “CO-SWSI-Control.xlsx”.
2. The **Config** worksheet contains properties needed to run the analysis. Properties highlighted in blue are entered by the user.
   1. The **NumberOfBasins** property specifies the number of river basins that are processed. This property is used for automated error checking. If basins are added or removed, this property should be updated.
   2. The **NumberOfHUCs** property specifies the number of HUCs that are processed. This property is used for automated error checking. If HUCs are added or removed, this property should be updated.
   3. The **RecentPeriodFlowType** property determines how the forecasted runoff component is treated in the recent period. To run a typical monthly analysis and generate historical SWSI values in the recent period, this property should be set to “**NaturalFlow**.” To run a re-forecast analysis and generate forecast SWSIs in the forecast period, this property should be set to “**ForecastedNaturalFlow**.”
3. The **Combined Inputs** worksheet specifies all station information necessary to run the Colorado SWSI analysis by HUC and river basin.
   1. To include or exclude stations from the HUC analysis, set the **Include** column to YES or NO, respectively.
   2. To use observed flows for the previous month’s streamflow for a station, set the **Include** column to YES-OBS.
      1. If the observed flow option is being used, consider whether all natural flow stations in the HUC should use observed flows.
   3. To include or exclude stations from the Basin analysis, set the **Basinwide Analysis** column to YES or NO, respectively.
   4. To change a data source for a natural flow station
      1. The only option is to set all **Datastore** options to use the NRCS AWDB web services to obtain SRVO data.
   5. To use observed flow data for a natural flow station
      1. The **Datastore** options should be retained to use the NRCS AWDB web services to obtain SRVO data. These data are used in the forecasted runoff component.
      2. The **Datastore2** options should be set up to obtain data from the ColoradoWaterHBGuest datastore.
      3. The **Datastore3** options can be set up to obtain data from the ColoradoWaterSMS datastore.
   6. To change a data source for a forecasted natural flow station
      1. The only option is to set all **Datastore** options to use the NRCS AWDB web services to obtain SRVO forecast data.
   7. To change a data source for a reservoir storage station
      1. The default option is to set all **Datastore** options to use the NRCS AWDB web services to obtain RESC data.
      2. Alternatively, the **Datastore** options can be set to use the ColoradoWaterSMS web services to obtain STORAGE data.
      3. If **Datastore** options are changed to use ColoradoWaterSMS, **Datastore2** options can be changed to use ColoradoWaterHBGuest web services to obtain ResMeasStorage data.
4. If a station is removed from the **Combined Inputs** worksheet, it should also be removed from the filling worksheets (**FlowDataFill**, **ReservoirDataFill**, and **Overrides**) to avoid processing errors. It suffices to set the **Include** column to “NO”; rows do not need to be deleted. For flow stations, this applies to both natural flow and observed flow stations.
5. In general, changes such as adding cell comments or inserting rows or columns to the control file should not disrupt the TSTool process because TSTool does not generally refer to specific cell ranges. The exceptions to this are in the Overrides and Reforecast List worksheets. However, it is very important not to disrupt named cell ranges, which are used heavily in the TSTool process. It is good practice to make a backup of the control workbook before making changes in case an error is introduced into the process.

## To run the monthly SWSI analysis

### Set up activities

1. **Create the current month’s analysis directory by copying the previous month’s directory.** The directories should be named to indicate the year and month being analyzed (YYYY-MM).
   1. Note: During the TSTool processing steps, output files are first removed so that, in the event that a step fails to create an output, the user will be able to detect this situation and not mistake old files for current results.
2. **Navigate to the new directory to open the control file (CO-SWSI-Control.xlsx) in Excel**.
   1. Go to the “Config” worksheet. Configuration properties that are entered by the user are highlighted in blue. Configuration properties that are calculated automatically are highlighted in gray.
      1. Every month, the following value should be updated:
         1. CurrentMonthDate
      2. If this is the first analysis of the water year, the following values should be reviewed and changed as necessary:
         1. HistoricalPeriodStartDate
         2. HistoricalPeriodEndDate
         3. SMSInputPeriodStartDay
         4. RecentPeriodGraphStartDate
   2. Go to the “Overrides” worksheet. Turn off last month’s override values by setting Include=NO for any values applied to the previous month’s analysis. Those data values may now be available from the source agencies.
   3. Close all Excel workbooks (and any other open files in the YYYY\_MM directory). The process will fail if a file is open and cannot be removed and re-written.

### Run the TSTool processing steps

1. **Open the TSTool software program**.
   1. The TSTool software program is installed at C:\CDSS\TSTool-XX.YY.ZZ\bin\TSTool.exe.
   2. TSTool version 11.04.03 or later is required to run the Colorado SWSI Automation Tool.
   3. Files with .TSTool extensions are TSTool command files that can be opened and run using TSTool. The user will need to run the TSTool command files in sequence to complete the Colorado SWSI analysis, with opportunities to review the inputs and results between steps. **Table 10** summarizes the approximate run time for each step and the overall processing time.
   4. To run a TSTool command file, the user should navigate to the File – Open Command File menu option, browse to the command file, click “Open” to load the command file, and then click the “Run All Commands” button.
   5. After running a TSTool processing step, all output files created by the TSTool process will be accessible from the TSTool “Output Files” tab. (Note that the control file is not created by TSTool, and therefore must be accessed through Windows Explorer.)
   6. The TSTool processing steps are linear, sequential steps. When changes are made to a particular step, that step needs to be rerun along with any subsequent steps in the numbered order. This concept is particularly important to understand during the data filling steps:
      1. In Step 25, the automated filling process always uses the raw data files from Steps 1-4 as input, and writes out auto-filled data files.
      2. In Step 27, the manual filling process always uses the auto-filled data from Step 25 as inputs, and writes out manual-filled data files.

Table . Approximate Run Times for TSTool Processing Steps

|  |  |
| --- | --- |
| **Step** | **Approximate Run Time (minutes)** |
| 01-DownloadNaturalFlowTimeSeries | 2 |
| 02-DownloadReservoirStorageTimeSeries | 2 |
| 04-DownloadNaturalFlowForecastTimeSeries | 2 |
| 20-CheckRawTimeSeries | <1 |
| 25-FillDataAuto | 1 |
| 27-FillDataManual | 1 |
| 30-CreateTimeSeriesForSWSI | <1 |
| 50-CalculateSWSI-HUC | 20 |
| 55-CalculateSWSI-Basin | 5 |
| **Total Processing Time**  **(required steps only)** | **35** |
| 60a-CompareHistSWSI-NRCS | <1 |
| 60b-GenerateCurrentSummaries | 10 |
| 60c-CompareFcstSWSI-NRCS | <1 |
| **Total Processing Time**  **(with additional steps)** | 47 |

***Note:*** Rather than running TSTool steps 01-27 separately, the user may opt to run the aggregated version named 00-RunSteps01-27.TSTool.

1. **Download the raw input data.** All available data are downloaded to ensure that a full archive of data is kept for the month’s analysis, and to minimize the need for subsequent downloads during the analysis. Input data are downloaded for each station listed in the control file on the “Combined Inputs” worksheet without consideration of which HUC or Basin will use the data. Station data are downloaded once and can then be used in multiple HUCs.
   1. **Download natural flow time series (and observed flow time series, if being used):**
      1. Load the 01-DownloadNaturalFlowTimeSeries.TSTool command file in TSTool.
         1. In the command pane, there may be a warning at the bottom of the command file indicating that the “Input file does not exist: "YYYY-MM\Input-TimeSeries-Raw\NaturalFlow\ObservedFlow-Month.dv." This file is not created if observed flow are not being used, so this warning can be disregarded.
      2. Click “Run All Commands.”
      3. When the run is finished, click on the Problems tab.
         1. Any rows that have a Severity of “WARNING” or “FAILURE” should be reviewed. The Problem column gives details about the severity status.
         2. A Warning with a Problem of “Input file does not exist: "YYYY-MM\Input-TimeSeries-Raw\NaturalFlow\ObservedFlow-Month.dv" is OK if observed flow data are not being used in the analysis.
         3. A Warning with a Problem of “For the natural flow data type, HUC ${HUCID} is assigned a mixture of observed and natural flow stations” is OK if this situation was intentional. Otherwise, the user can go to the Combined Inputs worksheet in the control file and specify that all natural flow stations for a given HUC use observed flow data.
         4. A Warning with a Problem of "${NumStations} expected but ${NumTimeSeries} created" indicates that the number of time series created does not match the number of stations. The message will indicate if the problem is with the natural flow data from NRCS, the observed flow data from ColoradoWaterSMS, or the observed flow data from ColoradoWaterHBGuest. The data source or the data source specifications on the Combined Inputs worksheet need to be investigated.
         5. A Warning with a Problem of “No data was returned for ${NumTimeSeriesDefault} stations” indicates that the data source specified on the Combined Inputs worksheet needs to be investigated. The message will indicate if the problem is with the natural flow data from NRCS, the observed flow data from ColoradoWaterSMS, or the observed flow data from ColoradoWaterHBGuest.
         6. If changes are made in the Combined Inputs worksheet, the TSTool command file has to be re-run.
      4. The output files can be opened from the “Output Files” tab. The Flow-Month.xlsx workbook includes all the raw flow data. Missing values are denoted by blanks.
   2. **Download reservoir storage data:**
      1. Load the 02-DownloadReservoirStorageTimeSeries.TSTool command file in TSTool.
      2. Click “Run All Commands.”
      3. When the run is finished, click on the Problems tab:
         1. Any rows that have a Severity of “WARNING” or “FAILURE” should be reviewed. The Problem column gives details about the severity status.
         2. A Warning with a Problem of ${NumTimeSeries} time series created but ${ReservoirCount} time series expected indicates that the number of time series created does not match the number of reservoirs. The message will indicate if the problem is with the data from NRCS AWDB, ColoradoWaterSMS, or ColoradoWaterHBGuest. The data source or the data source specifications on the Combined Inputs worksheet need to be investigated.
         3. A Warning with a Problem of “No data was returned for ${NumTimeSeries} stations” indicates that the data source specified on the Combined Inputs worksheet needs to be investigated. The message will indicate if the problem is with the NRCS AWDB, ColoradoWaterSMS, or ColoradoWaterHBGuest data.
         4. If changes are made in the Combined Inputs worksheet, the TSTool command file has to be re-run.
      4. The output files can be opened from the “Output Files” tab. The ReservoirStorage-Month.xlsx workbook includes all the end-of-month storage data. Missing values are denoted by blanks.
   3. **Download forecasted natural flow data:**
      1. Load the 04-DownloadNaturalFlowForecast.TSTool command file into TSTool.
      2. Click “Run All Commands.”
      3. When the run is finished, click on the Problems tab:
         1. Any rows that have a Severity of “WARNING” or “FAILURE” should be reviewed. The Problem column gives details about the severity status.
         2. A Warning with a Problem of "${NumTS} time series created but ${ForecastedCount} time series expected indicates that the data source specified on the Combined Inputs worksheet needs to be investigated.
         3. If changes are made in the Combined Inputs worksheet, the TSTool command file has to be re-run.
      4. The output files can be opened from the “Output Files” tab. The ForecastedNaturalFlow-Month.xlsx workbook includes all the forecasted natural flow data. Missing values are denoted by blanks.
2. **Analyze the raw data for missing values.**
   1. Load the 20-CheckRawTimeSeries.TSTool command file into TSTool.
   2. Click “Run All Commands.”
   3. When the run is finished, click on the Problems tab:
      1. Any rows that have a Severity of “WARNING” or “FAILURE” should be reviewed. The Problem column gives details about the severity status.
      2. There will be a Warning with a Problem of “Severity for RunCommands (WARNING) is max of commands in command file that was run.” This warning is OK and simply means that warnings were generated due to missing values.
      3. There will likely be many Warnings with Type=Missing and Problems of “Time series {TS\_Alias} value NaN at {YYYY-MM} is missing. These warnings are OK and simply mean that warnings were generated due to missing values.
   4. Use Windows Explorer to navigate to the 20-CheckRawTimeSeries folder. Open “TimeSeriesChecks.xlsx” in Excel.
      1. On the Natural Flow, Observed Flow, Reservoir Storage, and Forecasted Natural Flow worksheets, cells that contain the missing count are highlighted in red if a station has missing data.
      2. On the Missing Value List worksheet, missing values are listed by descending date.
      3. Note that during the Colorado SWSI Automation Tool development, Open Water Foundation performed a significant review of the historical data and addressed most issues using the automated filling options. However, new issues may arise because of changes in data availability.
      4. On the Natural Flow worksheet, make note of any stations with missing data, particularly in the historical period or for the previous month. (The data have not yet been shifted and transformed into component values, so the previous month’s flow value is needed for the previous month’s streamflow component.) The user should determine whether missing values should be filled, and if so, whether automatically using regression analysis or manually using user-determined override values.
         1. Note: if the user has specified to use observed flow data for the previous month’s streamflow component for a station, the missing counts for that station’s natural flow data will be too high. There is no effect on the results if the user chooses to fill unnecessary missing natural flow values; some of the filled data values will not be used where observed flow data are being used instead.
      5. On the Reservoir Storage worksheet, make note of any stations with missing data, particularly in the historical period or for the previous month. Determine whether missing values should be filled, and if so, whether automatically (using interpolation, historical monthly averages, or zeroes) or manually using user-determined override values. (Note that the data have not yet been shifted and transformed into component values, so the previous month’s storage value is needed for the reservoir storage component.)
      6. On the Forecasted Natural Flow worksheet, make note of any stations with missing data, particularly for the current month. Determine whether missing values should be filled. The only filling option currently implemented is user-determined override values.
      7. On the Observed Flow worksheet, make note of any stations with missing data, particularly in the historical period or for the previous month. (The data have not yet been shifted and transformed into component values, so the previous month’s flow value is needed for the previous month’s streamflow component.) The user should determine whether missing values should be filled, and if so, whether automatically using regression analysis or manually using user-determined override values.
      8. Open the control workbook (CO-SWSI-Control.xlsx) and enter new filling information (if needed) on the FlowDataFill, ReservoirDataFill, and Overrides worksheets. **Note:** **the auto-filling indicated on the FlowDataFill and ReservoirDataFill worksheets will only fill values that are missing in the raw datasets. In contrast, the manual overrides specified on the Overrides worksheet will be used regardless of whether the value in the auto-filled datasets is missing or not.**
      9. Close all workbooks. The process will fail if a file is open and cannot be removed and re-written. If the process does fail, simply close all workbooks and rerun this step. The user does not need to rerun earlier steps.
3. **Fill missing values using automated filling techniques in TSTool.**
   1. Load the 25-FillDataAuto.TSTool command file into TSTool.
      1. In the command pane, warnings may be associated with the observed data files if they don’t exist. This is OK if observed data are not being used in the analysis.
   2. Click “Run All Commands.”
   3. When finished running, click on the Problems tab.
      1. Any rows that have a Severity of “WARNING” or “FAILURE” should be reviewed. The Problem column gives details about the severity status.
      2. There will be a Warning with a Problem of “Severity for RunCommands (WARNING) is max of commands in command file that was run.” This warning is OK and simply means that warnings were generated due to missing values.
      3. There will likely be several Warnings with Type=Missing and Problems of “Time series {TS\_Alias} value NaN at {YYYY-MM} is missing. These warnings are OK and simply mean that warnings were generated due to missing values.
      4. A Warning with a Problem of “${StationsCount} filling stations expected, but data read for only ${NumStationsRead} stations” indicates that the filling data source information specified on the flow filling worksheet needs to be investigated. The message will indicate whether the issue is with the natural flow filling or the observed flow filling data.
         1. If changes are made on the FlowDataFill worksheet, the TSTool command file has to be re-run.
   4. To review the regression statistics from the natural flow filling, go to the Tables tab and open NatFlow\_RegressionStats. This table summarizes:
      1. The dependent station being filled (ID)
      2. The independent station used for filling (Independent\_ID)
      3. Dates of available data (DependentAnalysisStart, DependentAnalysisEnd, IndependentAnalysisStart, IndependentAnalysisEnd)
      4. Period used for filling (FillStart and FillEnd)
      5. Regression statistics for each month (where the month is denoted by suffixes of \_1 to \_12), such as correlation coefficient (e.g., R\_1) and coefficient of determination (e.g., R2\_1).
   5. If observed data are being used, and filling is being performed on the observed flow data, the regression statistics will be written to ObsFlow\_RegressionStats.
   6. To compare the raw and filled time series, commands are provided at the end of the command file. Run the commands to read the raw and filled time series. For a given station, select the raw and filled time series to plot using a line graph.
      1. To see the data flags, right-click on the graph and select “Properties.”
      2. Under Time Series Properties, select the Symbol tab.
      3. Select a symbol for the flagged data symbol and choose a symbol size larger than 0.
      4. Close the Properties window.
   7. Alternatively, to review the filled data using Excel, go to the Output Files tab:
      1. Open the NaturalFlow-Month-1AutoFilled.xlsx workbook to review the filled natural flow data.
      2. If observed data are being used, open the ObservedFlow-Month-1AutoFilled.xlsx workbook to review the filled observed flow data.
      3. Open the ReservoirStorage-Month-1AutoFilled.xlsx workbook to review the filled reservoir storage data.
      4. Missing values are denoted using blanks.
   8. Use Windows Explorer to navigate to the 25-FillDataAuto folder. Open “TimeSeriesChecks.xlsx” in Excel.
      1. Determine whether adjustments are needed to the auto-filling specifications.
         1. If changes are made to the auto-filling specifications, this step needs to be re-run in TSTool, as well as all subsequent steps. Previous steps do not need to be rerun.
      2. Determine whether additional missing values should be filled using overrides.
         1. Open the control workbook (CO-SWSI-Control.xlsx) and enter filling information on the Overrides worksheet. Manual overrides can be used for any date in the historical period, recent period, or current water year, for example to provide data where automated filling is difficult to perform, or for current data that may not yet be available from web services.
         2. Note that at this point in the process, the data have not yet been time-shifted and transformed into component values. The manual overrides should be specified using the date stamps and data types associated with the raw data.
   9. Close all workbooks. The process will fail if a file is open and cannot be removed and re-written.
4. **Fill missing values using manual overrides specified by the user.** 
   1. Load the 27-FillDataManual.TSTool command file into TSTool.
      1. In the command pane, warnings may be associated with the observed data files if they don’t exist. This is OK if observed data are not being used in the analysis.
   2. Click “Run All Commands.”
   3. When finished running, click on the Problems tab.
      1. Any rows that have a Severity of “WARNING” or “FAILURE” should be reviewed. The Problem column gives details about the severity status.
      2. There will be a Warning with a Problem of “Severity for RunCommands (WARNING) is max of commands in command file that was run.” This warning is OK and simply means that warnings were generated due to missing values.
      3. There will likely be several Warnings with Type=Missing and Problems of “Time series {TS\_Alias} value NaN at {YYYY-MM} is missing. These warnings are OK and simply mean that warnings were generated due to missing values.
   4. To check that the manual overrides were applied, open a filled time series as a table. Choose to have the flags shown as a superscript. Scroll to the override dates and confirm that the values and flags were set as expected.
   5. Alternatively, to review the filled data using Excel, go to the Output Files tab:
      1. Open the Input-Data-Final.xlsx workbook. This workbook contains the final input data and all data flags denoting data source, quality, and manipulations. **Table 11** contains a list of the data flags that are used in the process.

Table . Data Flags and Definitions

|  |  |
| --- | --- |
| **Data Flag Abbreviation** | **Data Flag Description** |
| R | Value filled using monthly linear regression |
| Z | Value filled using 0 |
| RZ | Value filled using monthly linear regression was negative and was replaced with 0 |
| I | Value filled using linear interpolation between surrounding values |
| H | Value filled using historical monthly averages |
| MO-\* | Value filled using manual override |
| M | Value is missing |
| HB | Value obtained from the State of CO HydroBase database |
| SMS | Value obtained from the State of CO Satellite Monitoring System |
| E | Value is edited (assigned by NRCS, value can be treated the same as a value without a data flag) |

* + 1. Missing values are denoted using blanks.
  1. Use Windows Explorer to navigate to the 27-FillDataManual folder. Open “TimeSeriesChecks.xlsx” in Excel.
     1. Determine whether any additional missing values should be filled. If so, make changes to the FlowDataFill, ReservoirDataFill, and Overrides worksheets. Repeat steps 6 and 7 as needed.
     2. Moving forward, the impacts of missing data are as follows:
        1. If data are missing in the historical period, fewer years will be used to establish the SWSI and NEP distributions, and the ranges of possible SWSI and NEP values will narrow.
        2. If data are missing in the recent period, SWSI and NEP results will also be missing in the recent period, which affects the graphical and tabular outputs.
        3. If data are missing in the current month, SWSI and NEP results will also be missing.
        4. The exception to this is stations where natural flow data are noted as missing, but are not being used because the user has elected to use observed streamflow for the previous month’s streamflow component. As long as the needed observed flow data are available, the SWSI and NEP results will be calculated.
  2. Close all Excel workbooks. The process will fail if a file is open and cannot be removed and re-written.

***Note:*** Rather than running TSTool steps 30-55 separately, the user may opt to run the aggregated version named 00-RunSteps30-50.TSTool.

