Data Evaluation

During CY 2014, no predischarge samples were collected from Ponds A-4, B-5, or C-2. All three terminal ponds were operated in a flow-through mode for all of CY 2014.

3.1.3 Rocky Flats Hydrology

The following section provides information for all automated surface-water monitoring and precipitation gage locations at the Site that operated during CY 2014. For locations with continuous flow measurement, graphical discharge summaries are provided. Graphical summaries are also provided for all precipitation gage locations. Numerical discharge and precipitation values are included in the tables in Appendix A.

Groundwater hydrology is also addressed. This includes a discussion of groundwater levels in various areas of interest via the preparation of hydrographs and potentiometric surface maps. Flow velocities are also calculated. Hydrographs for monitoring wells are included in Appendix A.

3.1.3.1 General Hydrologic Setting

Streams and seeps at the Site are largely ephemeral, with stream reaches gaining or losing flow, depending on the season and precipitation amounts. Section 3.1.3.6 discusses recent efforts to document observed seeps at the Site. Surface-water flow across the Site is primarily from west to east, with three major drainages traversing the Site. In 2014, three ponds within the COU collected and managed surface-water runoff. The Site drainages and ponds, including their respective pertinence to this report, are described below and shown on Figure 41.

The major stream drainages at Rocky Flats (including those in the COU and the surrounding Rocky Flats National Wildlife Refuge, also called the Refuge), from north to south, are Rock Creek, Walnut Creek, and Woman Creek. North Walnut Creek flows through Pond A-4, and South Walnut Creek flows through Pond B-5; both are tributaries to Walnut Creek. The hydrologic routing diagram (as of December 31, 2014) for the locations included in this report is shown on Figure 42.

The groundwater hydrology is generally characterized by relatively thin, shallow, saturated materials (in the COU, typically on the order of a few dozen feet thick or less, and less than 50 feet deep). This shallow saturated interval occurs within the unconsolidated Rocky Flats Alluvium, hillslope colluvium, valley-fill alluvium, artificial fill, and the weathered portion of the underlying bedrock. Collectively, these materials are referred to as the upper hydrostratigraphic unit (UHSU). Regionally, groundwater flows from west to east within the UHSU of the pediment surfaces, except where it is locally diverted toward the generally east-west trending drainages that bisect these pediments. Groundwater typically discharges at seeps and springs along pediment edges, or as baseflow to surface water. Vertical flow is sharply limited by the low-permeability claystones underlying the unconsolidated surficial materials. This underlying low-permeability bedrock surface comprises the Arapahoe and Laramie Formations, which are typically undifferentiated; the gentle eastward dip of the unconformity marking the contact between this bedrock and the overlying unconsolidated surficial materials acts to direct the groundwater flow. Locally, this bedrock may include sandstone lenses that

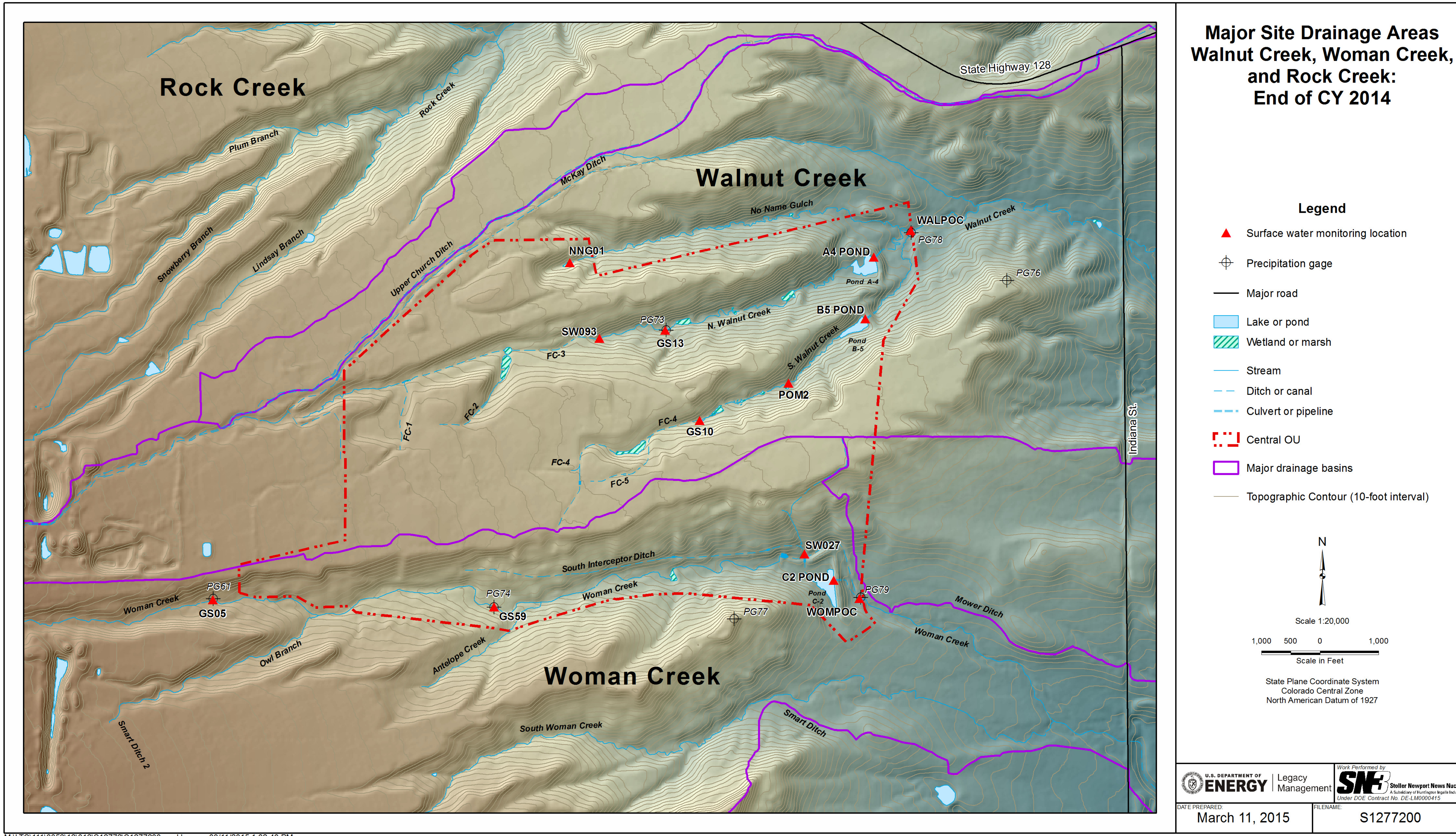

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Figure 41. Major Site Drainage Areas—Walnut Creek, Woman Creek, and Rock Creek: End of CY 2014