1. **Create the SWSI component input data**.
   1. Load the 30-CreateTimeSeriesForSWSI.TSTool command file into TSTool.
      1. In the command pane, warnings may be associated with the observed data files if they don’t exist. This is OK if observed data are not being used in the analysis.
   2. Click “Run All Commands.”
   3. When finished running, click on the Problems tab.
      1. Any rows that have a Severity of “WARNING” or “FAILURE” should be reviewed. The Problem column gives details about the severity status.
      2. There will be a Warning with a Problem of “Severity for RunCommands (WARNING) is max of commands in command file that was run.” This warning is OK and simply means that warnings were generated due to missing values.
      3. There will likely be several Warnings with Type=Missing and Problems of “Time series {TS\_Alias} value NaN at {YYYY-MM} is missing. These warnings are OK and simply mean that warnings were generated due to missing values.
   4. If desired, scroll to the bottom of the command file and run the commands to read the raw and transformed data.
   5. From this point forward in the process, the input data have been time-shifted and transformed into component values.
   6. Use Windows Explorer to navigate to the 30-CreateTimeSeriesForSWSI folder. Open “TimeSeriesChecks.xlsx” in Excel.
      1. If no observed flow data are being used, the missing value information should be the same as was obtained in Step 27, although the dates may have been time-shifted in creating the components.
      2. If observed flow data are being used, there should be fewer missing values because the program has at this point substituted observed flow for the previous month’s streamflow component.
   7. On the Output Files tab, open the SWSI-Components-Data.xlsx workbook. This workbook contains the final component data by station after transformations and time shifts. Most data flags are shown, though the forecasted runoff component no longer has data flags where historical natural flow data have been used, due to data accumulations.
   8. Close all workbooks. The process will fail if a file is open and cannot be removed and re-written.
2. **Calculate the SWSI results by HUC.**
   1. Load the 50-CalculateSWSI-HUC.TSTool command file into TSTool.
   2. Click “Run All Commands.”
   3. When finished running, click on the Problems tab.
      1. Any rows that have a Severity of “WARNING” or “FAILURE” should be reviewed. The Problem column gives details about the severity status.
      2. A Failure with a Problem of “ERROR - ${HUCCount} HUCs found but ${NumberOfHUCs} expected. Check HUC IDs and HUC Names in control file.” Indicates that there are typos in the HUC information on the Combined Inputs worksheet, resulting in duplicates. Fix the problem and then re-run this step.
      3. A Failure with a Problem similar to “ERROR for HUC ${HUCID} - ${SelectReservoirCount} reservoirs found but ${NumReservoirs} expected. FIX!” indicates a problem with the TSTool process and/or possibly duplicate stations assigned to a HUC for the same data type. Fix the problem and then re-run this step.
   4. Review all HUC products in the Results-Web folder, in particular the SWSI Current Summary workbook and the HUC graphical outputs, to quality control the results.
3. **Calculate the SWSI results by Basin.**
   1. Load the 55-CalculateSWSI-Basin.TSTool command file into TSTool.
   2. Click “Run All Commands.”
   3. When finished running, click on the Problems tab.
      1. Any rows that have a Severity of “WARNING” or “FAILURE” should be reviewed. The Problem column gives details about the severity status.
      2. A Failure with a Problem of “ERROR - ${BasinCount} Basins found but ${NumberOfBasins} expected. Check control file.” Indicates that there are typos in the Basin information on the Combined Inputs worksheet, resulting in duplicates. Fix the problem and then re-run this step.
      3. A Failure with a Problem similar to “ERROR for Basin ${Basin} - ${SelectReservoirCount} reservoirs found but ${NumReservoirs} expected. FIX!” indicates a problem with the TSTool process and/or possibly duplicate stations assigned to a Basin for the same data type. Fix the problem and then re-run this step.
   4. Review all Basin products in the Results-Web folder, in particular the SWSI Current Summary workbook and the graphical outputs, to quality control the results.

### Review and disseminate the output products

1. **Go to the YYYY\_MM\Results\_Web folder to review available graphical and tabular output products.**
2. **Provide the SWSI-Current-Summary.xlsx file to OIT to load into HydroBase.**
3. **Archive the following files (at a minimum) so that the Colorado SWSI outputs can be re-generated in the future:**
   1. CO-SWSI-Control.xlsx
   2. Input-TimeSeries-Raw/Input-Data-Final.xlsx (*Note: this file is not required to rerun the SWSI analysis, but it contains the final input data with all data flags that indicate data sources and filling that may be of interest to the user in deciphering results.*)
   3. Input-TimeSeries-ForSWSI/ForecastedRunoff/SWSI-Component-ForecastedRunoff.dv
   4. Input-TimeSeries-ForSWSI/ForecastedRunoff/Station-ForecastedRunoff-NEP.dv
   5. Input-TimeSeries-ForSWSI/PrevMoStreamflow/SWSI-Component-PrevMoStreamflow.dv
   6. Input-TimeSeries-ForSWSI/PrevMoStreamflow/Station-PrevMoStreamflow-NEP.dv
   7. Input-TimeSeries-ForSWSI/ReservoirStorage/SWSI-Component-ReservoirStorage.dv
   8. Input-TimeSeries-ForSWSI/ReservoirStorage/Station-ReservoirStorage-NEP.dv

*Note: With the above files saved, the user can rerun the SWSI analysis starting from Step 50 in the TSTool process.*

### Compare Colorado Historical SWSI Values to NRCS Historical SWSI Values (Optional)

1. **Run Historical SWSI Comparison**
   1. Load the 60a-CompareHistSWSI-NRCS.TSTool command file into TSTool.
   2. Click “Run All Commands.”
   3. Click on the Problems tab and confirm there are no warnings or failures.
   4. On the Output Files tab, click on the results graphs to review.

## To run Colorado SWSI Re-forecasts

1. **Set “RecentPeriodFlowType” property in control workbook to ForecastedNaturalFlow. Save and exit the workbook.**
2. **Follow the procedure specified above in “To run the monthly SWSI analysis.”**
3. **Extend the NRCS Forecast SWSI dataset.** This process uses NRCS Forecast SWSI data contained in the Input-TimeSeries-ForSWSI/ComparisonData/NRCS-SWSI-Recent.dv file. New values can be added to this dataset in one of two ways:
   1. New values can be manually added using a text editor by copying a previous line and then updating the values. If this approach is used, the user also needs to manually update the End property in the DateValue file header.
   2. Rename the existing file and then use TSTool to read the existing file and the file containing new values, merge the time series, and write out a new file with the original file name (Input-TimeSeries-ForSWSI/ComparisonData/NRCS-SWSI-Recent.dv).
4. **Generate dated Current SWSI Summaries for each month in the recent period.**
   1. Load the 60b-GenerateCurrentSummaries.TSTool command file into TSTool.
   2. Click “Run All Commands.”
   3. When finished, click on the Problems tab to ensure no warnings or failures were generated.
   4. Open the dated summary files from the Output Files tab.

### Compare Colorado Forecast SWSI Values to NRCS Forecast SWSI Values (Optional)

1. **Run Forecast SWSI Comparison**
   1. Load the 60c-CompareFcstSWSI-NRCS.TSTool command file into TSTool.
   2. Click “Run All Commands.”
   3. Click on the Problems tab and confirm there are no warnings or failures.
   4. On the Output Files tab, click on the results graphs to review.

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# **Appendix A – NRCS Native Flow Equations**

|  |
| --- |
| **Calculations completed to generate SRVO (Native Flow) data for AWDB Database** |
| Source: Gus Goodbody, NRCS. Last updated: 7/15/2015 |

| **Basin** | **HUC8 ID** | **HUC8 Name** | **Station ID** | **Station Name** | **Native Flow Calculation** | **Component ID/Name** | **Component Type** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| South Platte | 10190003 | Middle South Platte- Cherry Creek. Colorado. | 06707500 | SOUTH PLATTE RIVER AT SOUTH PLATTE | Externally Adjusted |  |  |
| South Platte | 10190003 | Middle South Platte- Cherry Creek. Colorado. | 06710385 | BEAR CREEK ABV EVERGREEN | no adjustments |  |  |
| South Platte | 10190003 | Middle South Platte- Cherry Creek. Colorado. | 06719505 | CLEAR CREEK AT GOLDEN | + | 06719505 - Clear Ck at Golden | Observed |
|  |  |  |  |  | - | 09021500 - Berthoud Pass Ditch nr Berthoud Pass | Diversion |
|  |  |  |  |  | + | 200540 - Church Ditch | Diversion |
|  |  |  |  |  | + | 700542 - Golden City Ditch | Diversion |
|  |  |  |  |  | - | VIDTUNCO - Vidler Tunnel | Diversion |
| South Platte | 10190003 | Middle South Platte- Cherry Creek. Colorado. | 06724000 | SAINT VRAIN CREEK AT LYONS | Externally Adjusted |  |  |
| South Platte | 10190003 | Middle South Platte- Cherry Creek. Colorado. | 06727000 | BOULDER CREEK NEAR ORODELL | Externally Adjusted |  |  |
| South Platte | 10190003 | Middle South Platte- Cherry Creek. Colorado. | 06729500 | SOUTH BOULDER CK NR ELDORADO SPRINGS, CO | + | 06729500 - South Boulder Ck nr Eldorado Springs | Observed |
|  |  |  |  |  | + | 06016130 - Gross Reservoir | Change in Storage |
|  |  |  |  |  | - | 09022500 - Moffat Water Tunnel at East Portal | Diversion |
|  |  |  |  |  | + | BOSDELCO - South Boulder Ck Div | Diversion |
| South Platte | 10190003 | Middle South Platte- Cherry Creek. Colorado. | 06738000 | BIG THOMPSON R AT MOUTH, NR DRAKE, CO | Externally Adjusted |  |  |
| South Platte | 10190003 | Middle South Platte- Cherry Creek. Colorado. | 06752000 | CACHE LA POUDRE R AT CANYON MOUTH | Externally Adjusted |  |  |
| Yampa/White | 10180001 | North Platte Headwaters. Colorado. | 06620000 | NORTH PLATTE R NR NORTHGATE | + | 06620000 - North Platte R nr Northgate | Observed |
|  |  |  |  |  | + | 06745500 - Cameron Pass Ditch | Diversion |
|  |  |  |  |  | + | 06746000 - Michigan Ditch | Diversion |
| South Platte | 10190001 | South Platte Headwater. Colorado. | 06695500 | ELEVENMILE CANYON RE NEAR LAKE GEORGE | Externally Adjusted |  |  |
| South Platte | 10190002 | Upper South Platte. Colorado. | 06707500 | SOUTH PLATTE RIVER AT SOUTH PLATTE | Externally Adjusted |  |  |
| South Platte | 10190002 | Upper South Platte. Colorado. | 06710385 | BEAR CREEK ABV EVERGREEN | no adjustments |  |  |
| South Platte | 10190004 | Clear. Colorado | 06719505 | CLEAR CREEK AT GOLDEN | + | 06719505 - Clear Ck at Golden | Observed |
|  |  |  |  |  | - | 09021500 - Berthoud Pass Ditch nr Berthoud Pass | Diversion |
|  |  |  |  |  | + | 200540 - Church Ditch | Diversion |
|  |  |  |  |  | + | 700542 - Golden City Ditch | Diversion |
|  |  |  |  |  | - | VIDTUNCO - Vidler Tunnel | Diversion |
| South Platte | 10190005 | St. Vrain. Colorado. | 06724000 | SAINT VRAIN CREEK AT LYONS | Externally Adjusted |  |  |
| South Platte | 10190005 | St. Vrain. Colorado. | 06727000 | BOULDER CREEK NEAR ORODELL | Externally Adjusted |  |  |
| South Platte | 10190005 | St. Vrain. Colorado. | 06729500 | SOUTH BOULDER CK NR ELDORADO SPRINGS, CO | + | 06729500 - South Boulder Ck nr Eldorado Springs | Observed |
|  |  |  |  |  | + | 06016130 - Gross Reservoir | Change in Storage |
|  |  |  |  |  | - | 09022500 - Moffat Water Tunnel at East Portal | Diversion |
|  |  |  |  |  | + | BOSDELCO - South Boulder Ck Div | Diversion |
| South Platte | 10190006 | Big Thompson. Colorado. | 06738000 | BIG THOMPSON R AT MOUTH, NR DRAKE, CO | Externally Adjusted |  |  |
| South Platte | 10190007 | Cache La Poudre. Colorado, Wyoming. | 06752000 | CACHE LA POUDRE R AT CANYON MOUTH NEAR FORT COLLINS | Externally Adjusted |  |  |
| South Platte | 10190012 | Middle South Platte- Sterling. Colorado, Nebraska. | 06707500 | SOUTH PLATTE RIVER AT SOUTH PLATTE | Externally Adjusted |  |  |
| South Platte | 10190012 | Middle South Platte- Sterling. Colorado, Nebraska. | 06710385 | BEAR CREEK ABV EVERGREEN | no adjustments |  |  |
| South Platte | 10190012 | Middle South Platte- Sterling. Colorado, Nebraska. | 06719505 | CLEAR CREEK AT GOLDEN | + | 06719505 - Clear Ck at Golden | Observed |
|  |  |  |  |  | - | 09021500 - Berthoud Pass Ditch nr Berthoud Pass | Diversion |
|  |  |  |  |  | + | 200540 - Church Ditch | Diversion |
|  |  |  |  |  | + | 700542 - Golden City Ditch | Diversion |
|  |  |  |  |  | - | VIDTUNCO - Vidler Tunnel | Diversion |
| South Platte | 10190012 | Middle South Platte-Sterling. Colorado, Nebraska. | 06724000 | SAINT VRAIN CREEK AT LYONS | Externally Adjusted |  |  |
| South Platte | 10190012 | Middle South Platte-Sterling. Colorado, Nebraska. | 06727000 | BOULDER CREEK NEAR ORODELL | Externally Adjusted |  |  |
| South Platte | 10190012 | Middle South Platte-Sterling. Colorado, Nebraska. | 06729500 | SOUTH BOULDER CK NR ELDORADO SPRINGS, CO | + | 06729500 - South Boulder Ck nr Eldorado Springs | Observed |
|  |  |  |  |  | + | 06016130 - Gross Reservoir | Change in Storage |
|  |  |  |  |  | - | 09022500 - Moffat Water Tunnel at East Portal | Diversion |
|  |  |  |  |  | + | BOSDELCO - South Boulder Ck Div | Diversion |
| South Platte | 10190012 | Middle South Platte-Sterling. Colorado, Nebraska. | 06738000 | BIG THOMPSON R AT MOUTH, NR DRAKE, CO | Externally Adjusted |  |  |
| South Platte | 10190012 | Middle South Platte-Sterling. Colorado, Nebraska. | 06752000 | CACHE LA POUDRE R AT CANYON MOUTH | Externally Adjusted |  |  |
| Arkansas | 11020001 | Arkansas Headwaters. Colorado. | 07091500 | ARKANSAS RIVER AT SALIDA | + | 07091500 - Arkansas R at Salida | Observed |
|  |  |  |  |  | - | 07081900 - Boustead Tunnel | Diversion |
|  |  |  |  |  | - | 09077500 - Busk Ivanhoe Tunnel | Diversion |
|  |  |  |  |  | + | 07007020 - Clear Creek Reservoir | Change in Storage |
|  |  |  |  |  | - | 09061500 - Columbine Ditch | Diversion |
|  |  |  |  |  | - | CO0006 - Ewing Ditch | Diversion |
|  |  |  |  |  | - | 07081899 - Homestake Tunnel | Diversion |
|  |  |  |  |  | + | CO0017 - Otero Pump Station | Diversion |
|  |  |  |  |  | + | 07007110 - Turquoise Lake | Change in Storage |
|  |  |  |  |  | + | 07007120 - Twin Lakes Reservoir | Change in Storage |
|  |  |  |  |  | - | CO0033 - Twin Lakes Tunnel | Diversion |