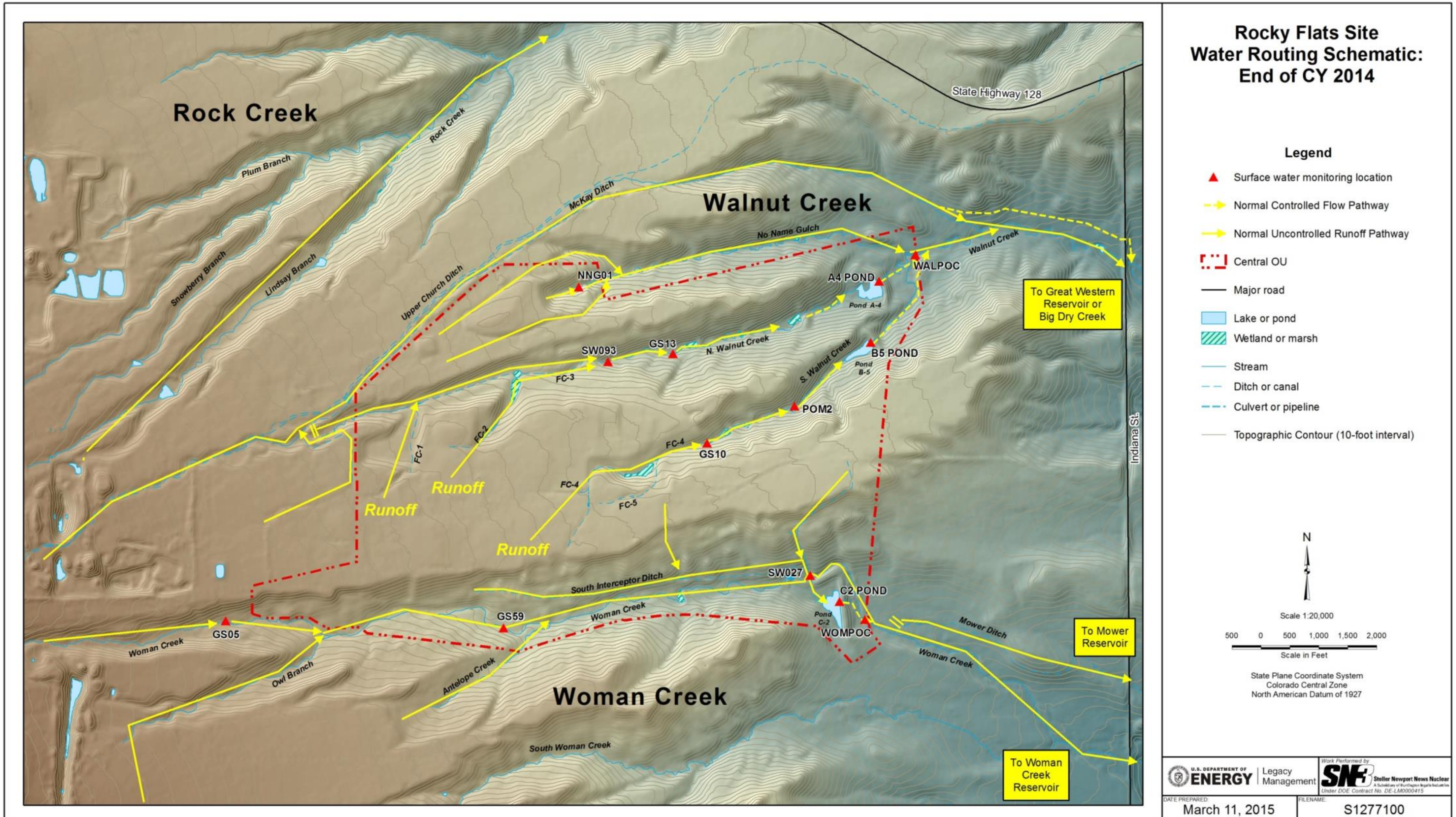

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Figure 42. Rocky Flats Site Water Routing Schematic: End of CY 2014

subcrop or are sufficiently shallow to be included in the UHSU. For a more thorough description of the hydrogeology at Rocky Flats, refer to the EG&G hydrogeologic report (EG&G 1995a).

Surface Water

Walnut Creek

Walnut Creek receives surface-water flow from the central third of the Refuge, including the majority of the COU. It consists of several tributaries: McKay Ditch, No Name Gulch, North Walnut Creek, and South Walnut Creek. These tributaries join Walnut Creek upstream of the Refuge's eastern boundary (Indiana Street). East of Indiana Street, Walnut Creek flows through a diversion structure normally configured to divert flow to the Broomfield Diversion Ditch around Great Western Reservoir and into Big Dry Creek. The Walnut Creek tributaries, from north to south, are described below.

McKay Ditch

The McKay Ditch was formerly a tributary to Walnut Creek within the Refuge boundary but was modified in July 1999 to allow for diversion into a new pipeline to keep McKay Ditch water from commingling with water in Walnut Creek upstream of Indiana Street. Although not normally a contributor to Walnut Creek (depending on headgate configuration), the McKay Ditch drainage is described here to clarify water routing. The new configuration allows the City and County of Broomfield to direct water through the McKay Ditch, across the northern portion of the Refuge around the COU, through the McKay Bypass Pipeline, and directly into Great Western Reservoir, without entering Walnut Creek. This configuration prevents the commingling of McKay Ditch water with water originating in the COU. McKay Ditch (as well as both the McKay Bypass Canal and McKay Bypass Pipeline) are outside the COU; these features are not maintained by LM.

No Name Gulch

This drainage is located downstream of the PLF. A surface-water diversion ditch is constructed around the perimeter of the PLF to divert surface-water runoff around the landfill area to No Name Gulch. Effluent from the PLFTS is also a surface-water source to No Name Gulch. Although the majority of No Name Gulch is outside the COU, it reenters the COU and joins Walnut Creek just upstream of the COU eastern boundary.

North Walnut Creek

Runoff from the northern portion of the COU flows into this drainage, which has one remaining pond: Pond A-4. The capacity of Pond A-4 is approximately 32 million gallons (99 acre-feet). In the normal operational configuration, water flows through the former Pond A-1, Pond A-2, and Pond A-3 areas to Pond A-4. Pond A-4 is normally operated in flow-through mode, allowing water to flow directly to lower Walnut Creek. The existing outlet works tower maintains approximately 10 percent of capacity (3.3 million gallons) during flow-through. If a valve closure at Pond A-4 causes water to temporarily be retained, a predischarge sample is collected prior to resuming discharge. Criteria for emergency discharge, regardless of predischarge pond sampling results, are detailed in the *Emergency Response Plan for Rocky Flats Site Dams* (ERP) (DOE 2010b).

South Walnut Creek

Runoff from the central portion of the COU flows into this drainage, which has one remaining pond: Pond B-5. The capacity of Pond B-5 is approximately 23 million gallons (71 acre-feet). In the normal operational configuration, water flows through the former Pond B-1, Pond B-2, Pond B-3, and Pond B-4 areas to Pond B-5. Pond B-5 is normally operated in a flow-through mode, allowing water to flow directly to lower Walnut Creek. The existing outlet works tower maintains approximately 10 percent of capacity (2.5 million gallons) during flow-through. If a valve closure at Pond B-5 causes water to temporarily be retained, a predischarge sample is collected prior to resuming discharge. Criteria for emergency discharge, regardless of predischarge pond sampling results, are detailed in the ERP.

Woman Creek

South of the COU is Woman Creek, which flows through the C-1 wetland (Dam C-1 was breached in 2004) and offsite onto Refuge lands toward Indiana Street. The Woman Creek drainage basin extends eastward from the base of the foothills, near Coal Creek Canyon, to Standley Lake. In the current configuration, Woman Creek flows into the Standley Lake Protection Project, also known as the Woman Creek Reservoir, located east of Indiana Street and upstream of Standley Lake, where the water is held until it is pump-transferred to Walnut Creek by the Woman Creek Reservoir Authority.

South Interceptor Ditch

The SID drainage is in the southern portion of the COU, and it is a tributary to Pond C-2. Surface-water runoff from the southern portion of the COU is intercepted by the SID, which flows from west to east into Pond C-2. Woman Creek water does not enter Pond C-2, but is diverted around Pond C-2 through the Woman Creek Diversion Canal. The capacity of Pond C-2 is approximately 23 million gallons (70 acre-feet). Pond C-2 is normally operated in a flow-through mode. The existing outlet works tower maintains approximately 2 percent of capacity (0.4 million gallons) during flow-through. If a valve closure at Pond C-2 causes water to temporarily be retained, a predischarge sample is collected prior to resuming discharge. Criteria for emergency discharge, regardless of predischarge pond sampling results, are detailed in the ERP.

Other Drainages

The third major drainage, other than Walnut and Woman Creeks, is Rock Creek. The Rock Creek drainage covers the northwestern portion of the Refuge. East-sloping alluvial plains to the west, several small stock ponds within the creek bed, and multiple steep gullies and stream channels to the east characterize the drainage channel. This entire basin is outside the COU.

Smart Ditch/South Woman Creek, located south of Woman Creek, is also completely outside the COU. The D-Series Ponds (D-1 and D-2) are located on Smart Ditch. This drainage and these ponds are not maintained by LM.

3.1.3.2 Surface-Water Hydrologic Data Presentation

Flow Data Collection and Computation

Data obtained at a continuous surface-water gaging station on a stream or conveyance, such as an irrigation ditch, consist of a continuous record of stage,[5] individual measurements of flow throughout a range of stages, and notations regarding factors that might affect the relation of stage to flow rate. These data, together with supplemental information such as climatological records, are used to compute daily mean discharges.

Continuous records of stage are obtained with electronic recorders that store stage values at selected time intervals or secondarily with radio-telemetry data-collection platforms that transmit near real-time data at selected time intervals to a central database for subsequent processing. Direct field measurements of flow are made with current meters, using methods adapted by the U.S. Geological Survey, or with flumes or weirs that are calibrated to provide a relation of observed stage to flow rate. These methods are described by Carter and Davidian (1968) and by Rantz (1982a, 1982b).

In computing flow records for nonstandard flow-control devices, results of individual measurements are plotted against the corresponding stage, and stage-flow rate relation curves are constructed. From these curves, rating tables indicating the computed flow rate for any stage within the range of the measurements are prepared. For standard devices (e.g., flumes and weirs), rating tables indicating the flow rate for any stage within the range of the device are prepared based on the geometry of the device. If it is necessary to define extremes of flow outside the range of the device, the curves can be extended using (1) logarithmic plotting; (2) velocity-area studies; (3) results of indirect measurements of peak flow rate, such as slope-area or contracted-opening measurements, and computation of flow over dams or weirs; or (4) step-back-water techniques.

Daily mean discharges are computed by averaging the individual flow measurements using the stage-flow rate curves or tables. If the stage-flow rate relation is subject to change because of frequent or continual changes in the physical features that form the control, the daily mean discharge is determined by the shifting-control method, in which correction factors based on the individual flow rate measurements and notes by the personnel making the measurements are applied to the gage heights before the flow rates are determined from the curves or tables. This shifting-control method also is used if the stage-flow rate relation is changed temporarily because of aquatic vegetation growth or debris on the control. For some gaging stations, formation of ice in the winter can obscure the stage-flow rate relations so that daily mean discharges need to be estimated from other information, such as temperature and precipitation records, notes of observations, and records for other gaging stations in the same or nearby basins for comparable periods.

For most gaging stations, there may be periods when no gage-height record is obtained or the recorded gage height is faulty so that it cannot be used to compute daily mean discharge. This record loss occurs when recording instruments malfunction or otherwise fail to operate properly,

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[5] Stage is the water level (in units such as feet or meters) in a conveyance structure.

intakes are plugged, the stilling well is frozen, or various other conditions occur. For such periods, the daily discharges are estimated from the recorded range in stage, the previous or following record, field discharge measurements, climatological records, and comparison with other gaging-station records from the same or nearby basins. Information explaining how estimated daily discharge values are identified in gaging-station records is provided in the "Identifying Estimated Daily Discharge" section below.

Data Presentation

The information published for each continuous-record surface-water gaging station consists of six parts: the station description, a map showing the drainage area for the station, a plot of the daily mean discharge for the calendar years(s), a table of daily mean discharge values for the calendar year with summary data, a tabular statistical summary of monthly mean discharge data for the calendar year, and a summary statistics table that includes statistical data of annual discharge and runoff. The tables are included in Appendix A, and the other information is presented below.

Station Description

The station description provides, under various headings, descriptive information including gaging-station location, drainage area, period of record, and gage information. The following information is provided:

- **Location:** This entry provides the gaging station state plane coordinates and geographic location. Gaging station state plane coordinates were obtained by geographic positioning system or digitized from Site geographic information system (GIS) coverages.
- **Drainage Area:** This entry provides the drainage area (in acres) of the gaged basin. If, because of unusual natural conditions or artificial controls, some part of the basin does not contribute flow to the total flow measured at the gage, the noncontributing drainage area also is identified. Drainage area is usually measured using digital techniques and the most accurate maps available. Because the type of map available might vary from one drainage basin to another, the accuracy of digitized drainage areas also can vary. Drainage areas are updated as better maps become available. Some of the gaging stations included in this report measure stage and flow rate in channels that convey water to or from reservoirs or other features; these channels might have little or no contributing drainage area. Drainage areas in this report were provided by Site GIS coverages.[6]
- **Period of Record:** This entry provides the period for which the Site has been collecting records at the gage. This entry includes the month and year of the start of collection of hydrologic records by the Site and the words "to current year" if the records are to be continued into the following year.
- **Gage:** This entry provides the type of gage currently in use and a condensed history of the types and locations of previous gages.

[6] Drainage area maps show Site configuration at the end of CY 2014.

Daily Mean Discharge Values

The daily mean discharge values computed for each gaging station during a calendar year are listed in the body of the data tables in Appendix A. In the monthly "Flow Rate" summary part of the table, the line headed "Average" lists the average flow rate in cubic feet per second during the month, and the lines headed "Maximum" and "Minimum" list the maximum and minimum daily mean discharges for each month. Total discharge for the month also is expressed in cubic feet, gallons, and acre-feet. The term "Partial Data" denotes a month with incomplete data.

Summary Statistics

A section of the table titled "Annual Summaries for CY 2014" follows the monthly mean data section. This section provides a statistical summary of annual flow rates and discharge for the labeled calendar year. The applicable units are to the left of the table value. The term "Partial Data" denotes a year with incomplete data.