|  |  |  |  |  | - | CO0040 - Wurtz Ditch | Diversion |
| Arkansas | 11020002 | Upper Arkansas. Colorado. | 07099400 | ARKANSAS RIVER ABOVE PUEBLO | + | 07099400 - Arkansas R ab Pueblo | Observed |
|  |  |  |  |  | + | 07091500 - Arkansas R at Salida | Combined Adjustments |
|  |  |  |  |  | + | 07099375 - Bessemer Ditch | Diversion |
|  |  |  |  |  | + | 07095900 - Canon City Hydraulic | Diversion |
|  |  |  |  |  | + | 07096100 - Canon City Oil Creek Ditch | Diversion |
|  |  |  |  |  | + | 07094400 - Canon City Water Works | Diversion |
|  |  |  |  |  | + | CO0001 - City Of Florence | Diversion |
|  |  |  |  |  | + | 09115000 - Larkspur Ditch at Marshall Pass | Diversion |
|  |  |  |  |  | + | 07096530 - Minnequa Canal | Diversion |
|  |  |  |  |  | + | CO0018 - Pbww Municipal Outlet | Diversion |
|  |  |  |  |  | + | 07007090 - Pueblo Reservoir | Change in Storage |
|  |  |  |  |  | - | CO0019 - Pueres Exchange Release | Diversion |
|  |  |  |  |  | + | CO0020 - Pueres Exchange/apod Storage | Diversion |
|  |  |  |  |  | + | CO0027 - South Canon Ditch | Diversion |
| Arkansas | 11020005 | Upper Arkansas- Lake Meredith. Colorado. | 07099400 | ARKANSAS RIVER ABOVE PUEBLO | + | 07099400 - Arkansas R ab Pueblo | Observed |
|  |  |  |  |  | + | 07091500 - Arkansas R at Salida | Combined Adjustments |
|  |  |  |  |  | + | 07099375 - Bessemer Ditch | Diversion |
|  |  |  |  |  | + | 07095900 - Canon City Hydraulic | Diversion |
|  |  |  |  |  | + | 07096100 - Canon City Oil Creek Ditch | Diversion |
|  |  |  |  |  | + | 07094400 - Canon City Water Works | Diversion |
|  |  |  |  |  | + | CO0001 - City Of Florence | Diversion |
|  |  |  |  |  | + | 09115000 - Larkspur Ditch at Marshall Pass | Diversion |
|  |  |  |  |  | + | 07096530 - Minnequa Canal | Diversion |
|  |  |  |  |  | + | CO0018 - Pbww Municipal Outlet | Diversion |
|  |  |  |  |  | + | 07007090 - Pueblo Reservoir | Change in Storage |
|  |  |  |  |  | - | CO0019 - Pueres Exchange Release | Diversion |
|  |  |  |  |  | + | CO0020 - Pueres Exchange/apod Storage | Diversion |
|  |  |  |  |  | + | CO0027 - South Canon Ditch | Diversion |
| Arkansas | 11020005 | Upper Arkansas- Lake Meredith. Colorado. | 07111000 | HUERFANO RIVER NEAR REDWING | no adjustments |  |  |
| Arkansas | 11020005 | Upper Arkansas- Lake Meredith. Colorado. | 07114000 | CUCHARAS RIVER AT BOYD RANCH NR LA VETA | no adjustments |  |  |
| Arkansas | 11020006 | Huerfano. Colorado. | 07111000 | HUERFANO RIVER NEAR REDWING | no adjustments |  |  |
| Arkansas | 11020006 | Huerfano. Colorado. | 07114000 | CUCHARAS RIVER AT BOYD RANCH NR LA VETA | no adjustments |  |  |
| Arkansas | 11020009 | Upper Arkansas- John Martin Reservoir. Colorado, Kansas | 07099400 | ARKANSAS RIVER ABOVE PUEBLO | + | 07099400 - Arkansas R ab Pueblo | Observed |
|  |  |  |  |  | + | 07091500 - Arkansas R at Salida | Combined Adjustments |
|  |  |  |  |  | + | 07099375 - Bessemer Ditch | Diversion |
|  |  |  |  |  | + | 07095900 - Canon City Hydraulic | Diversion |
|  |  |  |  |  | + | 07096100 - Canon City Oil Creek Ditch | Diversion |
|  |  |  |  |  | + | 07094400 - Canon City Water Works | Diversion |
|  |  |  |  |  | + | CO0001 - City Of Florence | Diversion |
|  |  |  |  |  | + | 09115000 - Larkspur Ditch at Marshall Pass | Diversion |
|  |  |  |  |  | + | 07096530 - Minnequa Canal | Diversion |
|  |  |  |  |  | + | CO0018 - Pbww Municipal Outlet | Diversion |
|  |  |  |  |  | + | 07007090 - Pueblo Reservoir | Change in Storage |
|  |  |  |  |  | - | CO0019 - Pueres Exchange Release | Diversion |
|  |  |  |  |  | + | CO0020 - Pueres Exchange/apod Storage | Diversion |
|  |  |  |  |  | + | CO0027 - South Canon Ditch | Diversion |
| Arkansas | 11020009 | Upper Arkansas- John Martin Reservoir. Colorado, Kansas | 07111000 | HUERFANO RIVER NEAR REDWING | no adjustments |  |  |
| Arkansas | 11020009 | Upper Arkansas- John Martin Reservoir. Colorado, Kansas | 07114000 | CUCHARAS RIVER AT BOYD RANCH NR LA VETA | no adjustments |  |  |
| Arkansas | 11020009 | Upper Arkansas- John Martin Reservoir. Colorado, Kansas | 07124500 | PURGATOIRE RIVER AT TRINIDAD | + | 07124500 - Trinidad Lake Inflow | Observed |
|  |  |  |  |  | + | 07007100 - Trinidad Lake | Change in Storage |
| Arkansas | 11020010 | Purgatoire. Colorado, New Mexico. | 07124500 | PURGATOIRE RIVER AT TRINIDAD | + | 07124500 - Trinidad Lake Inflow | Observed |
|  |  |  |  |  | + | 07007100 - Trinidad Lake | Change in Storage |
| Rio Grande | 13010001 | Rio Grande Headwaters. Colorado. | 08220000 | RIO GRANDE NEAR DEL NORTE | + | 08220000 - Rio Grande nr Del Norte | Observed |
|  |  |  |  |  | + | 08219000 - Beaver Reservoir | Change in Storage |
|  |  |  |  |  | - | 09341000 - Treasure Pass Ditch | Diversion |
|  |  |  |  |  | + | 08008170 - Continental Reservoir | Change in Storage |
|  |  |  |  |  | + | 08008150 - Santa Maria Reservoir | Change in Storage |
|  |  |  |  |  | - | CO0029 - Tabor Ditch | Diversion |
|  |  |  |  |  | - | CO0037 - Williams Creek-Squaw Pass Ditch | Diversion |
|  |  |  |  |  | - | 09352000 - Pine River Weminuche Pass Ditch | Diversion |
|  |  |  |  |  | + | 08008130 - Rio Grande Reservoir | Change in Storage |
|  |  |  |  |  | - | CO0036 - Weminuche Pass Ditch | Diversion |
| Rio Grande | 13010002 | Alamosa-Trinchera. Colorado, New Mexico. | 08236000 | ALAMOSA CREEK ABOVE TERRACE RESERVOIR | no adjustments |  |  |
| Rio Grande | 13010002 | Alamosa-Trinchera. Colorado, New Mexico. | 08240500 | TRINCHERA CK | no adjustments |  |  |
| Rio Grande | 13010002 | Alamosa-Trinchera. Colorado, New Mexico. | 08241500 | SANGRE DE CRISTO | + | 08241500 - Sangre De Cristo Ck | Observed |
|  |  |  |  |  | + | CO0012 - Indian Creek Diversion | Diversion |
|  |  |  |  |  | + | 3500570 - Sdc-Trinchera Canal | Diversion |
| Rio Grande | 13010002 | Alamosa-Trinchera. Colorado, New Mexico. | 08242500 | UTE CREEK | no adjustments |  |  |
| Rio Grande | 13010002 | Alamosa-Trinchera. Colorado, New Mexico. | 08250000 | CULEBRA CREEK AT SAN LUIS | + | 08250000 - Culebra Ck at San Luis | Observed |
|  |  |  |  |  | + | 08008140 - Sanchez Reservoir | Change in Storage |
| Rio Grande | 13010004 | Saguache. Colorado. | 08227000 | SAGUACHE CREEK NEAR SAGUACHE, CO | no adjustments |  |  |
| Rio Grande | 13010005 | Conejos. Colorado, New Mexico. | 08246500 | CONEJOS RIVER NEAR MOGOTE | + | 08246500 - Conejos R nr Mogote | Observed |
|  |  |  |  |  | + | 08008120 - Platoro Reservoir | Change in Storage |
| Colorado | 14010001 | Colorado Headwaters. Colorado. | 09019000 | COLORADO RIVER INFLOW TO LAKE GRANBY | + | 09019000 - Colorado R bl Lake Granby | Externally Adjusted-BOR |
|  |  |  |  |  | + | 09010000 - Grand River Ditch at La Poudre Pass | Diversion |
| Colorado | 14010001 | Colorado Headwaters. Colorado. | 09021000 | WILLOW CK INFLOW TO WILLOW CK RESERVOIR | Externally Adjusted |  |  |
| Colorado | 14010001 | Colorado Headwaters. Colorado. | 09038500 | WILLIAMS FORK BLW WILLIAMS FORK RESERVOIR | + | 09038500 - Williams Fk bl Williams Fk Reservoir | Observed |
|  |  |  |  |  | + | CO0041 - August P Gumlick Tunnel | Diversion |
|  |  |  |  |  | + | 0937300 - Big Lake Ditch | Diversion |
|  |  |  |  |  | + | 09009150 - Williams Fork Reservoir | Change in Storage |
| Colorado | 14010001 | Colorado Headwaters. Colorado. | 09070500 | COLORADO RIVER NEAR DOTSERO | + | 09070500 - Colorado R nr Dotsero | Observed |
|  |  |  |  |  | + | 09013000 - Alva B. Adams Tunnel at East Portal | Diversion |
|  |  |  |  |  | + | 0937300 - Big Lake Ditch | Diversion |
|  |  |  |  |  | + | 09009030 - Green Mountain Reservoir | Change in Storage |
|  |  |  |  |  | + | 09009020 - Dillon Reservoir | Change in Storage |
|  |  |  |  |  | + | 06702400 - Harold D. Roberts Tunnel Near Grant | Diversion |
|  |  |  |  |  | + | 09042000 - Hoosier Pass Tunnel Near Alma | Diversion |
|  |  |  |  |  | + | 09061500 - Columbine Ditch | Diversion |
|  |  |  |  |  | + | CO0006 - Ewing Ditch | Diversion |
|  |  |  |  |  | + | 09009040 - Homestake Reservoir | Change in Storage |
|  |  |  |  |  | + | 07081899 - Homestake Tunnel | Diversion |
|  |  |  |  |  | + | CO0040 - Wurtz Ditch | Diversion |
|  |  |  |  |  | + | 09010000 - Grand River Ditch at La Poudre Pass | Diversion |
|  |  |  |  |  | + | 09009060 - Lake Granby | Change in Storage |
|  |  |  |  |  | + | 09022500 - Moffat Water Tunnel at East Portal | Diversion |
|  |  |  |  |  | + | 09014500 - Shadow Mountain Reservoir | Change in Storage |
|  |  |  |  |  | + | 09009150 - Williams Fork Reservoir | Change in Storage |
|  |  |  |  |  | + | 09009160 - Willow Creek Reservoir | Change in Storage |
|  |  |  |  |  | + | 09041395 - Wolford Mountain Reservoir | Change in Storage |
| Colorado | 14010002 | Blue. Colorado. | 09057500 | BLUE RIVER INFLOW TO GREEN MOUNTAIN RES | + | 09057500 - Blue R bl Green Mountain Reservoir | Observed |
|  |  |  |  |  | + | 09009030 - Green Mountain Reservoir | Change in Storage |
|  |  |  |  |  | + | 09009020 - Dillon Reservoir | Change in Storage |
|  |  |  |  |  | + | 06702400 - Harold D. Roberts Tunnel Near Grant | Diversion |
|  |  |  |  |  | + | 09042000 - Hoosier Pass Tunnel Near Alma | Diversion |
| Colorado | 14010003 | Eagle. Colorado. | 09070000 | EAGLE RIVER BELOW GYPSUM | + | 09070000 - Eagle R bl Gypsum | Observed |
|  |  |  |  |  | + | 09061500 - Columbine Ditch | Diversion |
|  |  |  |  |  | + | CO0006 - Ewing Ditch | Diversion |
|  |  |  |  |  | + | 09009040 - Homestake Reservoir | Change in Storage |
|  |  |  |  |  | + | 07081899 - Homestake Tunnel | Diversion |
|  |  |  |  |  | + | CO0040 - Wurtz Ditch | Diversion |
| Colorado | 14010004 | Roaring Fork. Colorado. | 09085000 | ROARING FORK AT GLENWOOD SPRINGS | + | 09085000 - Roaring Fk at Glenwood Springs | Observed |
|  |  |  |  |  | + | 07081900 - Boustead Tunnel | Diversion |
|  |  |  |  |  | + | 09077500 - Busk Ivanhoe Tunnel | Diversion |
|  |  |  |  |  | + | 09009110 - Ruedi Reservoir | Change in Storage |
|  |  |  |  |  | + | CO0033 - Twin Lakes Tunnel | Diversion |
| Colorado | 14010005 | Colorado Headwaters-Plateau. Colorado. | 09095500 | COLORADO RIVER NEAR CAMEO |  |  |  |
| Gunnison | 14020001 | East-Taylor. Colorado. | 09109209 | TAYLOR RIVER BELOW TAYLOR PARK RESERVOIR | Externally Adjusted-BOR |  |  |
| Gunnison | 14020001 | East-Taylor. Colorado. | 09112500 | EAST RIVER AT ALMONT | no adjustments |  |  |
| Gunnison | 14020002 | Upper Gunnison. Colorado. | 09114500 | GUNNISON RIVER NEAR GUNNISON, CO | + | 09114500 - Gunnison R Near Gunnison | Observed |
|  |  |  |  |  | + | 09009120 - Taylor Park Reservoir | Change in Storage |
| Gunnison | 14020002 | Upper Gunnison. Colorado. | 09124500 | LAKE FORK AT GATEVIEW, CO | no adjustments |  |  |
| Gunnison | 14020003 | Tomichi. Colorado. | 09119000 | TOMICHI CREEK AT GUNNISON, CO | no adjustments |  |  |
| Gunnison | 14020004 | North Fork Gunnison. Colorado. | 09132500 | NORTH FORK GUNNISON R NR SOMERSET | + | 09132500 - NF Gunnison R nr Somerset | Observed |
|  |  |  |  |  | + | 09009100 - Paonia Reservoir | Change in Storage |
| Gunnison | 14020005 | Lower Gunnison. Colorado. | 09152500 | GUNNISON RIVER NR GRAND JUNCTION | + | 09152500 - Gunnison R nr Grand Junction | Observed |
|  |  |  |  |  | + | 09009010 - Blue Mesa Reservoir | Change in Storage |
|  |  |  |  |  | + | 09126000 - Crystal Reservoir | Change in Storage |
|  |  |  |  |  | + | 09127999 - Gunnison Tunnel | Diversion |
|  |  |  |  |  | + | 09009080 - Morrow Point Reservoir | Change in Storage |
|  |  |  |  |  | + | 09009100 - Paonia Reservoir | Change in Storage |
|  |  |  |  |  | + | 09147022 - Ridgway Reservoir | Change in Storage |
|  |  |  |  |  | + | 09125800 - Silverjack Reservoir | Change in Storage |
|  |  |  |  |  | + | 09009120 - Taylor Park Reservoir | Change in Storage |
| Gunnison | 14020006 | Uncompahange. Colorado. | 09147500 | UNCOMPAHGRE RIVER AT COLONA | + | 09147500 - Uncompahgre R at Colona | Observed |
|  |  |  |  |  | + | 09147022 - Ridgway Reservoir | Change in Storage |
| San Juan/Dolores | 14030002 | Upper Dolores. Colorado. | 09169000 | DOLORES RIVER BELOW MCPHEE RESERVOIR | Externally Adjusted-BOR |  |  |
| San Juan/Dolores | 14030003 | San Miguel. Colorado. | 09172500 | SAN MIGUEL RIVER NEAR PLACERVILLE | no adjustments |  |  |
| Yampa/White | 14050001 | Upper Yampa. Colorado. | 09239500 | YAMPA RIVER AT STEAMBOAT SPRINGS | + | 09239500 - Yampa R at Steamboat Springs | Observed |
|  |  |  |  |  | + | 09237495 - Stagecoach Reservoir nr Oak Creek | Change in Storage |
|  |  |  |  |  | + | YAMRESCO - Yamcolo Reservoir | Change in Storage |
| Yampa/White | 14050001 | Upper Yampa. Colorado. | 09242500 | ELKHEAD RIVER NEAR MILNER |  |  |  |
| Yampa/White | 14050001 | Upper Yampa. Colorado. | 09246200 | ELKHEAD CREEK ABOVE LONG GULCH | no adjustments |  |  |
| Yampa/White | 14050002 | Lower Yampa. Colorado. | 09251000 | YAMPA RIVER NEAR MAYBELL | + | 09251000 - Yampa R nr Maybell | Observed |
|  |  |  |  |  | + | 09237495 - Stagecoach Reservoir nr Oak Creek | Change in Storage |
|  |  |  |  |  | + | YAMRESCO - Yamcolo Reservoir | Change in Storage |
| Yampa/White | 14050003 | Little Snake. Colorado. | 09260000 | LITTLE SNAKE RIVER NEAR LILY | + | 09260000 - Little Snake R nr Lily | Observed |
|  |  |  |  |  | + | WY0001 - City Of Cheyenne Tunnel | Diversion |
| Yampa/White | 14050005 | Upper White. Colorado. | 09304500 | WHITE RIVER NEAR MEEKER | no adjustments |  |  |
| San Juan/Dolores | 14080101 | Upper San Juan. Colorado. | 09346400 | SAN JUAN RIVER NEAR CARRACAS | + | 09346400 - San Juan R nr Carracas | Observed |
|  |  |  |  |  | + | 08284160 - Azotea Tunnel | Diversion |
| San Juan/Dolores | 14080101 | Upper San Juan. Colorado. | 09353500 | LOS PINOS RIVER NEAR BAYFIELD | Externally Adjusted-BOR |  |  |
| San Juan/Dolores | 14080102 | Piedra. Colorado. | 09349800 | PIEDRA RIVER NEAR ARBOLES | no adjustments |  |  |
| San Juan/Dolores | 14080104 | Animas. Colorado. | 09361500 | ANIMAS RIVER AT DURANGO | no adjustments |  |  |
| San Juan/Dolores | 14080104 | Animas. Colorado. | 09363100 | FLORIDA RIVER BELOW LEMON RESERVOIR NR DURANGO | Externally Adjusted-BOR |  |  |
| San Juan/Dolores | 14080105 | Middle San Juan. Colorado. | 09365500 | LA PLATA RIVER AT HESPERUS | no adjustments |  |  |
| San Juan/Dolores | 14080107 | Mancos. Colorado. | 09370500 | MANCOS RIVER NEAR MANCOS | Externally Adjusted-CBRFC |  |  |