Identifying Estimated Daily Discharge

Estimated daily discharges published in water-discharge tables and figures of this annual report are identified by *italicizing* individual daily values or through color coding in hydrographs. For periods of no data, a gap is shown on the hydrographs.

Other Records Available

Information used in the preparation of the records in this report, such as discharge-measurement notes, gage-height records, and rating tables, are on file. Information on the availability of the unpublished information or on the published statistical analyses is available from personnel involved with data collection at the Site.

3.1.3.3 Surface-Water Discharge Data Summaries

Refuge Discharge Summary

Discharge summaries for the two major drainages on the Refuge receiving flow from the COU (Walnut and Woman Creeks at Indiana Street) are given on Figure 43 and Figure 44.[7] Walnut Creek flows are measured at GS03 and Woman Creek flows are measured at GS01. A summary of CY 2014 COU discharge at both WALPOC and WOMPOC is given in the next section. Through CY 2004, Walnut Creek discharged larger volumes than Woman Creek due to the contribution of imported water and runoff from impervious surfaces. After physical completion in CY 2005, the reduction of discharge in Walnut Creek and the corresponding change in relative volumes is clearly observed.

[7] The pre-closure period is for the dates January 1, 1997–October 1, 2004; the post-closure period is for the dates October 1, 2005–December 31, 2014.

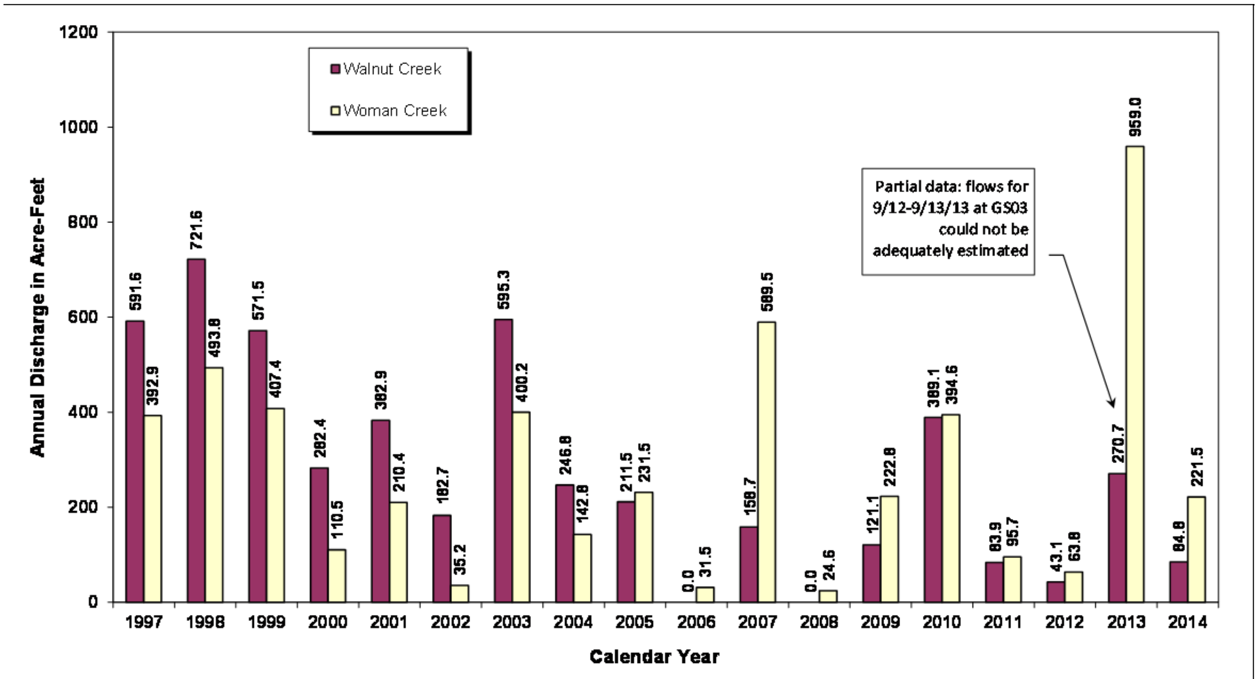


Figure 43. Annual Discharge Summary from Major Site Drainages: CY 1997–2014

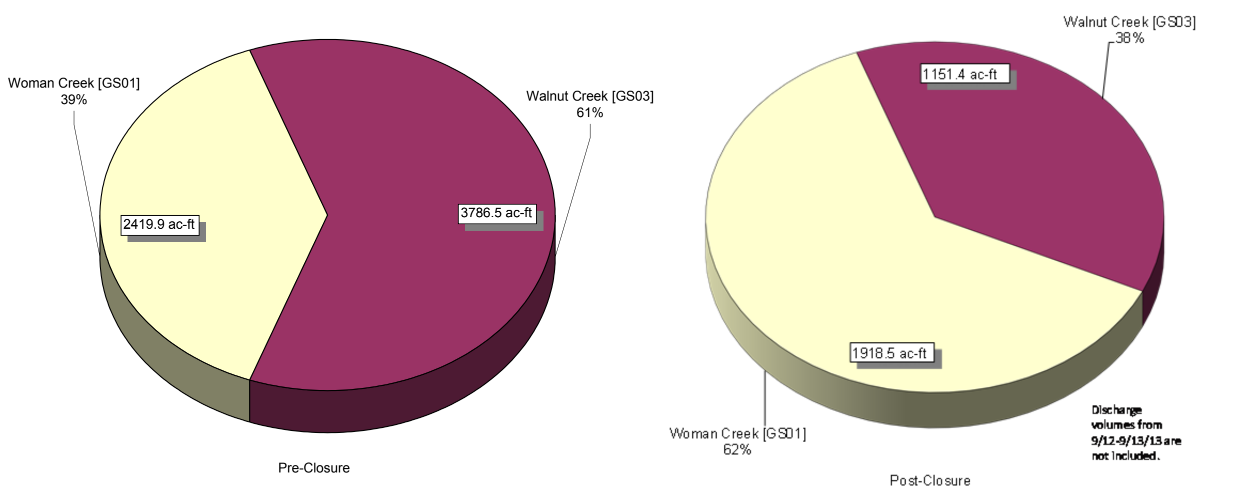
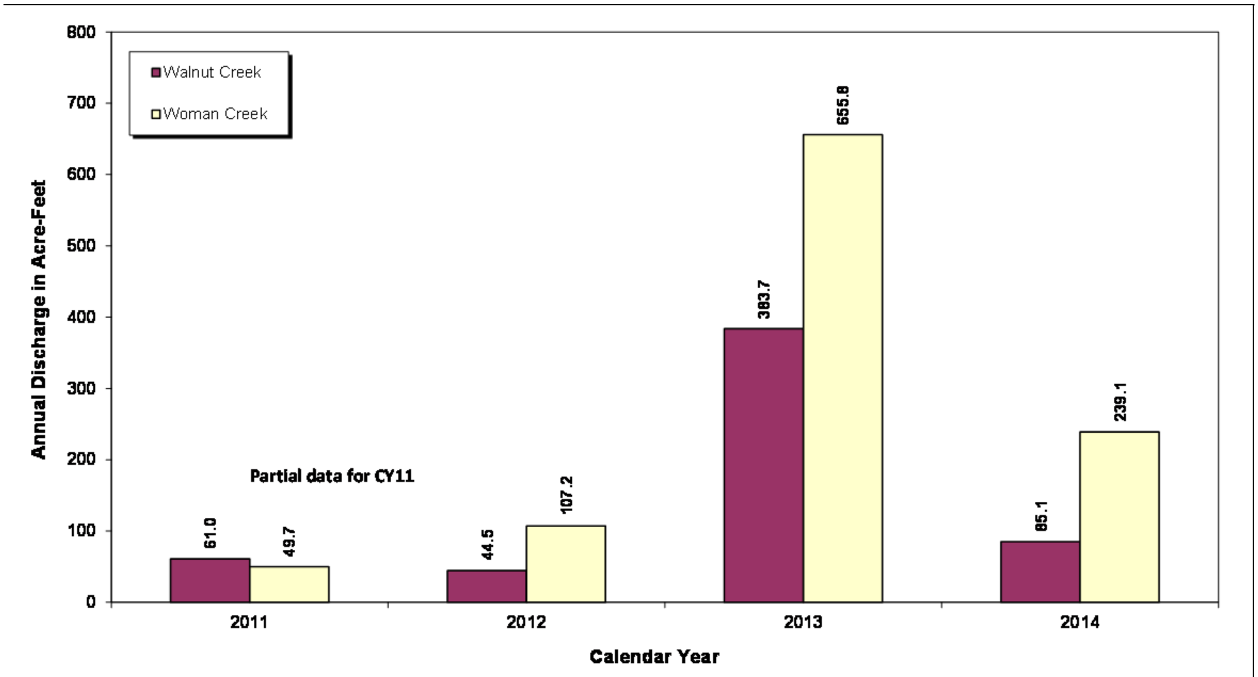