# **Appendix B – Station Assignments by HUC**

The station assignments by HUC shown in this appendix are included in the “Combined Inputs” worksheet of the control file. The following list was created on June 30, 2015 but may become out-of-date as CWCB and DWR revise the Colorado SWSI analysis.

| **HUC8** | **HUC Name** | **Data Type** | **ID** | **Station Name** |
| --- | --- | --- | --- | --- |
| 10190003 | Middle South Platte-Cherry Creek | ForecastedNaturalFlow | 06707500 | SOUTH PLATTE RIVER AT SOUTH PLATTE |
| 10190003 | Middle South Platte-Cherry Creek | ForecastedNaturalFlow | 06710385 | BEAR CREEK ABV EVERGREEN |
| 10190003 | Middle South Platte-Cherry Creek | ForecastedNaturalFlow | 06719505 | CLEAR CREEK AT GOLDEN |
| 10190003 | Middle South Platte-Cherry Creek | ForecastedNaturalFlow | 06724000 | SAINT VRAIN CREEK AT LYONS |
| 10190003 | Middle South Platte-Cherry Creek | ForecastedNaturalFlow | 06727000 | BOULDER CREEK NEAR ORODELL |
| 10190003 | Middle South Platte-Cherry Creek | ForecastedNaturalFlow | 06729500 | SOUTH BOULDER CK NR ELDORADO SPRINGS, CO |
| 10190003 | Middle South Platte-Cherry Creek | ForecastedNaturalFlow | 06738000 | BIG THOMPSON R AT MOUTH, NR DRAKE, CO |
| 10190003 | Middle South Platte-Cherry Creek | ForecastedNaturalFlow | 06752000 | CACHE LA POUDRE R AT CANYON MOUTH |
| 10190003 | Middle South Platte-Cherry Creek | ReservoirStorage | 06016020 | BARR LAKE |
| 10190003 | Middle South Platte-Cherry Creek | ReservoirStorage | 06016230 | MILTON RESERVOIR |
| 10190003 | Middle South Platte-Cherry Creek | ReservoirStorage | 06016280 | STANDLEY RESERVOIR |
| 10190003 | Middle South Platte-Cherry Creek | ReservoirStorage | 06016370 | HORSECREEK RESERVOIR |
| 10190003 | Middle South Platte-Cherry Creek | NaturalFlow | 06707500 | SOUTH PLATTE RIVER AT SOUTH PLATTE |
| 10190003 | Middle South Platte-Cherry Creek | NaturalFlow | 06710385 | BEAR CREEK ABV EVERGREEN |
| 10190003 | Middle South Platte-Cherry Creek | NaturalFlow | 06719505 | CLEAR CREEK AT GOLDEN |
| 10190003 | Middle South Platte-Cherry Creek | NaturalFlow | 06724000 | SAINT VRAIN CREEK AT LYONS |
| 10190003 | Middle South Platte-Cherry Creek | NaturalFlow | 06727000 | BOULDER CREEK NEAR ORODELL |
| 10190003 | Middle South Platte-Cherry Creek | NaturalFlow | 06729500 | SOUTH BOULDER CK NR ELDORADO SPRINGS, CO |
| 10190003 | Middle South Platte-Cherry Creek | NaturalFlow | 06738000 | BIG THOMPSON R AT MOUTH, NR DRAKE, CO |
| 10190003 | Middle South Platte-Cherry Creek | NaturalFlow | 06752000 | CACHE LA POUDRE R AT CANYON MOUTH |
| 10180001 | North Platte Headwaters | ForecastedNaturalFlow | 06620000 | NORTH PLATTE R NR NORTHGATE |
| 10180001 | North Platte Headwaters | NaturalFlow | 06620000 | NORTH PLATTE R NR NORTHGATE |
| 10190001 | South Platte Headwater | ForecastedNaturalFlow | 06695500 | ELEVENMILE CANYON RESV INFLOW |
| 10190001 | South Platte Headwater | ReservoirStorage | 06016010 | ANTERO RESERVOIR |
| 10190001 | South Platte Headwater | ReservoirStorage | 06016100 | ELEVENMILE CANYON RESERVOIR |
| 10190001 | South Platte Headwater | ReservoirStorage | 16016025 | SPINNEY MOUNTAIN RESERVOIR |
| 10190001 | South Platte Headwater | NaturalFlow | 06695500 | ELEVENMILE CANYON RE NEAR LAKE GEORGE |
| 10190002 | Upper South Platte | ForecastedNaturalFlow | 06707500 | SOUTH PLATTE RIVER AT SOUTH PLATTE |
| 10190002 | Upper South Platte | ForecastedNaturalFlow | 06710385 | BEAR CREEK ABV EVERGREEN |
| 10190002 | Upper South Platte | ReservoirStorage | 06016080 | CHEESMAN LAKE |
| 10190002 | Upper South Platte | ReservoirStorage | 09009020 | DILLON RESERVOIR |
| 10190002 | Upper South Platte | NaturalFlow | 06707500 | SOUTH PLATTE RIVER AT SOUTH PLATTE |
| 10190002 | Upper South Platte | NaturalFlow | 06710385 | BEAR CREEK ABV EVERGREEN |
| 10190004 | Clear | ForecastedNaturalFlow | 06719505 | CLEAR CREEK AT GOLDEN |
| 10190004 | Clear | NaturalFlow | 06719505 | CLEAR CREEK AT GOLDEN |
| 10190005 | St. Vrain | ForecastedNaturalFlow | 06724000 | SAINT VRAIN CREEK AT LYONS |
| 10190005 | St. Vrain | ForecastedNaturalFlow | 06727000 | BOULDER CREEK NEAR ORODELL |
| 10190005 | St. Vrain | ForecastedNaturalFlow | 06729500 | SOUTH BOULDER CK NR ELDORADO SPRINGS, CO |
| 10190005 | St. Vrain | ReservoirStorage | 06016130 | GROSS RESERVOIR |
| 10190005 | St. Vrain | ReservoirStorage | 06016220 | MARSHALL RESERVOIR |
| 10190005 | St. Vrain | ReservoirStorage | 06016260 | BUTTONROCK (RALPH PRICE) RESERVOIR |
| 10190005 | St. Vrain | ReservoirStorage | 06016290 | TERRY RESERVOIR |
| 10190005 | St. Vrain | ReservoirStorage | 06016300 | UNION RESERVOIR |
| 10190005 | St. Vrain | NaturalFlow | 06724000 | SAINT VRAIN CREEK AT LYONS |
| 10190005 | St. Vrain | NaturalFlow | 06727000 | BOULDER CREEK NEAR ORODELL |
| 10190005 | St. Vrain | NaturalFlow | 06729500 | SOUTH BOULDER CK NR ELDORADO SPRINGS, CO |
| 10190006 | Big Thompson | ForecastedNaturalFlow | 06738000 | BIG THOMPSON R AT MOUTH, NR DRAKE, CO |
| 10190006 | Big Thompson | ReservoirStorage | 06016040 | BOYD LAKE |
| 10190006 | Big Thompson | ReservoirStorage | 06016060 | CARTER LAKE |
| 10190006 | Big Thompson | ReservoirStorage | 06016180 | LAKE LOVELAND RESERVOIR |
| 10190006 | Big Thompson | ReservoirStorage | 06016190 | LONE TREE RESERVOIR |
| 10190006 | Big Thompson | ReservoirStorage | 06016200 | MARIANO RESERVOIR |
| 10190006 | Big Thompson | ReservoirStorage | 09009160 | WILLOW CREEK RESERVOIR |
| 10190006 | Big Thompson | ReservoirStorage | 09009060 | LAKE GRANBY |
| 10190006 | Big Thompson | NaturalFlow | 06738000 | BIG THOMPSON R AT MOUTH, NR DRAKE, CO |
| 10190007 | Cache La Poudre | ForecastedNaturalFlow | 06752000 | CACHE LA POUDRE R AT CANYON MOUTH |
| 10190007 | Cache La Poudre | ReservoirStorage | 06016030 | BLACK HOLLOW RESERVOIR |
| 10190007 | Cache La Poudre | ReservoirStorage | 06016050 | CACHE LA POUDRE |
| 10190007 | Cache La Poudre | ReservoirStorage | 06016070 | CHAMBERS LAKE |
| 10190007 | Cache La Poudre | ReservoirStorage | 06016090 | COBB LAKE |
| 10190007 | Cache La Poudre | ReservoirStorage | 06016120 | FOSSIL CREEK RESERVOIR |
| 10190007 | Cache La Poudre | ReservoirStorage | 06016140 | HALLIGAN RESERVOIR |
| 10190007 | Cache La Poudre | ReservoirStorage | 06016150 | HORSETOOTH RESERVOIR |
| 10190007 | Cache La Poudre | ReservoirStorage | 06016310 | WINDSOR RESERVOIR |
| 10190007 | Cache La Poudre | NaturalFlow | 06752000 | CACHE LA POUDRE R AT CANYON MOUTH NEAR FORT COLLINS |
| 10190012 | Middle South Platte-Sterling | ForecastedNaturalFlow | 06707500 | SOUTH PLATTE RIVER AT SOUTH PLATTE |
| 10190012 | Middle South Platte-Sterling | ForecastedNaturalFlow | 06710385 | BEAR CREEK ABV EVERGREEN |
| 10190012 | Middle South Platte-Sterling | ForecastedNaturalFlow | 06719505 | CLEAR CREEK AT GOLDEN |
| 10190012 | Middle South Platte-Sterling | ForecastedNaturalFlow | 06724000 | SAINT VRAIN CREEK AT LYONS |
| 10190012 | Middle South Platte-Sterling | ForecastedNaturalFlow | 06727000 | BOULDER CREEK NEAR ORODELL |
| 10190012 | Middle South Platte-Sterling | ForecastedNaturalFlow | 06729500 | SOUTH BOULDER CK NR ELDORADO SPRINGS, CO |
| 10190012 | Middle South Platte-Sterling | ForecastedNaturalFlow | 06738000 | BIG THOMPSON R AT MOUTH, NR DRAKE, CO |
| 10190012 | Middle South Platte-Sterling | ForecastedNaturalFlow | 06752000 | CACHE LA POUDRE R AT CANYON MOUTH |
| 10190012 | Middle South Platte-Sterling | ReservoirStorage | 06016170 | JULESBURG RESERVOIR |
| 10190012 | Middle South Platte-Sterling | ReservoirStorage | 06016240 | POINT OF ROCKS RESERVOIR |
| 10190012 | Middle South Platte-Sterling | ReservoirStorage | 06016250 | PREWITT RESERVOIR |
| 10190012 | Middle South Platte-Sterling | ReservoirStorage | 06016160 | JACKSON LAKE RESERVOIR |
| 10190012 | Middle South Platte-Sterling | ReservoirStorage | 06016270 | RIVERSIDE RESERVOIR |
| 10190012 | Middle South Platte-Sterling | ReservoirStorage | 06016110 | EMPIRE RESERVOIR |
| 10190012 | Middle South Platte-Sterling | NaturalFlow | 06707500 | SOUTH PLATTE RIVER AT SOUTH PLATTE |
| 10190012 | Middle South Platte-Sterling | NaturalFlow | 06710385 | BEAR CREEK ABV EVERGREEN |
| 10190012 | Middle South Platte-Sterling | NaturalFlow | 06719505 | CLEAR CREEK AT GOLDEN |
| 10190012 | Middle South Platte-Sterling | NaturalFlow | 06724000 | SAINT VRAIN CREEK AT LYONS |
| 10190012 | Middle South Platte-Sterling | NaturalFlow | 06727000 | BOULDER CREEK NEAR ORODELL |
| 10190012 | Middle South Platte-Sterling | NaturalFlow | 06729500 | SOUTH BOULDER CK NR ELDORADO SPRINGS, CO |
| 10190012 | Middle South Platte-Sterling | NaturalFlow | 06738000 | BIG THOMPSON R AT MOUTH, NR DRAKE, CO |
| 10190012 | Middle South Platte-Sterling | NaturalFlow | 06752000 | CACHE LA POUDRE R AT CANYON MOUTH |
| 11020001 | Arkansas Headwaters | ForecastedNaturalFlow | 07091500 | ARKANSAS RIVER AT SALIDA |
| 11020001 | Arkansas Headwaters | ReservoirStorage | 07007020 | CLEAR CREEK RESERVOIR |
| 11020001 | Arkansas Headwaters | ReservoirStorage | 07007110 | TURQUOISE LAKE |
| 11020001 | Arkansas Headwaters | ReservoirStorage | 07007120 | TWIN LAKES RESERVOIR |
| 11020001 | Arkansas Headwaters | ReservoirStorage | 09009040 | HOMESTAKE RESERVOIR |
| 11020001 | Arkansas Headwaters | NaturalFlow | 07091500 | ARKANSAS RIVER AT SALIDA |
| 11020002 | Upper Arkansas | ForecastedNaturalFlow | 07099400 | PUEBLO RESERVOIR INFLOW |
| 11020002 | Upper Arkansas | ReservoirStorage | 07007090 | PUEBLO RESERVOIR |
| 11020002 | Upper Arkansas | NaturalFlow | 07099400 | ARKANSAS RIVER ABOVE PUEBLO |
| 11020005 | Upper Arkansas-Lake Meredith | ForecastedNaturalFlow | 07099400 | ARKANSAS RIVER ABOVE PUEBLO |
| 11020005 | Upper Arkansas-Lake Meredith | ForecastedNaturalFlow | 07111000 | HUERFANO RIVER NEAR REDWING |
| 11020005 | Upper Arkansas-Lake Meredith | ForecastedNaturalFlow | 07114000 | CUCHARAS RIVER AT BOYD RANCH NR LA VETA |
| 11020005 | Upper Arkansas-Lake Meredith | ReservoirStorage | 07007070 | MEREDITH RESERVOIR |
| 11020005 | Upper Arkansas-Lake Meredith | ReservoirStorage | 07007130 | LAKE HENRY |
| 11020005 | Upper Arkansas-Lake Meredith | NaturalFlow | 07099400 | ARKANSAS RIVER ABOVE PUEBLO |
| 11020005 | Upper Arkansas-Lake Meredith | NaturalFlow | 07111000 | HUERFANO RIVER NEAR REDWING |
| 11020005 | Upper Arkansas-Lake Meredith | NaturalFlow | 07114000 | CUCHARAS RIVER AT BOYD RANCH NR LA VETA |
| 11020006 | Huerfano | ForecastedNaturalFlow | 07111000 | HUERFANO RIVER NEAR REDWING |
| 11020006 | Huerfano | ForecastedNaturalFlow | 07114000 | CUCHARAS RIVER AT BOYD RANCH NR LA VETA |
| 11020006 | Huerfano | ReservoirStorage | 07007030 | CUCHARAS RESERVOIR |
| 11020006 | Huerfano | NaturalFlow | 07111000 | HUERFANO RIVER NEAR REDWING |
| 11020006 | Huerfano | NaturalFlow | 07114000 | CUCHARAS RIVER AT BOYD RANCH NR LA VETA |
| 11020009 | Upper Arkansas-John Martin Reservoir | ForecastedNaturalFlow | 07099400 | ARKANSAS RIVER ABOVE PUEBLO |
| 11020009 | Upper Arkansas-John Martin Reservoir | ForecastedNaturalFlow | 07111000 | HUERFANO RIVER NEAR REDWING |
| 11020009 | Upper Arkansas-John Martin Reservoir | ForecastedNaturalFlow | 07114000 | CUCHARAS RIVER AT BOYD RANCH NR LA VETA |
| 11020009 | Upper Arkansas-John Martin Reservoir | ForecastedNaturalFlow | 07124500 | PURGATOIRE RIVER AT TRINIDAD |
| 11020009 | Upper Arkansas-John Martin Reservoir | ReservoirStorage | 07007010 | ADOBE CREEK RESERVOIR |
| 11020009 | Upper Arkansas-John Martin Reservoir | ReservoirStorage | 07007060 | JOHN MARTIN RESERVOIR |
| 11020009 | Upper Arkansas-John Martin Reservoir | NaturalFlow | 07099400 | ARKANSAS RIVER ABOVE PUEBLO |
| 11020009 | Upper Arkansas-John Martin Reservoir | NaturalFlow | 07111000 | HUERFANO RIVER NEAR REDWING |
| 11020009 | Upper Arkansas-John Martin Reservoir | NaturalFlow | 07114000 | CUCHARAS RIVER AT BOYD RANCH NR LA VETA |
| 11020009 | Upper Arkansas-John Martin Reservoir | NaturalFlow | 07124500 | PURGATOIRE RIVER AT TRINIDAD |
| 11020010 | Purgatoire | ForecastedNaturalFlow | 07124500 | PURGATOIRE RIVER AT TRINIDAD |
| 11020010 | Purgatoire | ReservoirStorage | 07007100 | TRINIDAD LAKE |
| 11020010 | Purgatoire | NaturalFlow | 07124500 | PURGATOIRE RIVER AT TRINIDAD |
| 13010001 | Rio Grande Headwaters | ForecastedNaturalFlow | 08220000 | RIO GRANDE NEAR DEL NORTE |
| 13010001 | Rio Grande Headwaters | ReservoirStorage | 08008130 | RIO GRANDE RESERVOIR |
| 13010001 | Rio Grande Headwaters | ReservoirStorage | 08008150 | SANTA MARIA RESERVOIR |
| 13010001 | Rio Grande Headwaters | ReservoirStorage | 08008170 | CONTINENTAL RESERVOIR |
| 13010001 | Rio Grande Headwaters | NaturalFlow | 08220000 | RIO GRANDE NEAR DEL NORTE |
| 13010002 | Alamosa-Trinchera | ForecastedNaturalFlow | 08236000 | ALAMOSA CREEK ABOVE TERRACE RESERVOIR |
| 13010002 | Alamosa-Trinchera | ForecastedNaturalFlow | 08240500 | TRINCHERA CK |
| 13010002 | Alamosa-Trinchera | ForecastedNaturalFlow | 08241500 | SANGRE DE CRISTO |
| 13010002 | Alamosa-Trinchera | ForecastedNaturalFlow | 08242500 | UTE CREEK |
| 13010002 | Alamosa-Trinchera | ForecastedNaturalFlow | 08250000 | CULEBRA CREEK AT SAN LUIS |
| 13010002 | Alamosa-Trinchera | ReservoirStorage | 08008160 | TERRACE RESERVOIR |
| 13010002 | Alamosa-Trinchera | ReservoirStorage | MTNRESCO | MOUNTAIN HOME |
| 13010002 | Alamosa-Trinchera | NaturalFlow | 08236000 | ALAMOSA CREEK ABOVE TERRACE RESERVOIR |
| 13010002 | Alamosa-Trinchera | NaturalFlow | 08240500 | TRINCHERA CK |
| 13010002 | Alamosa-Trinchera | NaturalFlow | 08241500 | SANGRE DE CRISTO |
| 13010002 | Alamosa-Trinchera | NaturalFlow | 08242500 | UTE CREEK |
| 13010002 | Alamosa-Trinchera | NaturalFlow | 08250000 | CULEBRA CREEK AT SAN LUIS |
| 13010004 | Saguache | ForecastedNaturalFlow | 08227000 | SAGUACHE CREEK NEAR SAGUACHE, CO |
| 13010004 | Saguache | NaturalFlow | 08227000 | SAGUACHE CREEK NEAR SAGUACHE, CO |
| 13010005 | Conejos | ForecastedNaturalFlow | 08246500 | CONEJOS RIVER NEAR MOGOTE |
| 13010005 | Conejos | ReservoirStorage | 08008120 | PLATORO RESERVOIR |
| 13010005 | Conejos | NaturalFlow | 08246500 | CONEJOS RIVER NEAR MOGOTE |
| 14010001 | Colorado Headwaters | ForecastedNaturalFlow | 09070500 | COLORADO RIVER NEAR DOTSERO |
| 14010001 | Colorado Headwaters | ReservoirStorage | 09009150 | WILLIAMS FORK RESERVOIR |
| 14010001 | Colorado Headwaters | ReservoirStorage | 09041395 | WOLFORD MOUNTAIN RESERVOIR |
| 14010001 | Colorado Headwaters | NaturalFlow | 09070500 | COLORADO RIVER NEAR DOTSERO |
| 14010002 | Blue | ForecastedNaturalFlow | 09057500 | BLUE RIVER INFLOW TO GREEN MOUNTAIN RES |
| 14010002 | Blue | ReservoirStorage | 09009030 | GREEN MOUNTAIN RESERVOIR |
| 14010002 | Blue | NaturalFlow | 09057500 | BLUE RIVER INFLOW TO GREEN MOUNTAIN RES |
| 14010003 | Eagle | ForecastedNaturalFlow | 09070000 | EAGLE RIVER BELOW GYPSUM |
| 14010003 | Eagle | NaturalFlow | 09070000 | EAGLE RIVER BELOW GYPSUM |
| 14010004 | Roaring Fork | ForecastedNaturalFlow | 09085000 | ROARING FORK AT GLENWOOD SPRINGS |
| 14010004 | Roaring Fork | ReservoirStorage | 09009110 | RUEDI RESERVOIR |
| 14010004 | Roaring Fork | NaturalFlow | 09085000 | ROARING FORK AT GLENWOOD SPRINGS |
| 14010005 | Colorado Headwaters-Plateau | ForecastedNaturalFlow | 09095500 | COLORADO RIVER NEAR CAMEO |
| 14010005 | Colorado Headwaters-Plateau | ReservoirStorage | 09009140 | VEGA RESERVOIR |
| 14010005 | Colorado Headwaters-Plateau | NaturalFlow | 09095500 | COLORADO RIVER NEAR CAMEO |
| 14020001 | East-Taylor | ForecastedNaturalFlow | 09109209 | TAYLOR R INF TO TAYLOR PARK RESERVOIR |
| 14020001 | East-Taylor | ForecastedNaturalFlow | 09112500 | EAST RIVER AT ALMONT |
| 14020001 | East-Taylor | ReservoirStorage | 09009120 | TAYLOR PARK RESERVOIR |
| 14020001 | East-Taylor | NaturalFlow | 09109209 | TAYLOR RIVER BELOW TAYLOR PARK RESERVOIR |
| 14020001 | East-Taylor | NaturalFlow | 09112500 | EAST RIVER AT ALMONT |
| 14020002 | Upper Gunnison | ForecastedNaturalFlow | 09124500 | LAKE FORK AT GATEVIEW, CO |
| 14020002 | Upper Gunnison | ForecastedNaturalFlow | 09124800 | GUNNISON R INF TO BLUE MESA RESERVOIR |
| 14020002 | Upper Gunnison | ReservoirStorage | 09009010 | BLUE MESA RESERVOIR |
| 14020002 | Upper Gunnison | ReservoirStorage | 09009080 | MORROW POINT RESERVOIR |
| 14020002 | Upper Gunnison | ReservoirStorage | 09009330 | FRUITLAND RESERVOIR |
| 14020002 | Upper Gunnison | ReservoirStorage | 09009340 | CRAWFORD RESERVOIR |
| 14020002 | Upper Gunnison | ReservoirStorage | 09125800 | SILVER JACK RESERVOIR |
| 14020002 | Upper Gunnison | NaturalFlow | 09114500 | GUNNISON RIVER NEAR GUNNISON, CO |
| 14020002 | Upper Gunnison | NaturalFlow | 09124500 | LAKE FORK AT GATEVIEW, CO |
| 14020003 | Tomichi | ForecastedNaturalFlow | 09119000 | TOMICHI CREEK AT GUNNISON, CO |
| 14020003 | Tomichi | ReservoirStorage | 09116500 | VOUGA RESERVOIR NEAR DOYLEVILLE |
| 14020003 | Tomichi | NaturalFlow | 09119000 | TOMICHI CREEK AT GUNNISON, CO |
| 14020004 | North Fork Gunnison | ForecastedNaturalFlow | 09132500 | NORTH FORK GUNNISON R NR SOMERSET |
| 14020004 | North Fork Gunnison | ReservoirStorage | 09009100 | PAONIA RESERVOIR |
| 14020004 | North Fork Gunnison | NaturalFlow | 09132500 | NORTH FORK GUNNISON R NR SOMERSET |
| 14020005 | Lower Gunnison | ForecastedNaturalFlow | 09152500 | GUNNISON RIVER NR GRAND JUNCTION |
| 14020005 | Lower Gunnison | NaturalFlow | 09152500 | GUNNISON RIVER NR GRAND JUNCTION |
| 14020006 | Uncompahgre | ForecastedNaturalFlow | 09147500 | UNCOMPAHGRE RIVER AT COLONA |
| 14020006 | Uncompahgre | ReservoirStorage | 09147022 | RIDGEWAY RESERVOIR |
| 14020006 | Uncompahgre | NaturalFlow | 09147500 | UNCOMPAHGRE RIVER AT COLONA |
| 14030002 | Upper Dolores | ForecastedNaturalFlow | 09169000 | DOLORES RIVER BELOW MCPHEE RESERVOIR |
| 14030002 | Upper Dolores | ReservoirStorage | 09009170 | GROUNDHOG RESERVOIR |
| 14030002 | Upper Dolores | ReservoirStorage | MPHC2000 | MCPHEE RESERVOIR |
| 14030002 | Upper Dolores | NaturalFlow | 09169000 | DOLORES RIVER BELOW MCPHEE RESERVOIR |
| 14030003 | San Miguel | ForecastedNaturalFlow | 09172500 | SAN MIGUEL RIVER NEAR PLACERVILLE |
| 14030003 | San Miguel | NaturalFlow | 09172500 | SAN MIGUEL RIVER NEAR PLACERVILLE |
| 14050001 | Upper Yampa | ForecastedNaturalFlow | 09239500 | YAMPA RIVER AT STEAMBOAT SPRINGS |
| 14050001 | Upper Yampa | ForecastedNaturalFlow | 09242500 | ELK RIVER NEAR MILNER, CO |
| 14050001 | Upper Yampa | ForecastedNaturalFlow | 09246200 | ELKHEAD CREEK ABOVE LONG GULCH |
| 14050001 | Upper Yampa | ReservoirStorage | 09237495 | STAGECOACH RESERVOIR NR OAK CREEK |
| 14050001 | Upper Yampa | ReservoirStorage | YAMRESCO | YAMCOLO RESERVOIR |
| 14050001 | Upper Yampa | NaturalFlow | 09239500 | YAMPA RIVER AT STEAMBOAT SPRINGS |
| 14050001 | Upper Yampa | NaturalFlow | 09242500 | ELKHEAD RIVER NEAR MILNER |
| 14050001 | Upper Yampa | NaturalFlow | 09246200 | ELKHEAD CREEK ABOVE LONG GULCH |
| 14050002 | Lower Yampa | ForecastedNaturalFlow | 09251000 | YAMPA RIVER NEAR MAYBELL |
| 14050002 | Lower Yampa | NaturalFlow | 09251000 | YAMPA RIVER NEAR MAYBELL |
| 14050003 | Little Snake | ForecastedNaturalFlow | 09260000 | LITTLE SNAKE RIVER NEAR LILY |
| 14050003 | Little Snake | NaturalFlow | 09260000 | LITTLE SNAKE RIVER NEAR LILY |
| 14050005 | Upper White | ForecastedNaturalFlow | 09304500 | WHITE RIVER NEAR MEEKER |
| 14050005 | Upper White | NaturalFlow | 09304500 | WHITE RIVER NEAR MEEKER |
| 14080101 | Upper San Juan | ForecastedNaturalFlow | 09346400 | SAN JUAN RIVER NEAR CARRACAS |
| 14080101 | Upper San Juan | ForecastedNaturalFlow | 09353500 | LOS PINOS RIVER NEAR BAYFIELD |
| 14080101 | Upper San Juan | ReservoirStorage | 09009130 | VALLECITO RESERVOIR |
| 14080101 | Upper San Juan | NaturalFlow | 09346400 | SAN JUAN RIVER NEAR CARRACAS |
| 14080101 | Upper San Juan | NaturalFlow | 09353500 | LOS PINOS RIVER NEAR BAYFIELD |
| 14080102 | Piedra | ForecastedNaturalFlow | 09349800 | PIEDRA RIVER NEAR ARBOLES |
| 14080102 | Piedra | NaturalFlow | 09349800 | PIEDRA RIVER NEAR ARBOLES |
| 14080104 | Animas | ForecastedNaturalFlow | 09361500 | ANIMAS RIVER AT DURANGO |
| 14080104 | Animas | ForecastedNaturalFlow | 09363100 | FLORIDA RIVER INFLOW TO LEMON RESERVOIR |
| 14080104 | Animas | ReservoirStorage | 09009070 | LEMON RESERVOIR |
| 14080104 | Animas | NaturalFlow | 09361500 | ANIMAS RIVER AT DURANGO |
| 14080104 | Animas | NaturalFlow | 09363100 | FLORIDA RIVER BELOW LEMON RESERVOIR NR DURANGO |
| 14080105 | Middle San Juan | ForecastedNaturalFlow | 09365500 | LA PLATA RIVER AT HESPERUS |
| 14080105 | Middle San Juan | ReservoirStorage | LONRESCO | LONG HOLLOW RESERVOIR |
| 14080105 | Middle San Juan | NaturalFlow | 09365500 | LA PLATA RIVER AT HESPERUS |
| 14080107 | Mancos | ForecastedNaturalFlow | 09370500 | MANCOS RIVER NEAR MANCOS |
| 14080107 | Mancos | ReservoirStorage | 09009050 | JACKSON GULCH RESERVOIR |
| 14080107 | Mancos | NaturalFlow | 09370500 | MANCOS RIVER NEAR MANCOS |

# **Appendix C – Colorado SWSI Automation Tool Workflow Details**

## Control File

An Excel workbook (CO-SWSI-Control.xlsx) is used to control the Colorado SWSI analysis. A description of the worksheets follows:

* Hist: History of the workbook. This worksheet should be used to note major changes to the control file or the Colorado SWSI Automation Tool program version.
* Notes: Descriptions of each worksheet
* Config: Worksheet where the configuration properties needed to run TSTool are specified. User-entered values are highlighted in blue. Values that are automatically calculated are highlighted in gray. The configuration properties are named to help TSTool retrieve the values.
* Combined Inputs: This worksheet defines the stations that are used in the HUC and the Basin analyses.
  + For reservoir storage, Datastore can be NrcsAwdb or ColoradoWaterSMS, while Datastore 2 can be ColoradoWaterHBGuest.
  + For natural flows, Datastore should be NrcsAwdb. For observed flow option, Datastore 2 should be ColoradoWaterHBGuest while Datastore3 can be ColoradoWaterSMS.
* FlowDataFill: Worksheet that specifies automated filling to be done on the natural flow stations.
* ReservoirDataFill: Worksheet that specifies automated filling to be done on the reservoirs.
* NatFlowCalcs: Scratch worksheet for natural flow calculations, to be modified monthly as necessary when data are not available from web services.
* Overrides: User-determined values that override any existing data.
* Lookup Tables: Tables of information needed by TSTool.
  + Month\_Table is used to loop on months and to specify when different components are used in the SWSI analysis.
  + RawDataChecks Style Table and RawDataChecks Condition Table are used to highlight missing counts > 0 in red in RawDataChecks.xlsx.
  + Data Fill Date Options are used to provide validation lists for Fill Start Date and Fill End Date on the FlowDataFill worksheet.
  + The Reservoir Start Fill Methods and Reservoir End Fill Methods are used to provide validation lists on the ReservoirDataFill worksheet.
  + The Data Types List is used to provide validation lists on the Overrides worksheet.
  + The DataFlags Style Table and DataFlags Condition Table are used to highlight cells based on the data flag in the cell comment in the Input\_Data\_Final.xlsx.
* HUC\_Reference: List of HUC ids and names for user reference only (not used by the program).

## TSTool Processing

There are five conceptual processing steps in the TSTool SWSI Automation Tool:

* Data download
* Data checks and filling
* Creation of SWSI components
* SWSI calculation and products
* Optional processes

This appendix provides an overview of each component, along with detailed explanations of the TSTool processes within each component. In the process flowcharts (**Figure 8**, **Figure 9**, **Figure 10**, **Figure 12**, and **Figure 13**):

* “TS Alias” refers to the time series aliases used by TSTool to identify time series.
* “TS Properties” are time series properties used by TSTool during processing and for outputs.
* “Data Flags” are used by TSTool to indicate manipulation of data values.

The process flow charts are also provided in PowerPoint format in the \_Documents\ \_SWSI-TSTool-Guide directory.

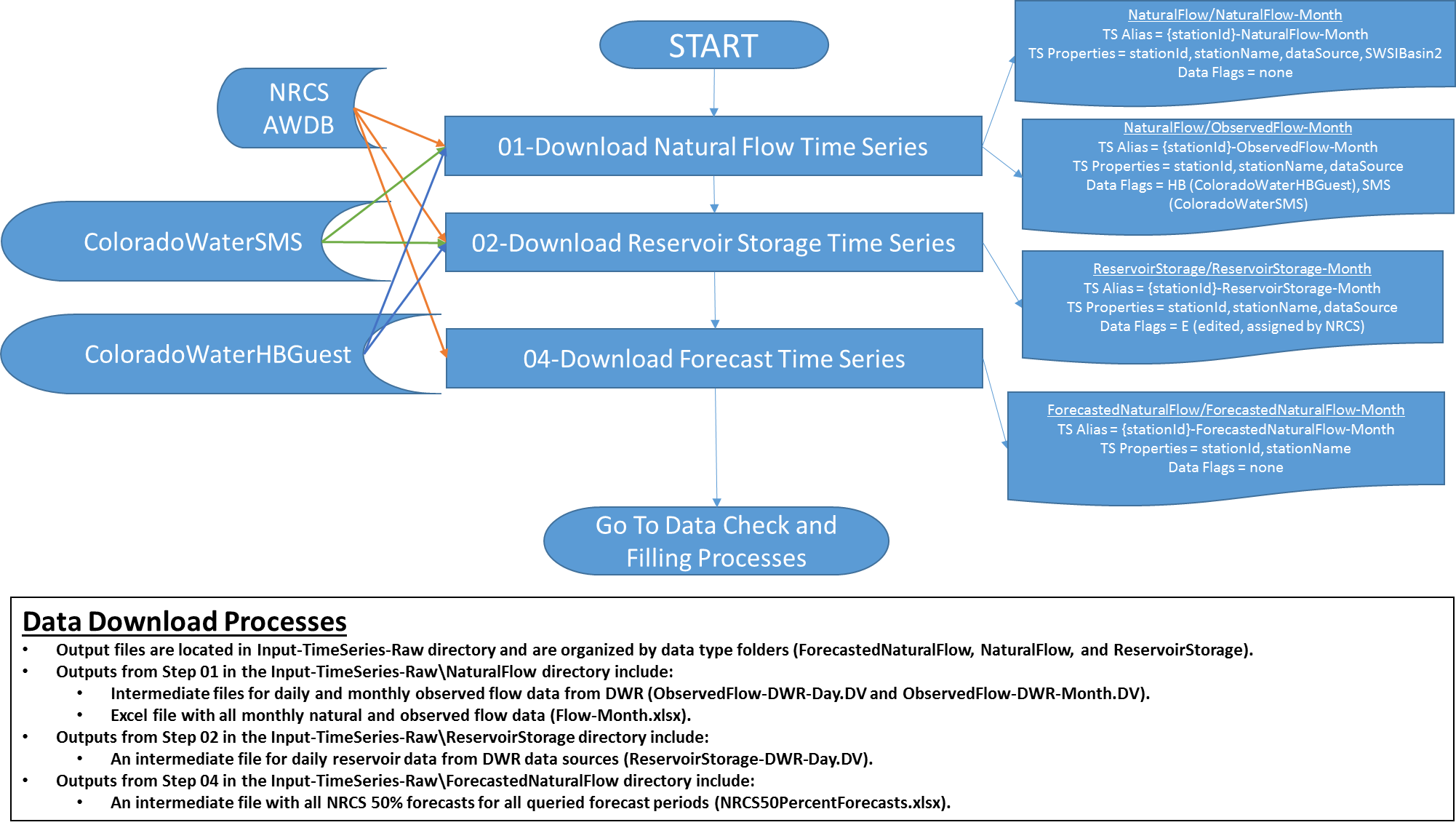


Figure . Flowchart of the Data Download Processes

**01 - Download Natural Flow Time Series.TSTool**

**Purpose:**

* Automatically download monthly “observed” natural flows for the full period of data availability for NaturalFlow stations identified on the Combined Inputs worksheet where the “Include” column is set to “YES”. These data are used for the previous month’s streamflow and forecasted runoff components in the Colorado SWSI.
* If needed, automatically download monthly observed (i.e., gaged) streamflows for the full period of data availability for NaturalFlow stations identified on the Combined Inputs worksheet where the “Include” column is set to “YES-OBS”. These data are used for the previous month’s streamflow component in the Colorado SWSI in rare cases when the required natural flow data are not available. If this option is applied, observed flow data are used for the previous month’s streamflow component for all periods (i.e., historical period, recent period, and current period).

**Workflow Details:**

* First, the command file checks to see if the user has specified that any observed flow data be used in the Colorado SWSI analysis. This case is signified by NaturalFlow stations on the Combined Inputs worksheet in the control file that have the “Include” column set to “YES-OBS”.
* If the observed flow case exists, the command file checks affected HUCs to see whether all natural flow stations in the affected HUC have been assigned to use observed flow data. If not, a warning message is written out to the user. The user can choose to ignore the warnings or to set all stations to use observed flow data.
* Natural flow data are downloaded for all NaturalFlow stations on the Combined Inputs worksheet where the “Include” column is set to “YES”. Natural flow data are downloaded even in the “observed flow” case because the data are used for the forecasted runoff component.
  + The command file is set up to use the NRCS AWDB web service to obtain monthly natural streamflow volumes (using the SRVO data type).
  + Stations can be associated with more than one HUC, so a unique station list is created as a table.
  + Station identifiers, station names, and the data source are set as properties to support SWSI processing and output products.
  + A time series property (SWSI Basin2) is set to differentiate stations in the Rio Grande basin from stations in other basins – this property is used in step 30 when accumulating monthly natural flows over the forecast period. Stations in the Rio Grande basin are accumulated through September, while stations in other basins are accumulated through July.
  + Automated checks are included to ensure that the number of time series matches the number of stations, and to warn the user about any time series that are completely missing.
  + The monthly natural flow data are written to a DateValue file.
* Observed flow data are downloaded for all NaturalFlow stations on the Combined Inputs worksheet where the “Include” column is set to “YES-OBS”. These data are used only for the previous month’s streamflow component.
  + If no stations are set to use observed flow data, this set of commands is bypassed and no observed flow output file is written.
  + The command file is set up to use the ColoradoWaterSMS and ColoradoWaterHBGuest web services to obtain historical streamflow volumes (using the DISCHRG and Streamflow data types, respectively). Typically, data from these two sources must be merged for a complete record.
  + The command files were set up assuming that all stations assigned to use observed flows will have data available from the ColoradoWaterHBGuest web service. Additional data can optionally be obtained using the ColoradoWaterSMS web service.
  + Stations can be associated with more than one HUC, so unique station lists are created as tables for each web service.
  + Processing for the ColoradoWaterSMS web service is done first.
    - The ColoradoWaterSMS web service returns daily streamflow data.
    - Calls to this service will fail if the request includes a start date before January 1, 2000. Therefore, the data call uses a start date of January 1, 2000 which is set in the control file as the SMSInputPeriodStartDayText property.
    - Station information for the ColoradoWaterSMS web service is specified in the “Datastore3” columns on the Combined Inputs worksheet.
    - Station identifiers, station names, and the data source are set as properties to support SWSI processing and output products.
    - Calls to the ColoradoWaterSMS web service do not automatically set units on the returned time series. Therefore, a “SetTimesSeriesProperty” command is used to set the units to cfs.
    - The data are converted to ac-ft/day.
    - The time series are converted from daily to monthly time series with units of ac\_ft.
    - The ColoradoWaterSMS and ColoradoWaterHBGuest web services in some cases use different location IDs for the same station. For example, for the Mancos near Mancos station, the ColoradoWaterSMS service uses a station identifier of MANMANCO while the ColoradoWaterHBGuest web service uses the identifier of 09370500. To anticipate this issue, the aliases for time series returned by the ColoradoWaterSMS web service are changed to use station identifiers as the location IDs.
    - Automated checks are included to ensure that the number of time series matches the number of stations, and to warn the user about any time series that are completely missing.
  + Processing for the ColoradoWaterHBGuest web service is done second.
    - The ColoradoWaterHBGuest web service returns monthly streamflow data.
    - Station information for the ColoradoWaterHBGuest web service is specified in the “Datastore2” columns on the Combined Inputs worksheet.
    - Station identifiers, station names, and the data source are set as properties to support SWSI processing and output products.
    - Automated checks are included to ensure that the number of time series matches the number of stations, and to warn the user about any time series that are completely missing.
  + Data from the ColoradoWaterSMS and ColoradoWaterHBGuest web services are merged to produce continuous monthly time series for each station.
    - HydroBase data are given precedence since these data are published values.
    - Data flags are set to “HB” or “SMS” to indicate the data source.
    - After merging, a “Scale” time series is used with a multiplier of 1 to reset the units from ACFT to “ac\_ft,” consistent with other data types used later on for the SWSI analysis.
    - The daily and monthly observed flow data are written to DateValue files.
  + The monthly natural and observed flow data are written to an Excel file called “Flow-Month.xlsx.”
* At times (for example, on holidays), the NRCS AWDB web services are down. If no data are returned, the user should check the NRCS website and try again when the services are running.

**02 - Download Reservoir Storage Time Series.TSTool**

**Purpose:**

* Automatically produce end-of-month reservoir time series for the full period of data availability for ReservoirStorage stations identified on the Combined Inputs worksheet.

**Workflow Details:**

* The command file is set up currently to use two data sources:
  + The NRCS AWDB web service.
  + The DWR ColoradoWaterSMS and ColoradoWaterHBGuest web services. If data are being obtained from DWR, Datastore 1 in the control file should be specified as ColoradoWaterSMS and Datastore 2 in the control file should be specified as ColoradoWaterHBGuest. The process will run if ColoradoWaterSMS is specified as Datastore 1, but Datastore 2 is left null (for example, because a reservoir is new and no data exist in HydroBase). Typically, data from these two sources must be merged for a complete record.
  + The NRCS and DWR data sources cannot be mixed for a given reservoir.
* Reservoirs can be associated with more than one HUC, so a unique list is created as a table.
* Unique lists are then created depending on the specified datastores so that separate data calls can be made to each data source (i.e., NRCS AWDB, ColoradoWaterSMS, ColoradoWaterHBGuest).
* Data are obtained from DWR data sources
  + Data are obtained from ColoradoWaterSMS.
    - Calls to the ColoradoWaterSMS web service will fail if the start date is prior to 2000. Therefore, before making the call to ColoradoWaterSMS, the input period is limited to begin in 2000.
    - The ColoradoWaterSMS web service returns daily data, so the start and end dates must also be specified on a daily time step.
    - Station ID, station name, and data source properties are assigned.
    - The units of the data returned from ColoradoWaterSMS are not set by default, so the units are explicitly set to ACFT.
    - Automated checks are performed to ensure that the number of time series created matches the expected number, and to warn the user about any time series that are completely missing.
  + Data are obtained from ColoradoWaterHBGuest.
    - The input period is reset to the full period.
    - The ColoradoWaterHBGuest datastore information is contained in the control workbook under Datastore2 columns on the Combined Inputs worksheet.
    - The ColoradoWaterHBGuest web service returns daily data, so the start and end dates must also be specified on a daily time step.
    - Station ID, station name, and data source properties are assigned.
    - Automated checks are performed to ensure that the number of time series created matches the expected number, and to warn the user about any time series that are completely missing.
  + ColoradoWaterSMS and ColoradoWaterHBGuest data are merged to produce continuous daily time series over the full period.
    - A new time series is created for the full period.
    - The new time series is filled first with data from ColoradoWaterHBGuest data, which takes precedence over ColoradoWaterSMS data. Data flags are set to “HB” for HydroBase to signify the data source.
    - The new time series is then filled with data from ColoradoWaterSMS data. Data flags are set to “SMS” to signify the ColoradoWaterSMS web service as the data source.
    - The merged data are multiplied by 1 and the units are set to ac\_ft to be consistent with the other data components.
  + The merged, daily DWR data are converted to end-of-month time series to be consistent with the data returned from the NRCS.
    - Station ID, station name, and data source properties are assigned.
    - The data flags from the daily time series are not transferred to the monthly time series.
* Data are obtained from the NRCS AWDB web service.
  + Station ID, station name, and data source properties are assigned.
  + Automated checks are performed to ensure that the number of time series created matches the expected number, and to warn the user about any time series that are completely missing.
  + At times (for example, on holidays), the NRCS AWDB web services are down. If no data are returned, the user should check the NRCS website and try again when the services are running.
* The final data written out represent end-of-month storage values in ac-ft using time series aliases of {stationId}-ReservoirStorage-Month regardless of data source. This facilitates generic logic in following steps.

**04 - Download Natural Flow Forecast.TSTool**

**Purpose:**

* Automatically produce time series of 50th percent exceedance forecasts for the appropriate forecast period for ForecastedNaturalFlow stations identified on the Combined Inputs worksheet.

**Workflow Details:**

* Stations can be associated with more than one HUC, so a unique station list is created as a table.
* Separate lists of unique stations are created depending on whether the station is located in the Rio Grande basin or the other basins. The forecast period (April-September) differs in the Rio Grande basin from the forecast period (April-July) used in other basins.
* “ExpandTemplateFile” commands are used to generate strings of concatenated station identifiers separated by commas (for example: stationA,stationB,stationC). The strings are saved as properties: ForecastedNaturalFlowListUniqueRioGrandeIds and ForecastedNaturalFlowListUniqueNonRioGrandeIds. These properties are used in “ReadNrcsAwdb” commands to specify the station list.
* Six separate calls are made to the NRCS AWDB data service depending on the station location and forecast period:
  + Rio Grande: APR-SEP, MAY-SEP, and JUN-SEP.
  + Non-Rio Grande: APR-JUL, MAY-JUL, and JUN-JUL.
* The calls to the NRCS AWDB service return natural flow (SRVO) forecasts with an exceedance probability of 50%.
* The results from each call to the NRCS AWDB service are saved in separate tables, but all results are appended to the master NRCS\_50PercentForecasts table.
* The forecast values are multiplied by 1000 to get units of ac-ft.
  + Note: As of June 2015, the NRCS service was returning forecast values with units of both ac-ft and kac-ft, though values indicated units solely of kac-ft. The NRCS confirmed via e-mail that all forecast values for locations in Colorado are in kac-ft and that the unit codes would be updated accordingly.
* The “TableToTimeSeries” command is used to generate time series of 50th percent exceedance forecasts by location as shown in **Table 12**.
* Properties are read from Excel to determine if the current month’s analysis is using the forecasted runoff component. If so, the forecast data returned from the NRCS will extend to the current month. If not, the time series need to be explicitly extended to the current month, though the values will be missing starting in July of the current year (because the last forecast issued by the NRCS each year is published in June).
* Station id and station name properties are assigned to the time series.
* An automated check is performed to confirm that the number of time series created matches the number of stations.
* At times (for example, on holidays), the NRCS AWDB web services are down. If no data are returned, the user should check the NRCS website and try again when the services are running.

Table . Forecast Values by Month and Location

|  |  |  |
| --- | --- | --- |
| Month | Rio Grande Basin | Non-Rio Grande Basin |
| jan | APR-SEP | APR-JUL |
| feb | APR-SEP | APR-JUL |
| mar | APR-SEP | APR-JUL |
| apr | APR-SEP | APR-JUL |
| may | MAY-SEP | MAY-JUL |
| jun | JUN-SEP | JUN-JUL |
| jul-DEC | Not applicable | Not applicable |

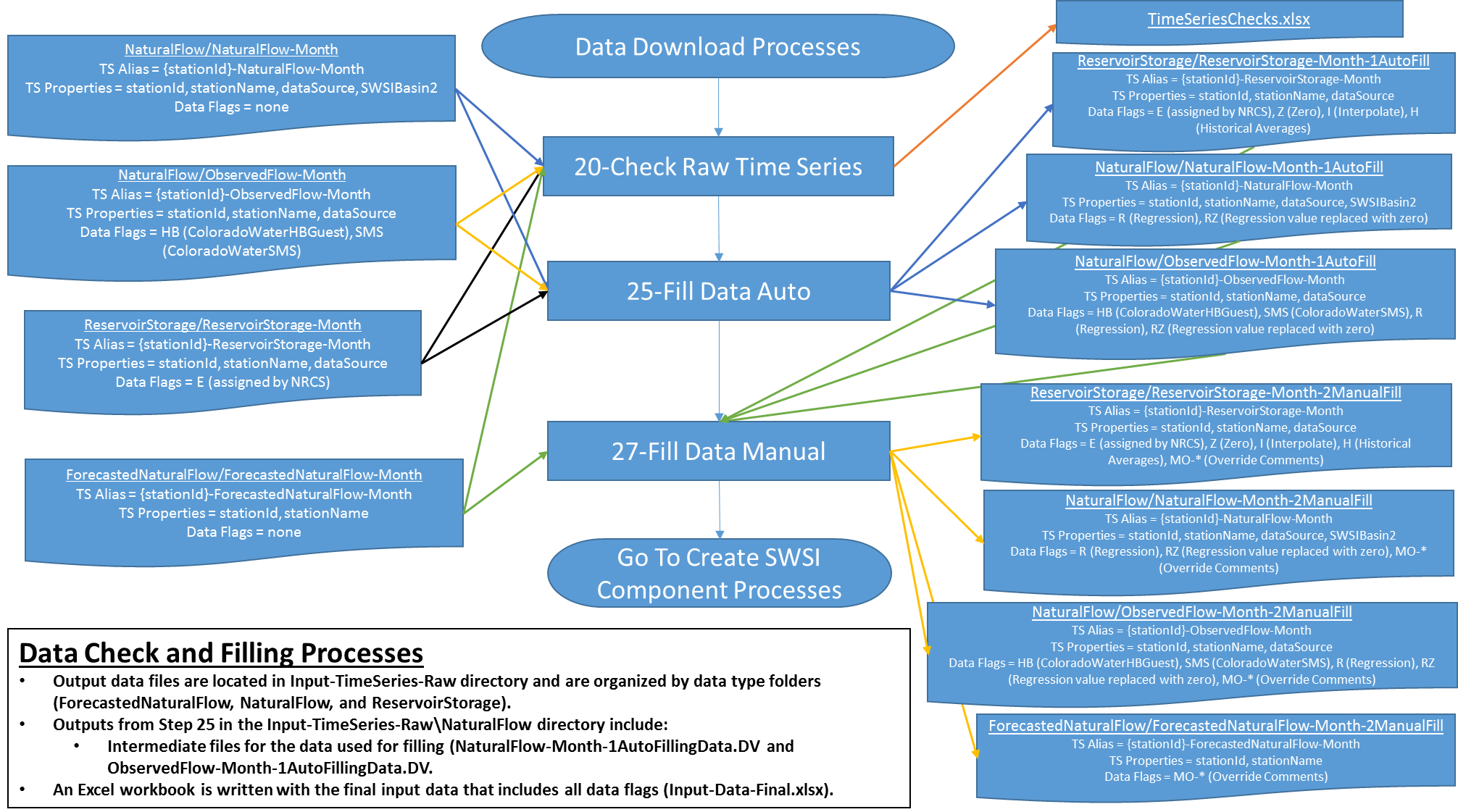


Figure . Flowchart of the Data Check and Filling Processes

**20 – Check Raw Time Series.TSTool**

**Purpose:**

* Summarize the number of missing values for each raw station time series for various time windows.