Figure 44. Relative Total Discharge Summary from Major Site Drainages: Pre- and Post-Closure Periods

Site Discharge Summary

Discharge summaries for the two major drainages draining the COU (Walnut and Woman Creeks) are given on Figure 45 and Figure 46. Walnut Creek flows are measured at WALPOC and Woman Creek flows are measured at WOMPOC. Since both locations were installed in September 2011, these figures only show CY 2011–2014 discharge volumes.



Note: CY 2013 discharge for WOMPOC has been revised.

Figure 45. Annual Discharge Summary from COU Drainages: CY 2011–2014

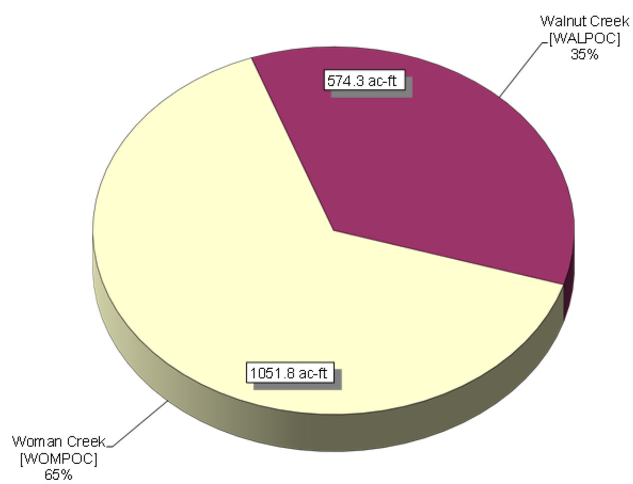
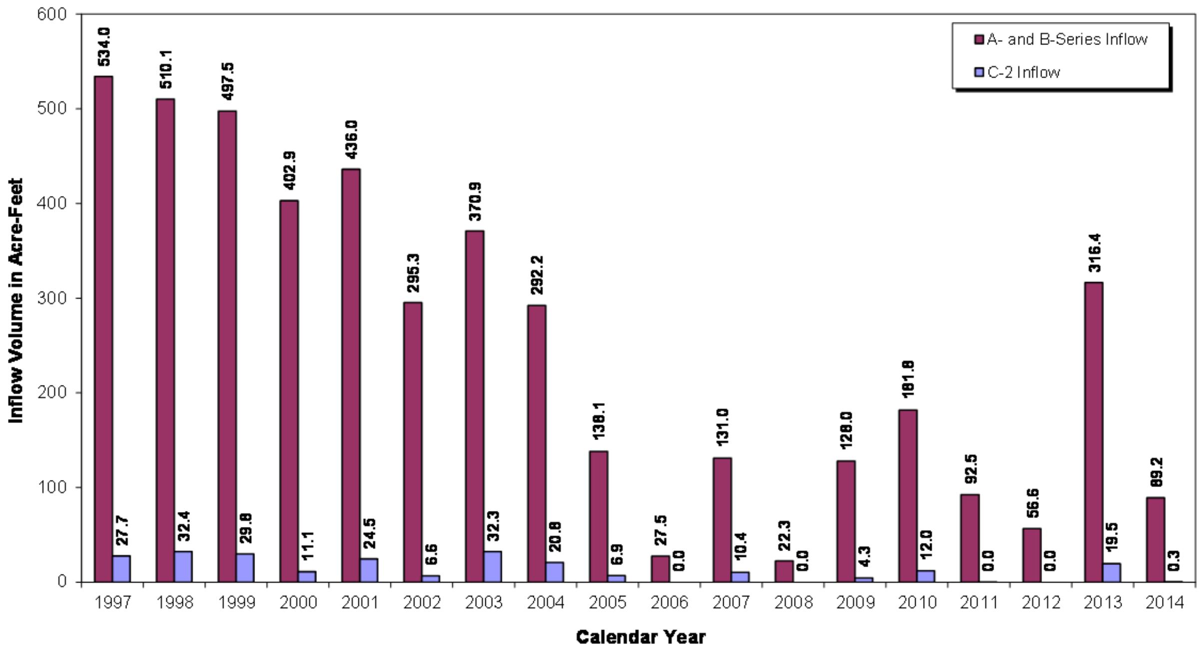