**Workflow Details:**

* The time series checks are performed by expanding a template file (Template-Check-InputTimeSeries.TSTool).
* The raw data time series are read from the start of the historical period to the current month.
* Time series properties are set to indicate the data type: natural flow, reservoir storage, or forecasted natural flow.
* The CalculateTimeSeriesStatistic command is used to count the number of missing values in each station time series and assign the value to a time series property.
* The natural flow data are used in both the previous month’s streamflow and the forecasted runoff components.
  + For the previous month’s streamflow component, June-August streamflow volumes are shifted forward by one month to use in July-September SWSI calculations. Therefore, raw data are needed in the months of June-August for the full analysis period through the previous month.
  + For the forecasted runoff component, April-September streamflow volumes are accumulated to represent the runoff over the forecast period.
    - Depending on the RecentPeriodFlowDataType property, the observed natural flows are used in the historical and recent periods, or just the historical period.
  + The above requirements are combined to assess the following missing count properties:
    - The number of missing values from April-September in the historical period.
    - If RecentPeriodFlowDataType=NaturalFlow, the number of missing values from April-September in the recent period.
    - If RecentPeriodFlowDataType=ForecastedNaturalFlow, the number of missing values from June-August in the recent period.
    - The number of missing values from June-August in the current water year through the previous month.
    - The number of missing values from June-August for the previous month.
* The forecasted natural flow data are used in the forecasted runoff component. Raw data values represent accumulated runoff volumes over the relevant forecast period. The forecasted runoff component is used from Jan-Jun in the SWSI analysis. These requirements are combined to assess the following missing count properties:
  + If RecentPeriodFlowDataType=ForecastedNaturalFlow, the number of missing values from Jan-Jun in the recent period.
  + The number of missing values from Jan-Jun for the current water year.
  + The number of missing values from Jan-Jun for the current month.
* The reservoir storage data are used for the reservoir storage component year-round in the SWSI analysis. The previous month’s end-of-month storage value is shifted forward by one month to represent the current month’s beginning-of-month storage value. These requirements are combined to assess 4 missing count properties:
  + The number of missing values in the historical period.
  + The number of missing values in the recent period.
  + The number of missing values in the current water year through the previous month.
  + The number of missing values for the previous month.
* The missing count properties are written to summary tables and sorted for output.
  + For natural flow data, the output is sorted by number of missing values in the historical period (descending) to highlight the stations with the most missing data.
  + For the forecasted runoff data, the output is sorted by the number of missing values for the current month (descending).
  + For the reservoir storage data, the output is sorted by number of missing values in the historical period (descending) to highlight the stations with the most missing data.
* If observed flow data are being used in the analysis:
  + The observed flow data are used in the previous month’s streamflow component.
  + For the previous month’s streamflow component, June-August streamflow volumes are shifted forward by one month to use in July-September SWSI calculations. Therefore, raw data are needed in the months of June-August for the full analysis period through the previous month.
  + The above requirements are combined to assess 4 missing count properties:
    - The number of missing values from June-August in the historical period.
    - The number of missing values from June-August in the recent period.
    - The number of missing values from June-August in the current water year through the previous month.
    - The number of missing values from June-August for the previous month.
* The results are written to an Excel workbook and conditional formatting is applied to highlight cells where the missing count is greater than 0 in red.
* Additionally, a list of missing values is created and written to Excel, assuming that the number of missing values is greater than zero.

**25 – Fill Data Auto.TSTool**

**Purpose:**

* Fill missing values in the raw time series using automated filling techniques in TSTool (i.e., regression analysis, interpolation, historical monthly averages, and zero values).

**Workflow Details:**

* To fill missing values in the natural flow dataset:
  + The raw natural flow data are read.
  + A property is set to indicate that these stations are needed for the SWSI analysis, to differentiate later on from stations used solely for filling data.
  + The filling table is read from the control workbook from the FlowDataFill worksheet where Flow Type = Natural and Include <> “NO”.
  + A list of stations is created to indicate filling stations whose data have not yet been downloaded.
  + Data are obtained for these additional stations from the NRCS AWDB web services.
  + An automatic check is performed to confirm that data were returned for all additional stations.
  + A loop is run over the stations that need to be filled.
    - Properties are set to indicate the filling station ID, the fill start date, and the fill end date.
    - The FillRegression command is used to perform the filling using monthly regression equations. The regression statistics are written to the NatFlow\_RegressionStats table.
    - Filled data are assigned a data flag of “R” to indicate regression filling.
    - To prevent cases where the filled value is negative, a ReplaceValue command is used to set negative values to zero and reset the data flag to RZ to indicate filled values were replaced with zeroes. This situation can happen when a downstream station with much larger flows is used for filling, resulting in a regression equation with a negative intercept.
  + The original or filled data are written to DateValue and Excel formats.
  + The filling data are written to DateValue format as an archive.
* If observed flow data are being used:
  + To fill missing values in the observed flow dataset:
    - The raw observed flow data are read.
    - A property is set to indicate that these stations are needed for the SWSI analysis, to differentiate later on from stations used solely for filling data.
    - The filling table is read from the control workbook from the FlowDataFill worksheet where Flow Type = Observed and Include <> “NO”.
    - If any observed data filling has been specified:
      * A list of stations is created to indicate filling stations whose data have not yet been downloaded.
      * Data are obtained for these additional stations from the ColoradoWaterHBGuest web service.
      * An automatic check is performed to confirm that data were returned for all additional stations.
      * A loop is run over the stations that need to be filled.
        + Properties are set to indicate the filling station ID, the fill start date, and the fill end date.
        + The FillRegression command is used to perform the filling using monthly regression equations. The regression statistics are written to the ObsFlow\_RegressionStats table.
        + Filled data are assigned a data flag of “R” to indicate regression filling.
        + To prevent cases where the filled value is negative, a ReplaceValue command is used to set negative values to zero and reset the data flag to RZ to indicate filled values were replaced with zeroes. This situation can happen when a downstream station with much larger flows is used for filling, resulting in a regression equation with a negative intercept.
    - The original or filled data are written to DateValue and Excel formats.
    - The filling data are written to DateValue format as an archive.
* To fill missing values in the reservoir storage dataset:
  + The raw reservoir storage data are read.
  + The filling table is read from the control workbook from the ReservoirDataFill worksheet.
  + The first filling loop involves filling the start of the data record with zeroes if the reservoir was not yet storing water. Filled data flags are set to Z for zeroes.
  + The second filling loop involves filling missing values by interpolating between existing values. This approach is typically selected when only a few data values are missing. Filled data flags are set to I for interpolate.
  + The third filling loop involves filling missing values using historical monthly averages. This approach is typically used when more than one year of data is missing. Filled data flags are set to H for historical monthly averages.
  + The fourth filling loop is applied to reservoirs that have been decommissioned and are no longer storing water. In this case, missing values are set to zero through the current month. Filled data flags are set to Z for zeroes.
  + The filled data are written to DateValue and Excel formats.
* A data check summary is performed on the filled natural flow data, the filled observed flow data (if used), the filled reservoir storage data, and the raw forecasted natural flow data to provide an update on the status of missing data. The time series aliases and dates with missing values are written to a summary table and to Excel.

**27 – Fill Data Manual.TSTool**

**Purpose:**

* Fill missing values (or replace existing values) in the raw time series using user-specified values.

**Workflow Details:**

* The override table is read from the control workbook from the Overrides worksheet.
* Conditional formatting tables are read from the control workbook on the Lookup Values worksheet.
* If observed data are being used in the analysis:
  + The auto-filled observed flow data are read.
  + The SetTimeSeriesValuesFromTable command is used to apply override values and set filled data flags based on the overrides comment column from the control workbook.
* The auto-filled natural flow data are read.
* The SetTimeSeriesValuesFromTable command is used to apply override values and set filled data flags based on the overrides comment column from the control workbook.
* The auto-filled reservoir storage data are read.
* The SetTimeSeriesValuesFromTable command is used to apply override values and set filled data flags based on the overrides comment column from the control workbook.
* The raw forecasted natural flow data are read.
* The SetTimeSeriesValuesFromTable command is used to apply override values and set filled data flags based on the overrides comment column from the control workbook.
* The manual-filled time series are written to DateValue format for use in later TSTool processing steps.
* A summary of the final input data are written to Input\_Data\_Final.xlsx. Cell comments are used to show where data values were filled. The cells are also color-coded based on the data fill flag to facilitate user review.
* A data check summary is performed on the manual-filled natural flow data, the manual-filled reservoir storage data, and the manual-filled forecasted natural flow data to provide an update on the status of missing data. The time series aliases and dates with missing values are written to a summary table and to Excel.

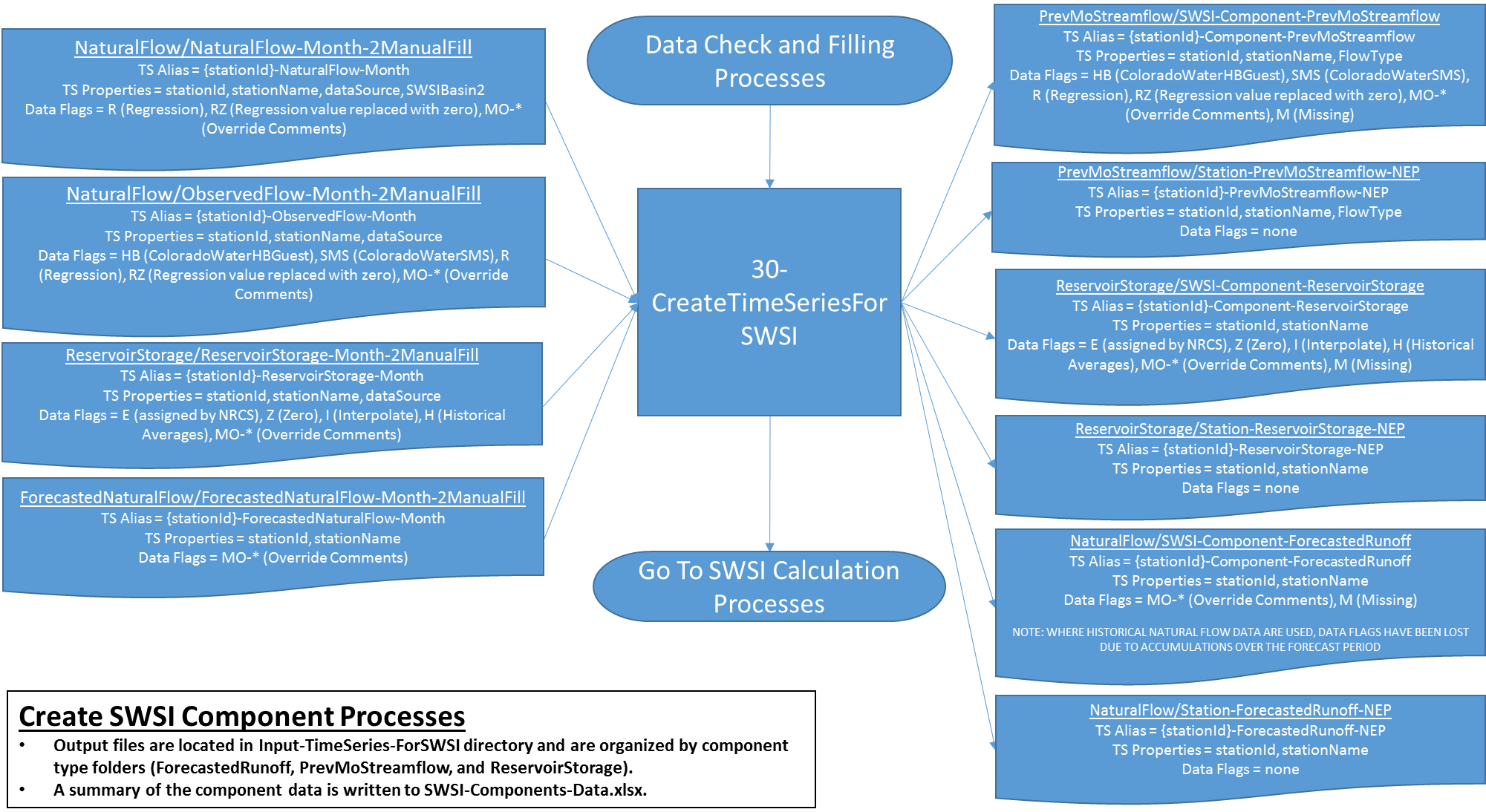


Figure . Flowchart of the Create SWSI Component Processes

**30 – Create Time Series for SWSI.TSTool**

**Purpose:**

* Automatically produce the component time series needed for the SWSI calculation by station so that they can be added by HUC in a later processing step.

**Workflow Details:**

* Reservoir storage component
  + This component is used year-round.
  + Input data are shifted forward by one month to use the previous month’s end-of-month value as the current month’s beginning-of-month storage value. The data shift is accomplished using the “ShiftTimeByInterval” command.
* Previous month’s streamflow component (see **Table 3** for example data transformations)
  + This component is used from Jul-Sep.
  + The expected situation is that natural flow data will be used. However, the user can opt to use observed flow data for one or more stations instead.
  + The natural flow data are read and assigned a FlowType property of “NatFlow”.
  + If observed data are being used:
    - The observed flow data are read.
    - For each station assigned to use observed flow data:
      * The natural flow time series is freed from memory.
      * The observed flow time series is copied to a new time series with an alias of {stationId}-Component-PrevMoStreamflow which is consistent with that used for the natural flow data.
      * The new time series is assigned a FlowType property of “ObsFlow” to help distinguish in the outputs where observed flow data were used.
  + All data are shifted forward by one month to use the previous month’s volume as the current month’s previous month’s streamflow value. The data shift is accomplished using the “ShiftTimeByInterval” command.
  + The monthly values are set to 0 from Oct-Jun (when this component is not used) using a “SetConstant” command.
* Forecast runoff component
  + This component is used Jan-Jun.
  + The historical period is treated differently from the current period, so two component time series are generated and then merged.
  + For the historical period:
    - Historical natural flow data are accumulated over the appropriate forecast period based on month and location (see **Table 12**).
      * The SWSI Basin2 time series property is used to differentiate stations in the Rio Grande basin versus stations outside the Rio Grande basin.
        + Because of the transformations applied to the natural flow data to accumulate runoff volumes over the forecast period, the data flags are not propagated through this step.
    - Two “RunningStatisticTimeSeries” commands are used to perform the accumulation of monthly natural flows to the forecast period (one for Rio Grande stations, and one for non-Rio Grande stations).

Offset-duration notation is used to specify the start and end of the accumulation period (see **Table 13**). For example, in January for a station in the Rio Grande basin, the monthly flows need to be accumulated for APR-SEP and the offset-duration value is specified as 3-8. Relative to Jan, Apr is 3 months ahead and Sep is 8 months ahead.

Table . Offset notation used to accumulate monthly historical natural flows over the forecast period.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Month | Rio Grande Basin | | Non-Rio Grande Basin | |
|  | **Forecast Period** | **Offset-Duration Notation** | **Forecast Period** | **Offset-Duration Notation** |
| jan | APR-SEP | 3-8 | APR-JUL | 3-6 |
| feb | APR-SEP | 2-7 | APR-JUL | 2-5 |
| mar | APR-SEP | 1-6 | APR-JUL | 1-4 |
| apr | APR-SEP | 0-5 | APR-JUL | 0-3 |
| may | MAY-SEP | 0-4 | MAY-JUL | 0-2 |
| jun | JUN-SEP | 0-3 | JUN-JUL | 0-1 |
| jul-DEC | Not applicable | Not applicable | Not applicable | Not applicable |

* + - * The data values are set to 0 in Jul-Dec when the forecast runoff component is not used.
      * The data values are set to 0 for the current period, when forecasts are used instead of “observed” natural flows.
  + For the current period:
    - Forecasted natural flows over the forecast period are used.
    - The data values are set to 0 in Jul-Dec when the forecast runoff component is not used.
    - The data values are set to 0 for the historical, when “observed” natural flows are used instead of forecasts.
  + If the RecentPeriodFlowType = NaturalFlow, then the forecasted runoff in the recent period is computed like the historical period. This is the default case where historical natural flows are used for the forecasted runoff component.
  + If the RecentPeriodFlowType = ForecastedNaturalFlow, then the forecasted runoff in the recent period is computed like the current period. This is the re-forecast option where forecasts are used for the forecasted runoff component in the recent period.
  + The historical and current time series are merged. **Figure 11** presents an example of a merged time series to demonstrate that values are more variable in the current period (when forecasts are used) than in the historical period (when historical natural flows are used).
    - In the historical period, “observed” natural flows are accumulated from monthly natural flow values. We know what the natural flows were in past years. This fact means that for the months of Jan-Apr, when the forecast period is constant, the forecasted runoff component values are also constant from month to month. In May and June, the forecasted runoff component values decrease to reflect less time from the current month until the end of the forecast period.
    - In the current period, when forecasts are used, the forecasted runoff component is more variable because it also reflects forecast model uncertainty.

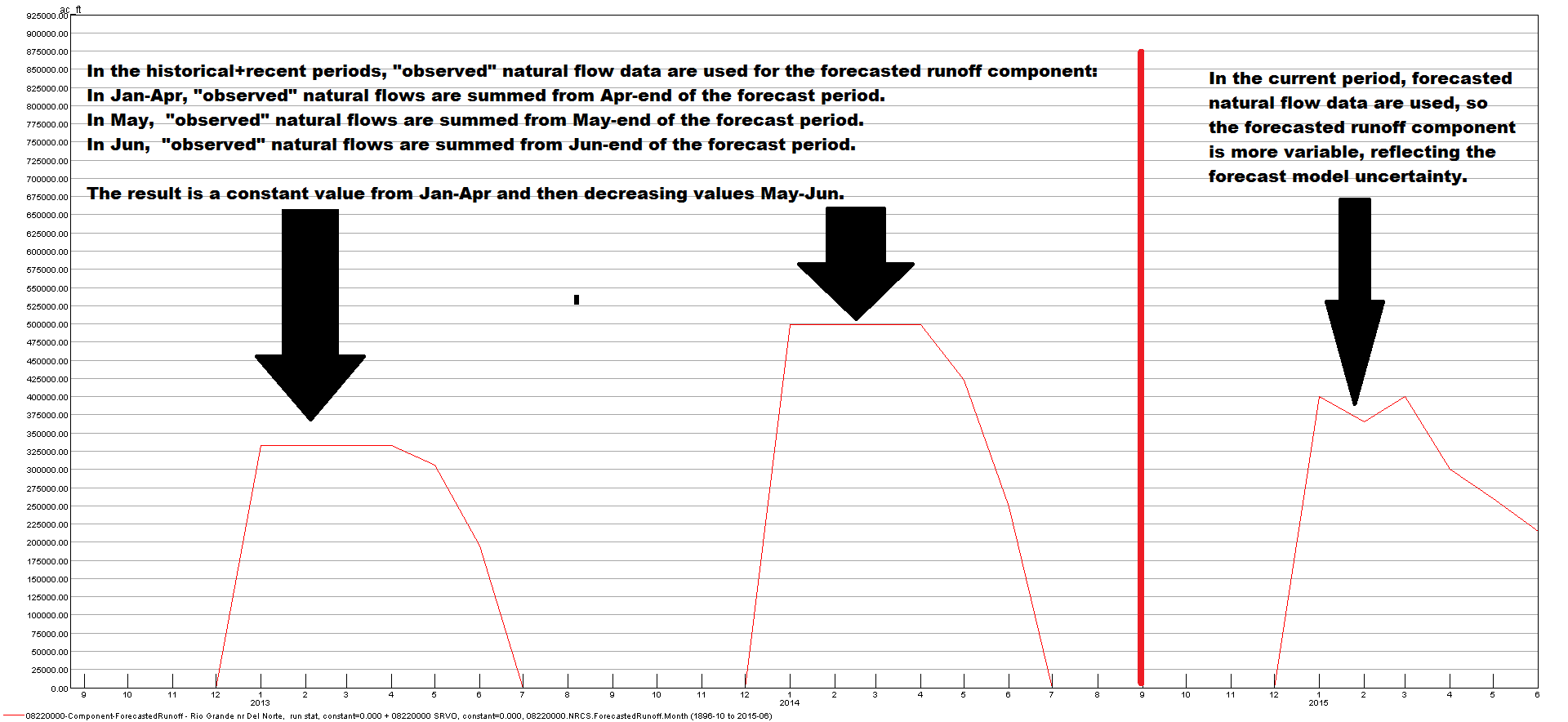


Figure . Example of the Forecasted Runoff Component

* NEP Values by Month are calculated for each station by first calculating the Gringorten plotting position and then multiplying the results by 100. The NEP time series are set to missing in months when the component is not being used.
* A data check summary is performed on the final component data. The time series aliases and dates with missing values are written to a summary table and to Excel.

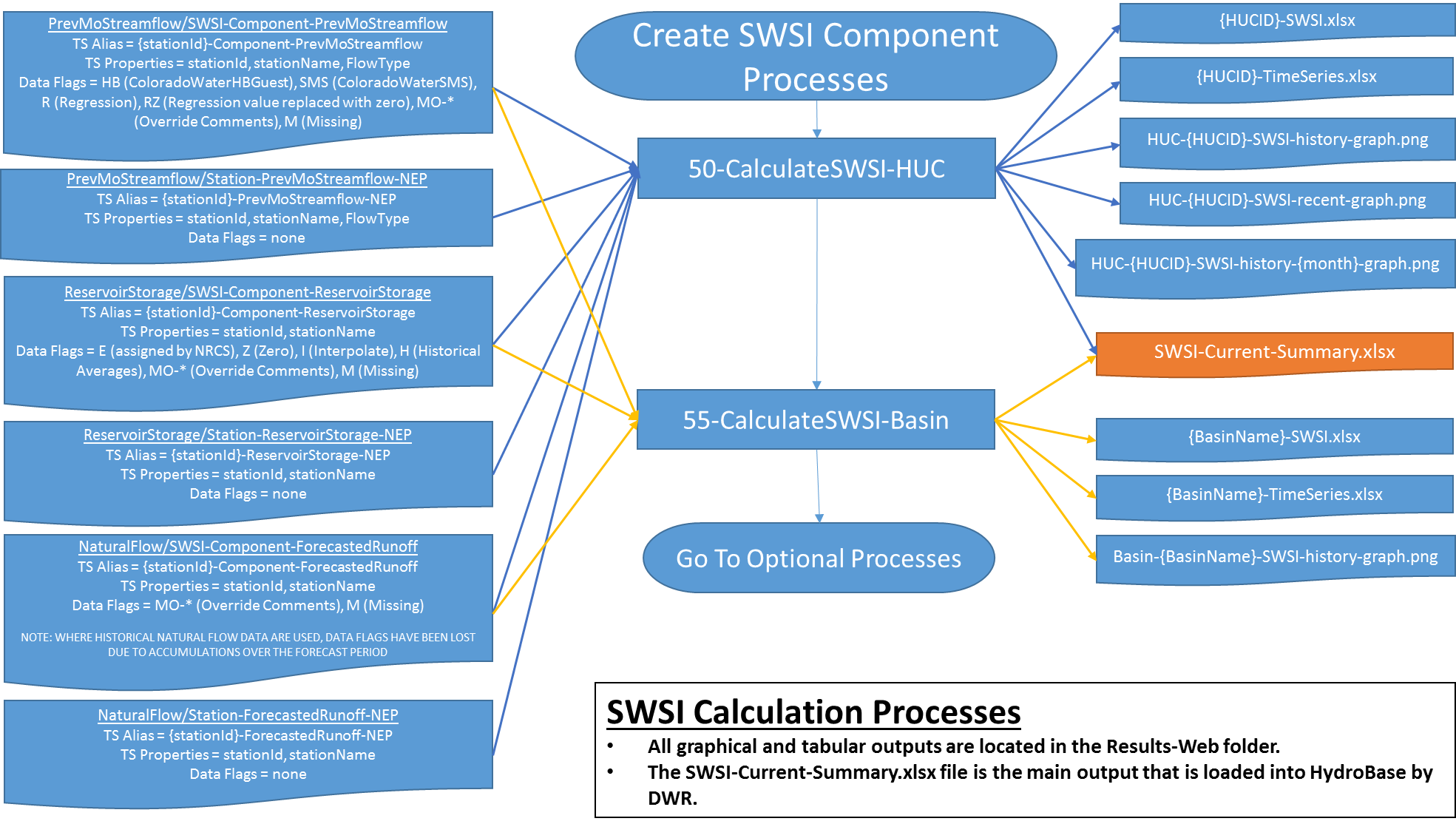


Figure . Flowchart of the SWSI Calculation Processes

**50 – Calculate SWSI - HUC.TSTool**

**Purpose:**

* Perform all of the SWSI-related calculations and generate all of the SWSI output products on a HUC8 basis.

**Workflow Details:**

* Many properties are read from the control file related to the start and end dates of the historical, recent, and current periods, as well as dates and annotation placements to support the graphical outputs.
* A lookup table of month properties is read from Excel that crosswalks month IDs (1-12) with month abbreviations (JAN-DEC). This information is used to loop on months and generate monthly outputs in graphical and tabular formats. This table is also used to set three flags that indicate which SWSI components are used in the current month: ReservoirFlag, PrevMoFlowFlag, and ForecastFlag.
* There are six station component data files read as inputs:
  + Reservoir storage component-volumes
  + Reservoir storage component-NEP by month
  + Previous month’s streamflow component-volumes
  + Previous month’s streamflow component- NEP by month
  + Forecasted runoff component-volumes
  + Forecasted runoff component- NEP by month
* The current month’s volume and percent of average values are set as time series properties on each station time series.
* The combined inputs table is read and used to generate a list of unique HUC8 identifiers that are used to loop for the SWSI processing.
* An automated check is done to compare the number of unique HUC IDs with the expected number. This helps to identify typos in the HUC ID and name that may result in HUCs being erroneously processed multiple times. If a warning is produced, the user should review the control file to ensure the NumberOfHUCs property is correct and that the HUC and HUC Name columns on the Combined Inputs worksheet do not have any typos or inconsistencies.
* The Summary Output Table for HUCs is created based on DNR requirements as follows, with column name and data type indicated:
  + Basin, string (River Basin)
  + HUC\_ID, string (8-digit HUC8 identifier)
  + HUC\_Name, string (HUC Name)
  + Date, datetime (YYYY-MM of current month’s analysis)
  + SWSI, double (surface water supply index value that ranges from -4.16 to +4.16)
  + NEP, double (non-exceedance probability that ranges from 0-100%)
  + SWSI\_Prev\_Yr, double (SWSI value for this month last year, value ranging from -4.16 to +4.16)
  + Chg\_SWSI\_Prev\_Yr, double (calculated as SWSI – SWSI\_Prev\_Yr)
* The Summary Output Table for HUC Components is created based on DNR requirements as follows, with column name and data type indicated:
  + Basin, string (River Basin)
  + HUC\_ID, string (8-digit HUC8 identifier)
  + HUC\_Name, string (HUC Name)
  + Date, string (YYYY-MM of current month’s analysis)
  + Component Type, string (Reservoir Storage, Previous Month’s Streamflow, or Forecasted Runoff)
  + Component ID, string (station identifier)
  + Component Name, string (station name)
  + Component Volume, double (component volume in ac-ft)
  + Component Percent Of Average, double (percent of historical average)
* The process then enters into a loop on HUC identifiers. For the current HUC:
  + Set the hucName property to be used in outputs.
  + Set the riverBasin property to be used in outputs.
  + Create a table of the assigned previous month’s streamflow stations (HUC\_PrevMoStreamflowStations) and set a property of the station count (NumPrevMoStreamflowGages).
  + Create a table of the assigned reservoirs (HUC\_Reservoirs) and set a property of the station count (NumReservoirs).
  + Create a table of the assigned forecasted runoff stations (HUC\_ForecastedRunoffStations) and set a property of the station count (NumForecastedRunoffGages).
  + Calculate the sum of the reservoir storage component for the HUC (TS alias = HUC:${HUCID}-Component-ReservoirStorage.
    - For the reservoirs assigned to the current HUC, assign time series properties of HUC that are used to write station values to the Summary Output Table. These properties are assigned to both the station volume and percent of average time series.
    - Perform an automated check that the number of reservoirs summed for the HUC value matches the expected number. If a warning is generated, make sure that the input data files have data for all assigned reservoirs.
  + Calculate results for the HUC’s reservoir storage component.
    - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
    - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
  + Calculate the sum of the previous month’s streamflow component for the HUC (TS alias = HUC:${HUCID}-Component-PrevMoStreamflow.
    - For the gages assigned to the current HUC, assign time series properties of HUC that are used to write station values to the Summary Output Table. These properties are assigned to both the station volume and percent of average time series.
    - Perform an automated check that the number of gages summed for the HUC value matches the expected number. If a warning is generated, make sure that the input data files have data for all assigned gages.
  + Calculate results for the HUC’s previous month’s streamflow component.
    - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
    - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
  + Calculate the sum of the forecasted runoff component for the HUC (TS alias = HUC:${HUCID}-Component-ForecastedRunoff.
    - For the gages assigned to the current HUC, assign time series properties of HUC that are used to write station values to the Summary Output Table. These properties are assigned to both the station volume and percent of average time series.
    - Perform an automated check that the number of gages summed for the HUC value matches the expected number. If a warning is generated, make sure that the input data files have data for all assigned gages.
  + Calculate results for the HUC’s forecasted runoff component.
    - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
    - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
  + Calculate the data composite for the HUC as the sum of the three components (reservoir storage + previous month’s streamflow + forecasted runoff). The TS alias of the data composite time series is HUC:${HUCID}-DataComposite.
  + Calculate results for the HUC’s data composite.
    - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
    - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
    - Assign properties (hucName and riverBasin) to the HUC data composite SWSI time series (time series alias is HUC:${HUCID}-DataComposite-SWSI) that will be output to the Summary Output Table.
  + Create an Excel workbook for the current HUC that has worksheets for each month. This workbook is named ${HUCID}-SWSI.xlsx.
  + Begin a nested loop on months to generate results and outputs. For the current month:
    - Assign the month abbreviation as a property.
    - Remove the html output file for the current HUC and month.
    - Write all of the historical results for the current month to a table named HUC:${HUCID}-${MonthAbbrev}
      * Data Composite (ac-ft)
      * Data Composite Percent of Average (%)
      * Data Composite Plotting Position (--)
      * Data Composite Non-Exceedance Probability (%)
      * Data Composite Surface Water Supply Index (--)
      * Reservoir Storage (ac-ft)
      * Reservoir Storage Percent of Average (%)
      * Reservoir Storage Plotting Position (--)
      * Reservoir Storage Non-Exceedance Probability (%)
      * Reservoir Storage Surface Water Supply Index (--)
      * Previous Month Streamflow (ac-ft)
      * Previous Month Streamflow Percent of Average (%)
      * Previous Month Streamflow Plotting Position (--)
      * Previous Month Streamflow Non-Exceedance Probability (%)
      * Previous Month Streamflow Surface Water Supply Index (--)
      * Forecasted Runoff (ac-ft)
      * Forecasted Runoff Percent of Average (%)
      * Forecasted Runoff Plotting Position (--)
      * Forecasted Runoff Non-Exceedance Probability (%)
      * Forecasted Runoff Surface Water Supply Index (--)
    - For the recent and current periods, use the current month’s data composite volume and component volumes to look up NEP and SWSI results using the historical data in HUC:${HUCID}-${MonthAbbrev}.
    - Add results for the recent and current periods to the HUC:${HUCID}-${MonthAbbrev} table. Of the results listed above, all results are computed for the recent+current periods EXCEPT the plotting position. This is because the NEP and SWSI values are determined using a lookup function rather than computed from the plotting position as is done in the historical period.
    - The HUC:${HUCID}-${MonthAbbrev} table is sorted by Data Composite descending.
    - The HUC:${HUCID}-${MonthAbbrev} table is written to an HTML file and to the corresponding month worksheet in ${HUCID}-SWSI.xlsx.
    - The monthly results are used to produce monthly output graphs in Results-Web/graphs-png/${MonthId}-${MonthAbbrev}-HUC
      * The current month’s values are put into yearly time series for plotting.
      * A template file is expanded for the current HUC and month. The tsp is saved to Results-Web/graphs-tsp/${MonthId}-${MonthAbbrev}-HUC
    - This is the end of the month loop.
  + The ${HUCID}-SWSI.xlsx workbook is closed, which causes TSTool to write the results in memory to file.
  + Results across all months are plotted for the full history and for the recent+current periods only.
    - Template files are expanded for the current HUC for both the historical graph and the recent graph. The tsp files are saved to Results-Web/graphs-tsp/ALL-HUC.
    - PNG files for the historical and the recent graphs are saved to Results-Web/graphs-png/ALL-HUC.
  + All time series data for the HUC are output to Excel.
    - The existing file (${HUCID}-TimeSeries.xlsx) is removed.
    - The relevant time series are selected and written to Results-Web/ts/(${HUCID}-TimeSeries.xlsx.
  + A temporary copy (Summary\_Output\_Table\_HUC\_Temp) of the Summary\_Output\_Table\_HUC is made. This is because the TimeSeriesToTable commands always create a new table instead of appending results to an existing table.
  + The HUC’s current results are written to the Summary\_Output\_Table\_HUC\_temp table.
  + The results are appended from Summary\_Output\_Table\_HUC\_temp to Summary\_Output\_Table\_HUC, and the temporary table is released from memory.
  + A temporary copy (Summary\_Output\_Table\_HUC\_Components\_Temp) of the Summary\_Output\_Table\_HUC\_Components is made. This is because the TimeSeriesToTable commands always create a new table instead of appending results to an existing table.
  + The HUC’s current component results are written to the Summary\_Output\_Table\_HUC\_Components\_temp table.
    - If a component is not used in the current month, neither the stations nor the accompanying data values are written.
    - If a component is used, but a station’s data values are missing, the station name and identifier are written to the table but the data values are blank.
    - Data values are zero when the result is zero (for example, there is no reservoir storage).
    - Data values should never appear as NaN.
  + The results are appended from Summary\_Output\_Table\_HUC\_Components\_temp to Summary\_Output\_Table\_HUC\_Components, and the temporary table is released from memory.
  + To prepare for the next HUC, all time series are deselected, the three generic tables (HUC\_PrevMoStreamflowStations, HUC\_Reservoirs, and HUC\_ForecastedRunoffStations) are freed, and the three generic properties (NumPrevMoStreamflowGages, NumReservoirs, and NumForecastedRunoffGages) are reset to 0.
  + This is the end of the HUC loop.
* The Summary\_Output\_Table\_HUC is finalized and output.
  + Table math is done to compute Chg\_SWSI\_Prev\_Yr as SWSI – SWSI\_Prev\_Yr.
  + The table is sorted on river basin ascending and HUC ID ascending.
  + The table is written out to Results-Web/swsi-summary in Excel format (SWSI-Current-Summary.xlsx) on the HUC Summary worksheet and in HTML format (SWSI--Current-Summary-HUC.html).
* The Summary\_Output\_Table\_HUC\_Components is finalized and output.
  + The table is sorted on river basin ascending, HUC ID, Component Type, and Component ID.
  + The table is written out to Results-Web/swsi-summary in Excel format (SWSI-Current-Summary.xlsx) on the HUC Components worksheet and in HTML format (SWSI-Current-Summary-HUC-Components.html).

**55 – Calculate SWSI - Basin.TSTool**

**Purpose:**

* Perform all of the SWSI-related calculations and generate all of the SWSI outputs on a river basin basis.

**Workflow Details:**

* Many properties are read from the control file related to start and dates of the historical, recent, and current periods, as well as dates and annotation placements to support the graphical outputs.
* There are three station component data files read as inputs:
  + Reservoir storage component-volumes
  + Previous month’s streamflow component-volumes
  + Forecasted runoff component-volumes
* The combined inputs table is read and used to generate a list of unique river basins that is used to loop for the SWSI processing.
* A lookup table of month properties is read from Excel that crosswalks month ids (1-12) with month abbreviations (JAN-DEC). This information is used to loop on months and generate monthly outputs in graphical and tabular formats.
* An automated check is done to compare the number of unique river basins with the expected number. This helps to identify typos in the basin name that may result in basins being erroneously processed multiple times.
* The Summary Output Table for basins is created based on DWR requirements as follows:
  + Basin, string (River Basin)
  + Date, datetime (YYYY-MM of current month’s analysis)
  + SWSI, double (surface water supply index value that ranges from -4.16 to +4.16)
  + NEP, double (non-exceedance probability that ranges from 0-100%)
  + SWSI\_Prev\_Mo, double (SWSI value for last month, value ranging from -4.16 to +4.16)
  + Chg\_SWSI\_Prev\_Mo, double (calculated as SWSI – SWSI\_Prev\_Mo)
  + SWSI\_Prev\_Yr, double (SWSI value for this month last year, value ranging from -4.16 to +4.16)
  + Chg\_SWSI\_Prev\_Yr, double (calculated as SWSI – SWSI\_Prev\_Yr)
* The process then enters into a loop on basins. For the current basin:
  + Create a table of the assigned previous month’s streamflow stations (Basin\_PrevMoStreamflowStations) and set a property of the station count (NumPrevMoStreamflowGages).
  + Create a table of the assigned reservoirs (Basin\_Reservoirs) and set a property of the station count (NumReservoirs).
  + Create a table of the assigned forecasted runoff stations (Basin\_ForecastedRunoffStations) and set a property of the station count (NumForecastedRunoffGages).
  + Calculate the sum of the reservoir storage component for the Basin (TS alias = ${BasinName}-Component-ReservoirStorage).
    - For the reservoirs assigned to the current Basin, assign time series properties of Basin that are used to write station values to the Summary Output Table.
    - Perform an automated check that the number of reservoirs summed for the Basin value matches the expected number.
  + Calculate results for the Basin’s reservoir storage component.
    - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
    - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
  + Calculate the sum of the previous month’s streamflow component for the Basin (TS alias = ${BasinName}-Component-PrevMoStreamflow.
    - For the gages assigned to the current Basin, assign time series properties of Basin that are used to write station values to the Summary Output Table.
    - Perform an automated check that the number of gages summed for the Basin value matches the expected number.
  + Calculate results for the Basin’s previous month’s streamflow component.
    - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
    - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
  + Calculate the sum of the forecasted runoff component for the Basin (TS alias = ${BasinName}-Component-ForecastedRunoff.
    - For the gages assigned to the current Basin, assign time series properties of Basin that are used to write station values to the Summary Output Table
    - Perform an automated check that the number of gages summed for the Basin value matches the expected number.
  + Calculate results for the Basin’s forecasted runoff component.
    - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
    - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
  + Calculate the data composite for the Basin as the sum of the three components (reservoir storage + previous month’s streamflow + forecasted runoff). The TS alias of the data composite time series is ${BasinName}-DataComposite.
  + Calculate results for the Basin’s data composite.
    - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
    - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
    - Assign properties (BasinName) to the Basin data composite SWSI time series (time series alias is ${BasinName}-DataComposite-SWSI) that will be output to the Summary Output Table.
  + Create an Excel workbook for the current Basin that has worksheets for each month. This workbook is named ${BasinName}-SWSI.xlsx.
  + Begin a nested loop on months to generate results and outputs. For the current month:
    - Assign the month abbreviation as a property.
    - Remove the html output file for the current Basin and month.
    - Write all of the historical results for the current month to a table named ${BasinName}-${MonthAbbrev}
      * Data Composite (ac-ft)
      * Data Composite Percent of Average (%)
      * Data Composite Plotting Position (--)
      * Data Composite Non-Exceedance Probability (%)
      * Data Composite Surface Water Supply Index (--)
      * Reservoir Storage (ac-ft)
      * Reservoir Storage Percent of Average (%)
      * Reservoir Storage Plotting Position (--)
      * Reservoir Storage Non-Exceedance Probability (%)
      * Reservoir Storage Surface Water Supply Index (--)
      * Previous Month Streamflow (ac-ft)
      * Previous Month Streamflow Percent of Average (%)
      * Previous Month Streamflow Plotting Position (--)
      * Previous Month Streamflow Non-Exceedance Probability (%)
      * Previous Month Streamflow Surface Water Supply Index (--)
      * Forecasted Runoff (ac-ft)
      * Forecasted Runoff Percent of Average (%)
      * Forecasted Runoff Plotting Position (--)
      * Forecasted Runoff Non-Exceedance Probability (%)
      * Forecasted Runoff Surface Water Supply Index (--)
    - For the recent and current periods, use the current month’s data composite volume and component volumes to look up NEP and SWSI results using the historical data in ${BasinName}-${MonthAbbrev}.
    - Append results for the recent and current periods to the ${BasinName}-${MonthAbbrev} table. Of the results listed above, all results are computed for the recent+current periods EXCEPT the plotting position. This is because the NEP and SWSI values are determined using a lookup function rather than computed from the plotting position as is done in the historical period.
    - The ${BasinName}-${MonthAbbrev} table is sorted by Data Composite descending.
    - The ${BasinName}-${MonthAbbrev} table is written to an HTML file and to the corresponding month worksheet in ${BasinName}-SWSI.xlsx.
    - This is the end of the month loop.
  + The ${BasinName}-SWSI.xlsx workbook is closed, which prompts TSTool to write the results in memory to file.
  + Results across all months are plotted for the full period.
    - A template file is expanded for the current Basin. The tsp file is saved to Results-Web/graphs-tsp/ALL-Basin.
    - A PNG file is saved to Results-Web/graphs-png/ALL-Basin.
  + All time series data for the Basin are output to Excel.
    - The existing file (${BasinName}-TimeSeries.xlsx) is removed.
    - The relevant time series are selected and written to Results-Web/ts/${BasinName}-TimeSeries.xlsx.
  + A temporary copy (Summary\_Output\_Table\_ Temp) of the Summary\_Output\_Table is made. This is because the TimeSeriesToTable commands always create a new table instead of appending results to an existing table.
  + The Basin’s current results are written to the Summary\_Output\_Table\_ temp table.
  + The results are appended from Summary\_Output\_Table\_ temp to Summary\_Output\_Table, and the temporary table is released from memory.
  + To prepare for the next Basin, all time series are deselected, the three generic tables (Basin\_PrevMoStreamflowStations, Basin\_Reservoirs, and Basin\_ForecastedRunoffStations) are freed, and the three generic properties (NumPrevMoStreamflowGages, NumReservoirs, and NumForecastedRunoffGages) are reset to 0.
  + This is the end of the Basin loop.
* The Summary\_Output\_Table is finalized and output.
  + Table math is done to compute Chg\_SWSI\_Prev\_Mo as SWSI – SWSI\_Prev\_Mo and Chg\_SWSI\_Prev\_Yr as SWSI – SWSI\_Prev\_Yr.
  + The table is sorted on river basin ascending.
  + The table is written out to Results-Web/swsi-summary in Excel format (SWSI-Current-Summary.xlsx) on the Basin Summary worksheet and in HTML format (SWSI--Current-Summary-Basin.html).