Figure 46. Relative Total Discharge Summary from COU Drainages: CY 2011–2014

Pond Discharge Summary

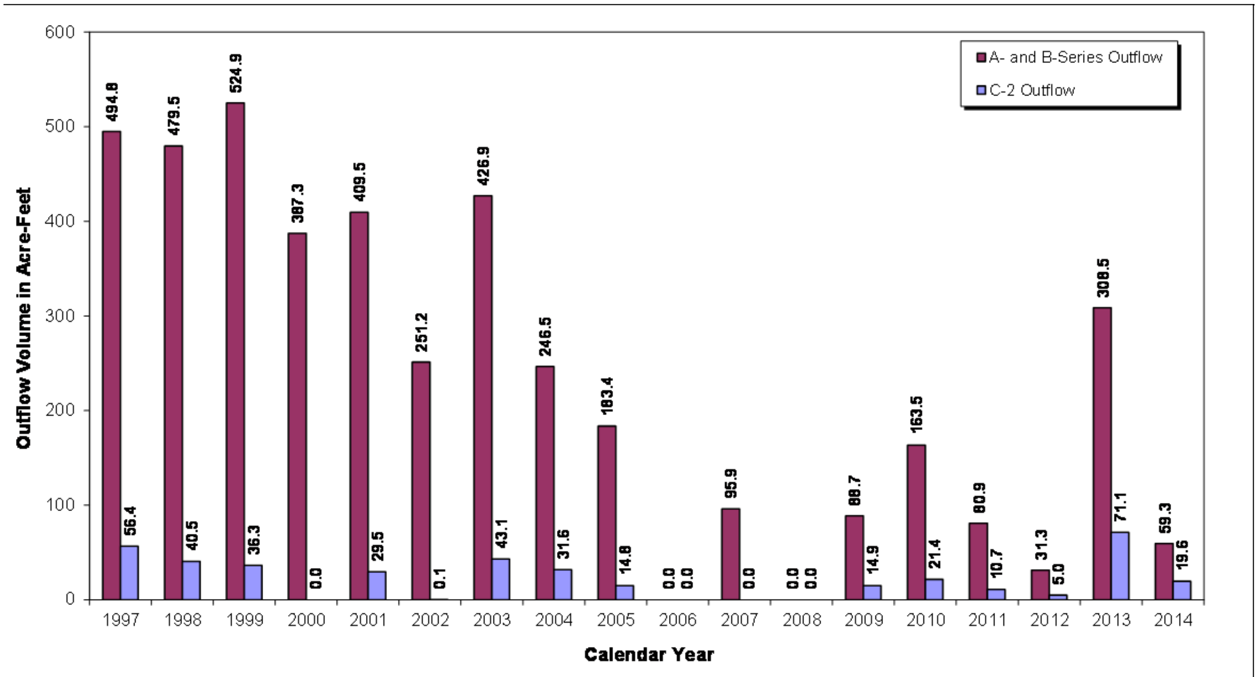
Figure 47 and Figure 48 show the annual ponds inflows and outflows, respectively. Due to the historic intermittent pump transfers of Pond B-5 water to Pond A-4, the flow volumes for the A- and B-Series Ponds are combined. The reduction in pond water volumes as the Site progressed toward closure is clearly observed. Figure 49 shows the relative total CY 1997–2014 inflow volumes from the major drainages tributary to the ponds (as measured at GS10, SW027, SW093, and the former Wastewater Treatment Plant (WWTP) [995POE]).[8, 9] Figure 50 shows discharge volumes from the ponds (as measured at GS08, GS11, and GS31). Pond inflows do not necessarily equal outflows for any given year due to the storage of water in the ponds across water years, evaporative/seepage losses/gains, and local runoff to the ponds.



Notes: A- and B-Series Inflow is the sum of GS10, the former WWTP, and SW093. The C-2 Inflow is the volume measured at SW027.

Figure 47. Pond Inflows: CY 1997–2014

[8] The WWTP was removed from service on November 4, 2004.
[9] The pre-closure period is for the dates January 1, 1997–October 1, 2004; the post-closure period is for the dates October 1, 2005–December 31, 2014.



Notes: A- and B-Series Outflow is the sum of GS11 and GS08. The C-2 Outflow is the volume measured at GS31.

Figure 48. Pond Outflows: CY 1997–2014

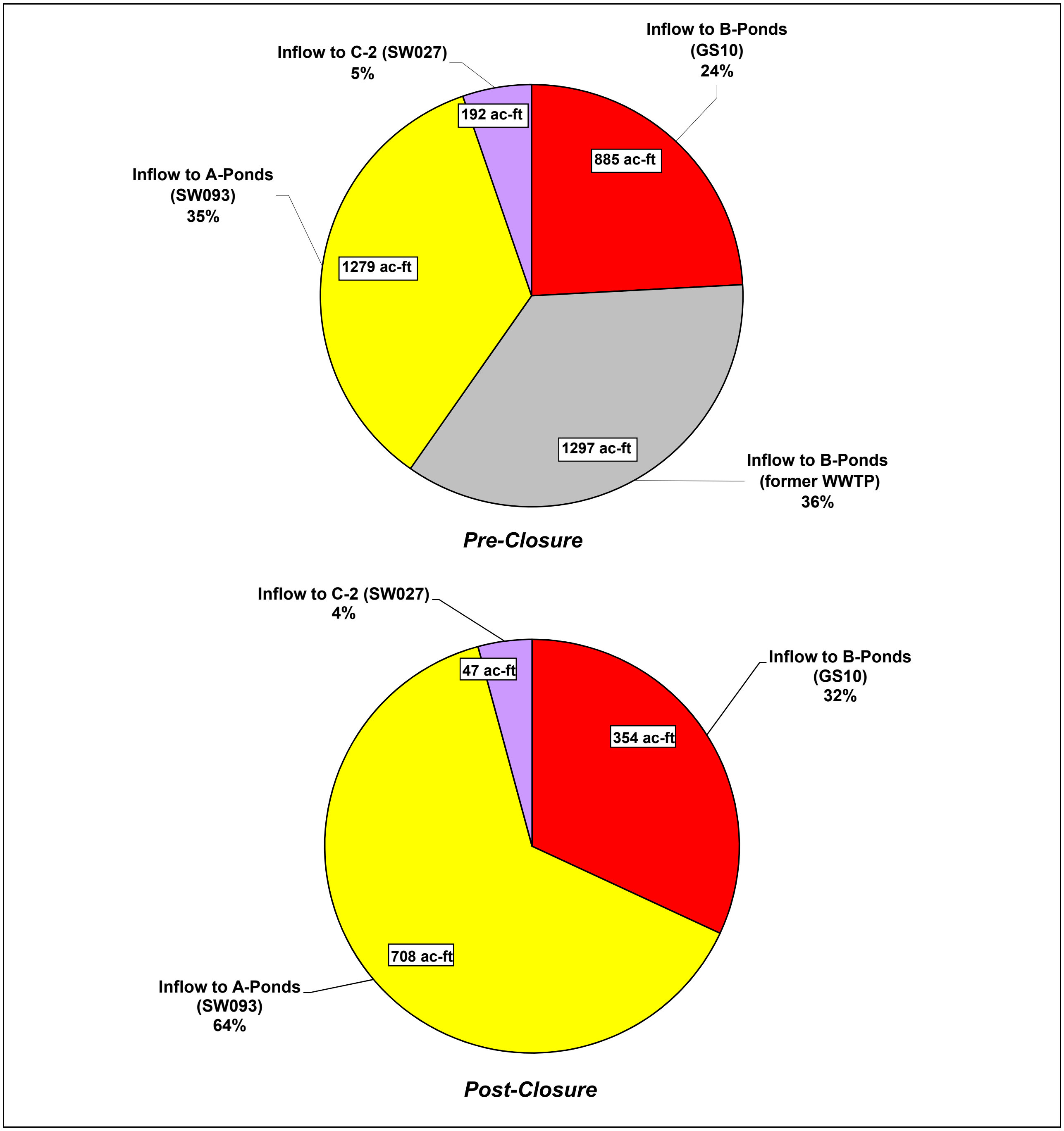


Figure 49. Relative Total Inflow Volumes for Site Ponds: Pre- and Post-Closure Periods

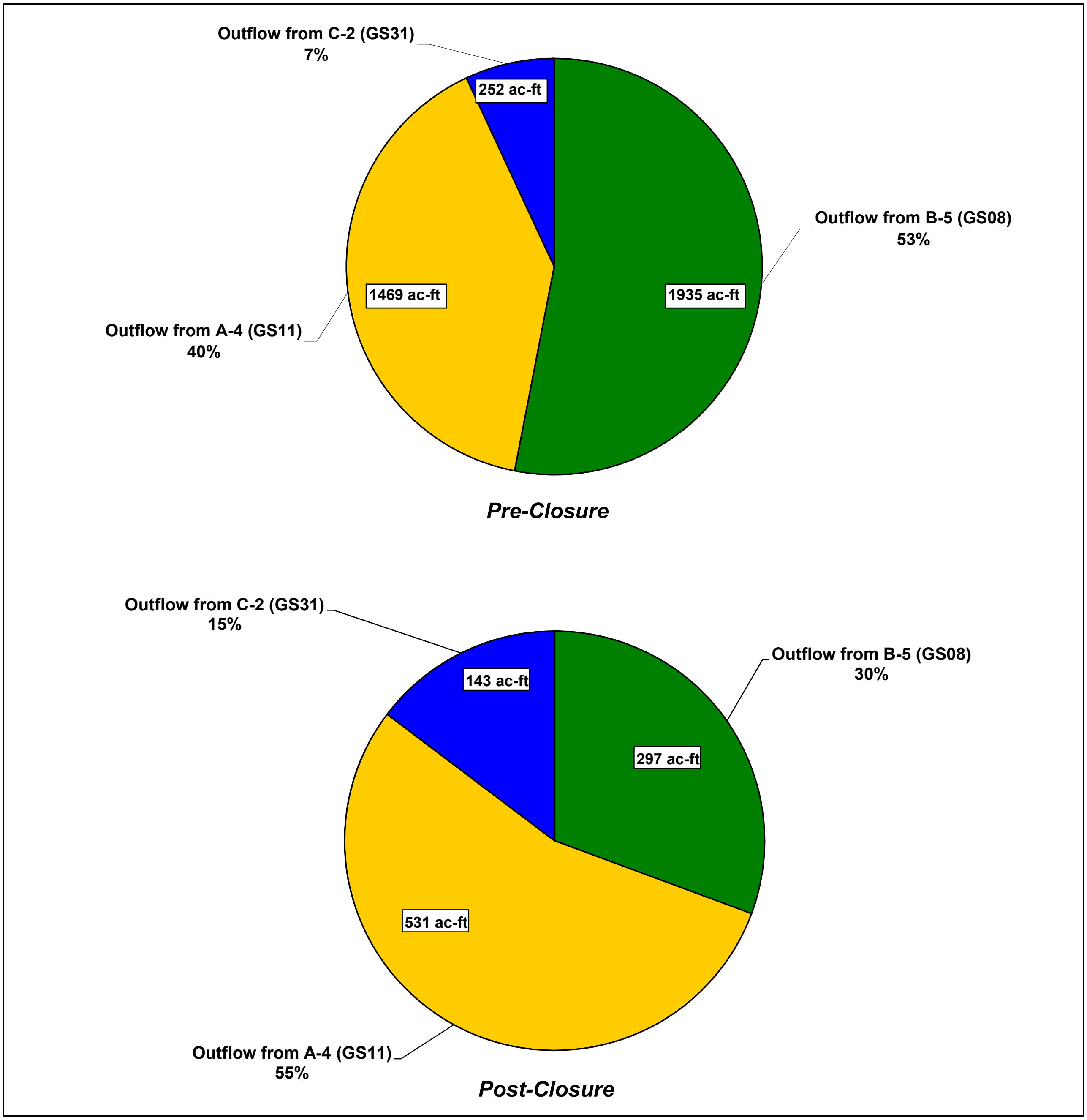


Figure 50. Relative Total Outflow Volumes for Site Ponds: Pre- and Post-Closure Periods

GS01: Woman Creek at Indiana Street

Location: Woman Creek 200 feet upstream of Indiana Street; State Plane: E2093824, N744889.

Drainage Area: The basin includes the Woman Creek drainage and southern portions of the COU; areas west of Highway 93 also contribute runoff (total drainage acreage undetermined).

Period of Record: September 16, 1991, to current year.

Gage: Water-stage recorder and 18-inch Parshall flume (flume is located just east of Indiana Street, sampling conducted on Refuge property). Prior to March 24, 1998, flow measurement was at the onsite sampling location using a 9-inch Parshall flume.