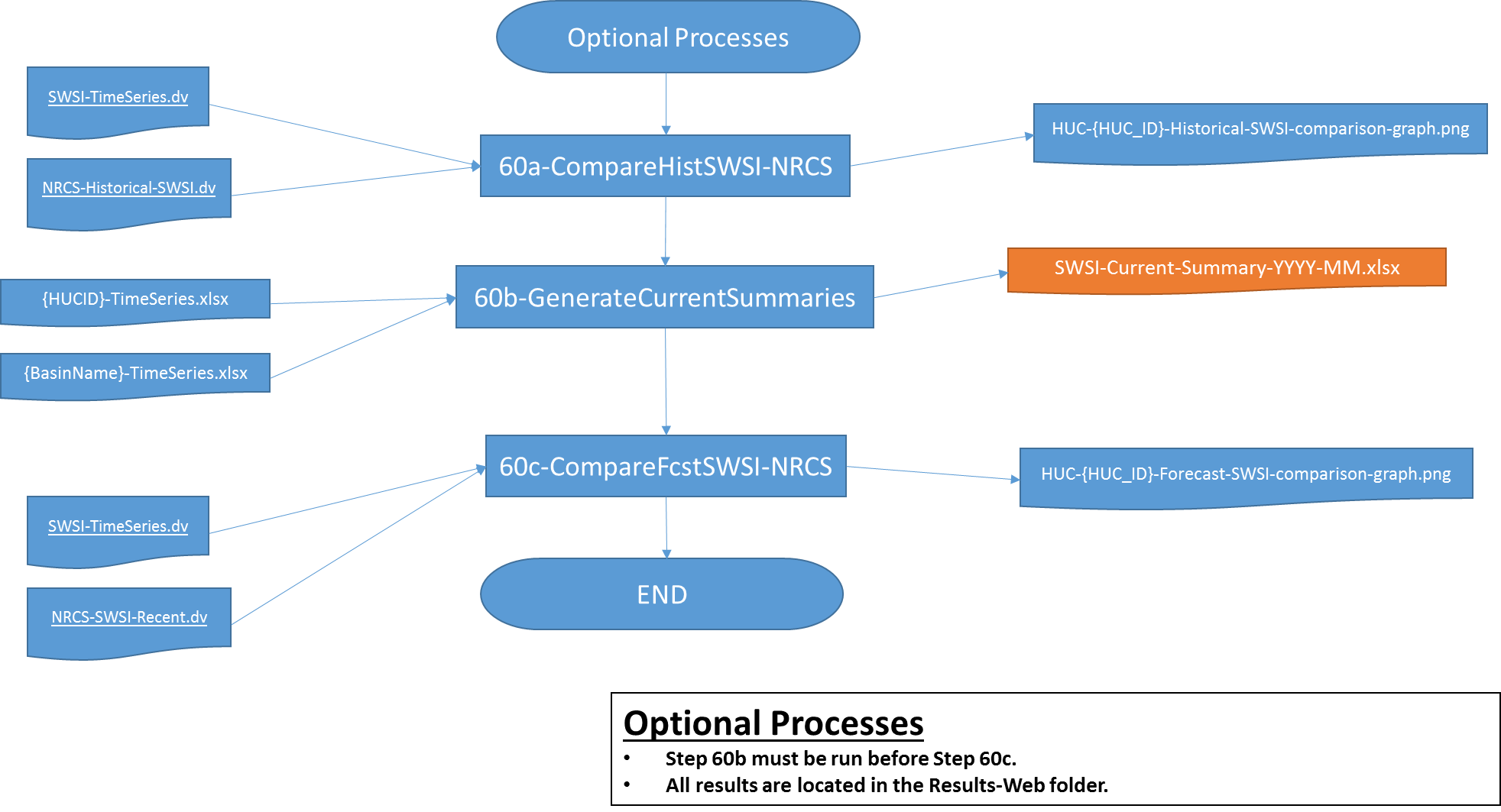
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Figure . Flowchart of the Optional Processes

**60a –CompareHistSWSI-NRCS.TSTool**

**Purpose:**

* To compare the historical SWSI values computed using the Colorado SWSI Automation Tool to those calculated by the NRCS for the historical period.

**Workflow Details:**

* Properties are read from Excel for the start and the end dates of the historical period.
* Read the Combined Inputs table and make a list of unique HUCs.
* Perform an automated check on the number of HUCs.
* Read the NRCS historical SWSI values for the historical period.
* Read the Colorado historical SWSI values for the historical period.
* Loop on the HUCs.
* Expand a template to make a time series product for the HUC comparing the Colorado and NRCS SWSI values.
* Create and output a graphic based on the time series product.

**60b –Generate Current Summaries.TSTool**

**Purpose:**

* To produce dated versions of the Current SWSI Summary workbook for each month in the recent period. This step was developed primarily to support the need to produce re-forecasted SWSI values, though it can be used for historical SWSIs as well.

**Workflow Details:**

* Make a list of the unique river basins.
* Read in the river basin time series results.
* To avoid having a large number of extraneous time series in memories, free all basin time series from memory, except the Data Composite NEP and SWSI time series.
* Assign a BasinTS property that indicates the time series that represent basin results. This property is used later for time series selection.
* Make a list of the unique HUCs.
* Read in the HUC time series results.
* To avoid having a large number of extraneous time series in memories, free all HUC time series from memory, except the Data Composite NEP, Data Composite SWSI, and Component NEP time series.
* Assign HUC\_ID, Basin, and HUC\_Name time series properties to the HUC time series. These properties are later written to the HUC Summary table.
* Assign a HUCTS property that indicates the time series that represent HUC results. This property is used later for time series selection.
* Read in the component volume and NEP time series.
* Assign a StationTS property that indicates the time series that represent station results. This property is used later for time series selection.
* Assign ComponentType properties to the station time series. These properties are later written to the HUC Component Summary.
* Read a list of months to be processed from Excel. The columns contain values that will be used to set the RunMonthDate, PreviousMonthDate, and PreviousYearDate properties to be set.
* Calculate a RunMonthMM column that is used to determine which components are being used in the month’s analysis.
* Begin a loop on the months to be processed.
* ReservoirFlag, PrevMoFlowFlag, and ForecastFlag properties are set to indicate which components are being used.
* Create the Basin Summary, HUC Summary, and HUC Components tables.
* Create a dated Excel workbook as SWSI-Current-Summary-RunMonthDate.xlsx.
* Copy basin properties to the Basin Summary table.
* Insert basin results into the Basin Summary table.
* Calculate Change in SWSI columns in the Basin Summary table.
* Sort the Basin Summary table by Basin name.
* Write the Basin Summary table to Excel.
* Copy HUC properties to the HUC Summary table.
* Insert HUC results into the HUC Summary table.
* Calculate Change in SWSI columns in the HUC Summary table.
* Sort the HUC Summary table by Basin name and HUC ID.
* Write the HUC Summary table to Excel.
* Begin a loop on the HUCs.
* For each HUC, create tables of the assigned stations.
* If the reservoir storage component is being used for the current month and the HUC has at least one assigned reservoir:
  + Create a temporary copy of the HUC Components table.
  + Append rows for the HUC-reservoir assignments.
  + Set the component type to ReservoirStorage.
  + Insert the reservoir storage results into the temporary HUC Components table.
  + Append results from the temporary HUC Components table to the HUC Components table.
  + Free the temporary HUC Components table.
* If the previous month’s streamflow component is being used for the current month and the HUC has at least one assigned station:
  + Create a temporary copy of the HUC Components table.
  + Append rows for the HUC-station assignments.
  + Set the component type to PrevMoStreamflow.
  + Insert the station results into the temporary HUC Components table.
  + Append results from the temporary HUC Components table to the HUC Components table.
  + Free the temporary HUC Components table.
* If the forecasted runoff component is being used for the current month and the HUC has at least one assigned station:
  + Create a temporary copy of the HUC Components table.
  + Append rows for the HUC-station assignments.
  + Set the component type to ForecastedRunoff.
  + Insert the station results into the temporary HUC Components table.
  + Append results from the temporary HUC Components table to the HUC Components table.
  + Free the temporary HUC Components table.
* Free the HUC-station tables from memory to be used in the next HUC.
* End of the HUC loop.
* The HUC Components table is sorted on Basin, HUC ID, Component Type, and Component ID.
* The HUC Components table is written to Excel.
* The dated summary workbook is closed, prompting TSTool to write the results from memory to file.
* The Basin Summary, HUC Summary, and HUC Components tables are freed from memory to prepare for the next month.
* End of the month loop.

**60c –CompareFcstSWSI-NRCS.TSTool**

**Purpose:**

* To compare the forecast SWSI values computed using the Colorado SWSI Automation Tool to those calculated by the NRCS for the recent period.

**Workflow Details:**

* Properties are read from Excel for the start of the recent period and the current date.
* Read the Combined Inputs table and make a list of unique HUCs.
* Perform an automated check on the number of HUCs.
* Read the NRCS forecast SWSI values for the recent period.
* Read the Colorado forecast SWSI values for the recent period.
* Loop on the HUCs.
* Expand a template to make a time series product for the HUC comparing the Colorado and NRCS SWSI values.
* Create and output a graphic based on the time series product.

# **Appendix D – Historical Period Data Issues**

DWR provided to OWF the initial version of the CO-SWSI-Control.xlsx file. During the development of the Colorado SWSI Automation Tool, the historical data were reviewed by OWF and the issues are documented herein along with the implemented solutions. Unresolved issues are noted using red text.

**Observed Natural Flows**

* A station identifier without the leading zero was fixed in the master control file.
* Multiple stations had no historical SRVO data from the NRCS and were replaced with alternate station selections.
  + 06695000 S Platte abv Eleven Mile: This was a data entry error and was replaced with 06695500 Eleven Mile Canyon Reservoir Inflow.
  + 07097000 Arkansas R abv Portland: Gage was replaced with 07099400 Arkansas R abv Pueblo.
  + 07124200 Purgatoire R at Madrid: Gage was replaced with 07124500 Purgatoire River at Trinidad.
  + 09110000 Taylor R at Almont: Gage was replaced with 09109209 Taylor River below Taylor Park Reservoir.
  + 09166950 Lost Canyon Creek near Dolores: This gage and 09166500 Dolores at Dolores were removed. Replacement gage is 09169000 Dolores River below McPhee Reservoir.
  + 09354500 Los Pinos River at La Boca: Gage was replaced with 09353500 Los Pinos River nr Bayfield.
  + 09362750 Florida R abv Lemon Res: Gage was replaced with 09363100 Florida R Inflow to Lemon Reservoir.
* Multiple gages start after the historical period start of Oct 1970 or have periods of missing SRVO data during the historical period that were filled for a complete dataset.
  + 06710385 Bear Creek above Evergreen: Data start 1984.
  + 07111000 Huerfano River near Redwing: Missing data 1991-94.
  + 07114000 Cucharas River at Boyd Ranch nr La Veta: Missing data 1987-1994.
  + 08241500 Sangre de Cristo: Multiple missing periods, mostly before 1980.
  + 09169000 Dolores River below McPhee Reservoir: Some missing data 1980-1984.
  + 09242500 Elkhead River near Milner: Data start 1990 and winter values missing 2009-2012.
  + 09246200 Elkhead Creek above Long Gulch: Data start 1995.
  + 09370500 Mancos River near Mancos: Data start 1975 and missing data 1984-1990.
  + After applying automated filling in the historical and recent periods, one data value continues to be missing for 06719505 Clear Creek at Golden for 2014-08.
* Multiple gages have negative values in the SRVO time series obtained from the NRCS. Natural flow volumes can be computed to be negative if there are errors in the input terms, in particular during low flow months. If negative values occur in the months of June-August, when data are needed for the previous month’s streamflow component, then manual overrides were specified to eliminate the negative values while preserving runoff volumes with adjacent months.
  + 06729500 SOUTH BOULDER CK NR ELDORADO SPRINGS, CO:
    - Affects HUCs 10190003, 10190005, 10190012.
    - 3 negative values during months when the data are used for SWSI analysis APR-SEP)
    - Prev Mo Flow Component negative 1989-09
    - Forecasted Runoff component ok
  + 08250000 CULEBRA CREEK AT SAN LUIS
    - Affects HUC 13010002
    - 13 negative values during months when the data are used for SWSI analysis APR-SEP)
    - Prev Mo Flow Component negative: 9 values
    - Forecasted Runoff component ok
  + 09070500 COLORADO RIVER NEAR DOTSERO
    - Affects HUC 14010001
    - No negative values during months when data are used for SWSI analysis
  + 09132500 NORTH FORK GUNNISON R NR SOMERSET
    - Affects HUC 14020004
    - No negative values during months when data are used for SWSI analysis
  + 09251000 YAMPA R NEAR MAYBELL
    - Affects HUC 14050002
    - 1 negative value during months used for SWSI
    - Prev Mo Flow Component negative: 1 value
    - Forecasted Runoff component ok
  + 09370500 MANCOS RIVER NEAR MANCOS
    - Affects HUC 14080107
    - 5 negative values during months when the data are used for SWSI analysis APR-SEP)
    - Prev Mo Flow Component negative: 5 values
    - Forecasted Runoff component ok
  + Manual overrides were specified to correct negative values that occurred in the months when data were needed for the previous month’s streamflow component. Adjacent months were altered to preserve overall runoff volumes, with consideration of whether the values occurred on the rising or falling limb of the hydrograph. However, the specified values are subjective and no investigation was done into whether the specified values significantly affect the results.
* There were at least two cases where the station identifier and name used by the NRCS are not the same as used by the USGS. While the NRCS could not explain the history of this issue, they confirmed the stations being used are correct. The NRCS information for these stations follows:
  + 09169000 Dolores River below McPhee Reservoir
  + 09363100 FLORIDA RIVER INFLOW TO LEMON RESERVOIR
* There was at least one case where the specified stations are redundant (i.e., both upstream tributary gages and downstream outlet gages are included) and would cause flow volumes to be double-counted.
  + HUC 14010001 Colorado Headwaters Colorado. OWF removed the upstream tributary gages from the analysis per DWR direction.

**Forecasted Natural Flows**

* Multiple HUCs use different station sets for observed natural flows and forecasted natural flows. OWF discussed this issue with DWR and this approach is being retained to ensure natural flow values are available in real-time.
  + HUC 14010001 Colorado Headwaters Colorado: Three additional upstream gages were specified for the observed natural flows. OWF removed the upstream tributary gages from the analysis per DWR direction so the gage sets are now the same in the observed and forecast period.
  + HUC 14020002 Upper Gunnison Colorado: The Gunnison River gage changes between the observed and forecast period.
  + HUC 14050001 Upper Yampa: Gage 09246400 was replaced with gage 09246200 so the gage sets are now the same in the observed and forecast period.
* The NRCS AWDB service returns forecast values with mixed unit codes – some are ac-ft and some are kac-ft – although the forecast values do not change order-of-magnitude with the unit changes. After e-mails with the NRCS, OWF is assuming all forecast values are kac-ft regardless of the unit code returned. The NRCS intends to fix the unit codes being returned by the web service.
* Multiple stations did not return forecast data.
  + 09246400: Gage was replaced with 09246200 ELKHEAD CREEK ABOVE LONG GULCH.
  + 06710500: Gage was replaced with 06710385 BEAR CREEK ABV EVERGREEN.

**Reservoir Storage**

* Two reservoirs are not included in the NRCS AWDB service. Data need to be obtained from the State of Colorado data sources. The ColoradoWaterSMS data service fails for a start date before 2000.
  + LONRESCO LONG HOLLOW RESERVOIR: Reservoir began filling in 2014. Elevation data begin in 2014 but storage data are not available until February 2015.
  + BKIRESCO BUCKEYE RESERVOIR: Although the reservoir was built many years ago, HydroBase data begin in 1992 and SMS data begin in 2007. DWR is investigating StateMod as a potential source for pre-1992 data. The Colorado SWSI Automation Tool does not currently read StateMod data. DWR can add manual overrides to specify the data or a future tool enhancement could include adding StateMod as a data source. For now, the reservoir was removed from the analysis.
* Multiple reservoirs came on-line after 1970 based on the available storage data. The period between the start of the historical period and the start of the storage data are filled with zero values.
  + 16016025 SPINNEY MOUNTAIN RESERVOIR: Data start 1981-10
  + 07007090 PUEBLO RESERVOIR: Data start 1973-12
  + 07007100 TRINIDAD LAKE: Data start 1977-08
  + 09041395 WOLFORD MOUNTAIN RESERVOIR: Data start 1995-06
  + 09125800 SILVER JACK RESERVOIR: Data start 1973-07
  + 09116500 VOUGA RESERVOIR NEAR DOYLEVILLE: Data start 1997-10
  + 09147022 RIDGEWAY RESERVOIR: Data start 1986-10
  + MPHC2000 MCPHEE RESERVOIR: Data start 1984-03
  + 09237495 STAGECOACH RESERVOIR NR OAK CREEK: Data start 1988-10
  + YAMRESCO YAMCOLO RESERVOIR: Data start 1980-10
  + LONRESCO LONG HOLLOW RESERVOIR: Data start 2015-02
* Based on a visual assessment of the storage data, multiple reservoirs have undergone changes in operations during the historical period and/or were filling during the beginning of the historical period. No action was taken – these issues are noted for the record.
  + 06016160 JACKSON LAKE RESERVOIR: Apparent operations change in 1990.
  + 07007110 TURQUOISE LAKE: Reservoir was filling in the 70s?
  + 07007120 TWIN LAKES RESERVOIR: Operations change in 1983?
  + 07007070 MEREDITH RESERVOIR: Operations change in 1982
  + 07007010 ADOBE CREEK RESERVOIR: Operations change in 1981?
  + 09009100 PAONIA RESERVOIR: Change in operations ~1980?
  + MPHC2000 MCPHEE RESERVOIR : Reservoir was filling until 1986?
  + 09237495 STAGECOACH RESERVOIR NR OAK CREEK: Reservoir was filling until 1989?
  + YAMRESCO YAMCOLO RESERVOIR: Reservoir was filling until 1981?
* Multiple reservoirs have missing data after the point at which they began storing water. These data values can be filled using linear interpolation or historical average monthly data values for a complete dataset.
  + 06016280 STANDLEY RESERVOIR: Missing WY2002
  + 06016260 BUTTONROCK (RALPH PRICE) RESERVOIR: Missing 1975-10 to 1982-09 and 1991-10 to 2005-10 plus other sporadic points
  + 06016040 BOYD LAKE: Missing a few data points
  + 06016180 LAKE LOVELAND RESERVOIR: Missing a few data points
  + 06016190 LONE TREE RESERVOIR: Missing a few data points
  + 06016200 MARIANO RESERVOIR: Missing a few data points
  + 08008150 SANTA MARIA RESERVOIR: Missing WY 1976
  + MTNRESCO MOUNTAIN HOME: Multiple missing periods (mostly short)
  + 09009330 FRUITLAND RESERVOIR: Missing data 1991-1993
  + 09009340 CRAWFORD RESERVOIR: Missing data 1991-1993
  + 09125800 SILVER JACK RESERVOIR: Sporadic missing data until 1987
  + 09009170 GROUNDHOG RESERVOIR: Sporadic missing
* For HUC 10190012, Jackson Lake Reservoir was used with station ID 06016160. The name was ambiguous but station selection was confirmed using NRCS station metadata.
* After automated filling, only one missing value remained for Standley Reservoir for 2015-02.

# **Appendix E – Current Water Year Data Issues**

During the development of the Colorado SWSI Automation Tool, the current water year data were reviewed by OWF and the issues are documented herein along with the implemented solutions. Unresolved issues are noted using red text.

* The Cucharas Reservoir has been decommissioned and is no longer storing water. In Step 25 FillDataAuto, the storage data for Cucharas Reservoir are filled with zeroes through the current month.
* Mountain Home Reservoir storage data were missing from the NRCS AWDB web service beginning in February 2015, which prevented results from being computed for HUC 13010002 Alamosa-Trinchera and for the Rio Grande basin. The data source was switched to ColoradoWaterSMS and ColoradWaterHBGuest.
* The remaining missing values are documented in **Table 14**. DWR should consider specifying manual overrides to fill these values.

Table . Missing Data Values that Require Overrides

|  |  |  |  |
| --- | --- | --- | --- |
| **Time Series Alias** | **Station ID** | **Station Name** | **Date** |
| 07124500-ForecastedNaturalFlow-Month | 07124500 | PURGATOIRE RIVER AT TRINIDAD | 2015-03 |
| 06016280-ReservoirStorage-Month | 06016280 | STANDLEY RESERVOIR | 2015-02 |
| 07124500-ForecastedNaturalFlow-Month | 07124500 | PURGATOIRE RIVER AT TRINIDAD | 2015-02 |
| 07124500-ForecastedNaturalFlow-Month | 07124500 | PURGATOIRE RIVER AT TRINIDAD | 2015-01 |
| 06719505-NaturalFlow-Month | 06719505 | CLEAR CREEK AT GOLDEN | 2014-08 |

# **Appendix F – Recent Period Data Issues**

During the development of the Colorado SWSI Automation Tool, the recent period data were reviewed by OWF and the issues are documented herein along with the implemented solutions. Unresolved issues are noted using red text.

* To avoid a burden being placed on DWR to fill a large number of missing values in the recent period, OWF implemented automated filling for the natural flows and the reservoir storage data through the end of the recent period. If desired, DWR can supply manual overrides to fill data in the recent period (see Table 14).