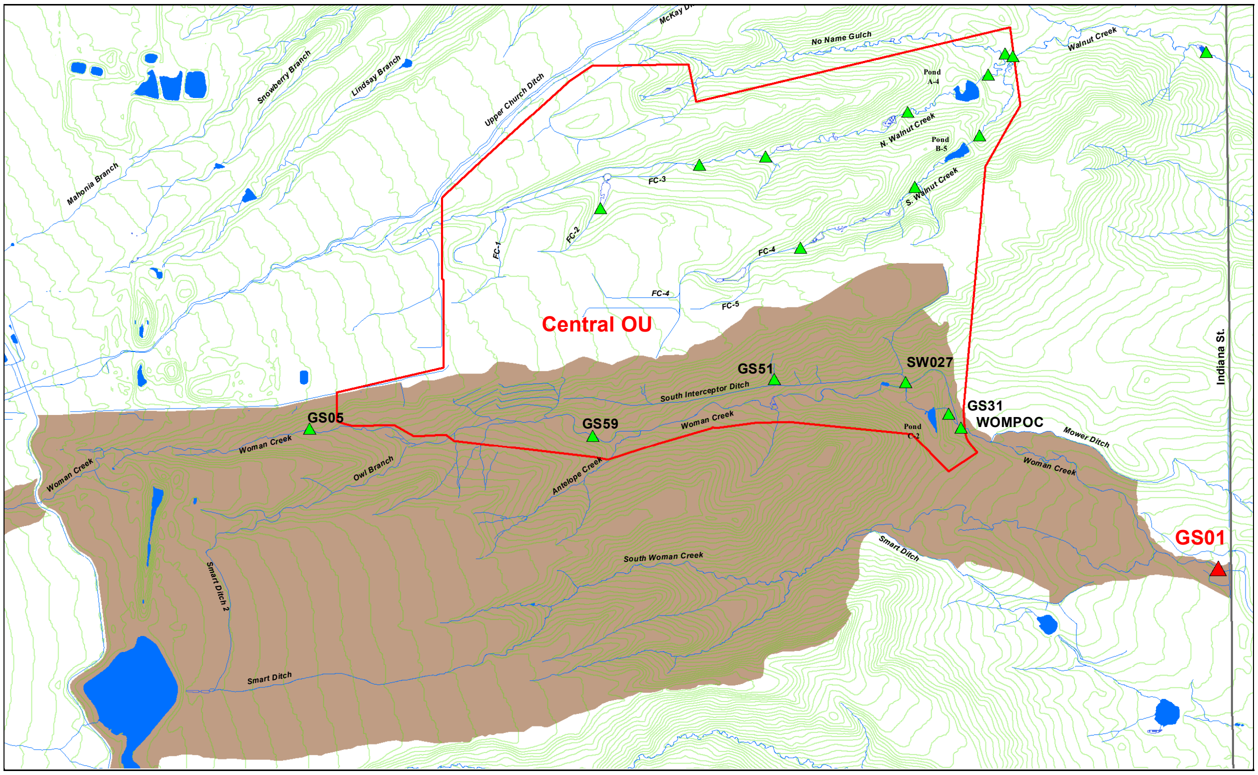


Figure 51. GS01 Drainage Area

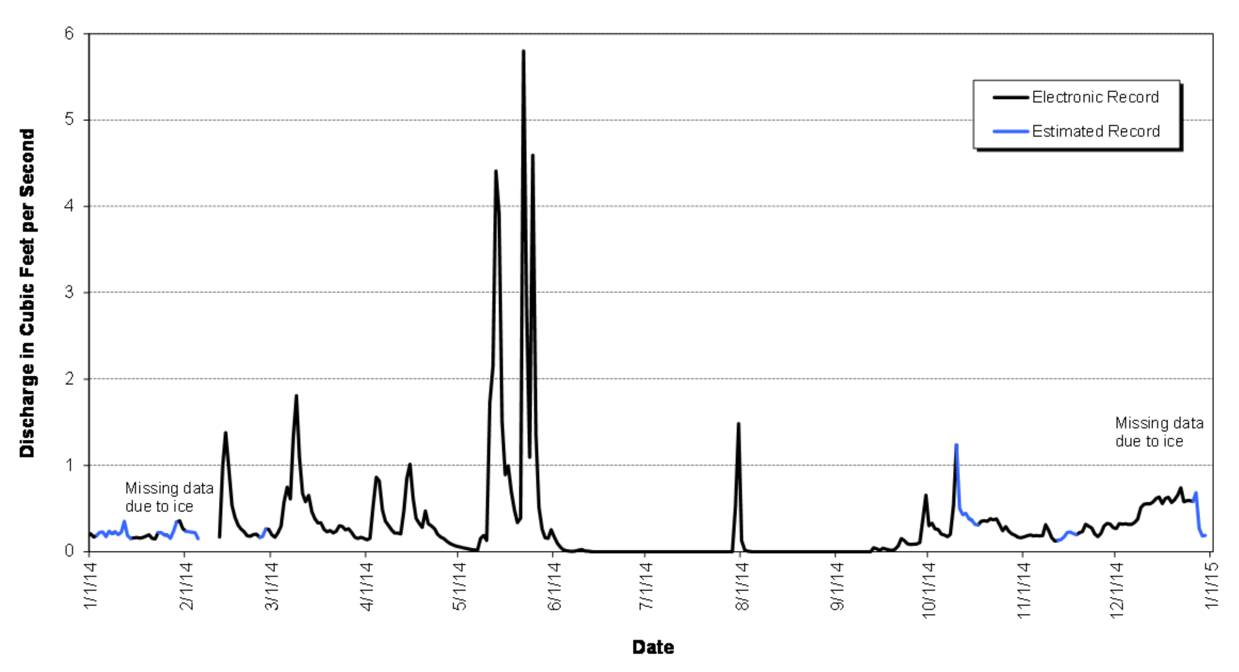


Figure 52. CY 2014 Mean Daily Hydrograph at GS01: Woman Creek at Indiana Street

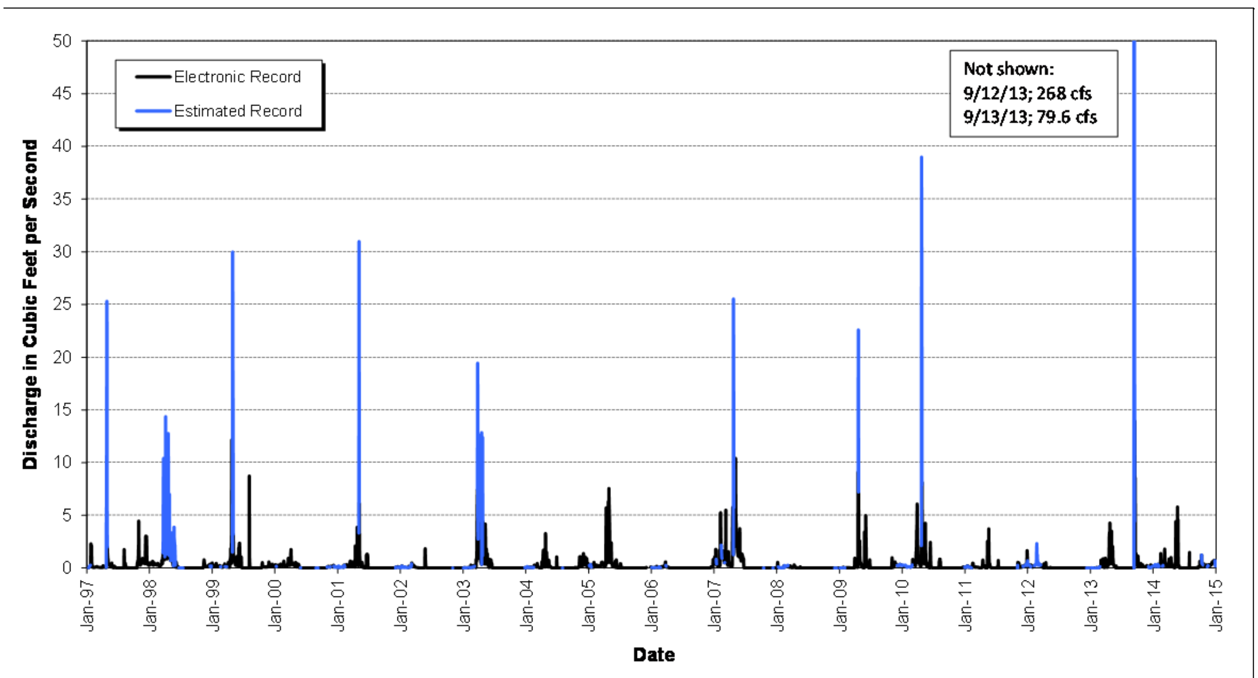


Figure 53. CY 1997–2014 Mean Daily Hydrograph at GS01: Woman Creek at Indiana Street

GS03: Walnut Creek at Indiana Street

Location: Walnut Creek at Flume Pond outlet upstream of Indiana Street; State Plane: E2093618, N753646.

Drainage Area: The basin includes the Walnut Creek drainage and the majority of the COU; areas west of Highway 93 also contribute runoff (total drainage acreage undetermined).

Period of Record: September 2, 1991, to current year.

Gage: Water-stage recorder and parallel 6-inch and 36-inch Parshall flumes prior to November 5, 2002. Rated stream section during flume construction (GS03T; November 5, 2002–February 12, 2003). Three-foot HL flume starting February 12, 2003.

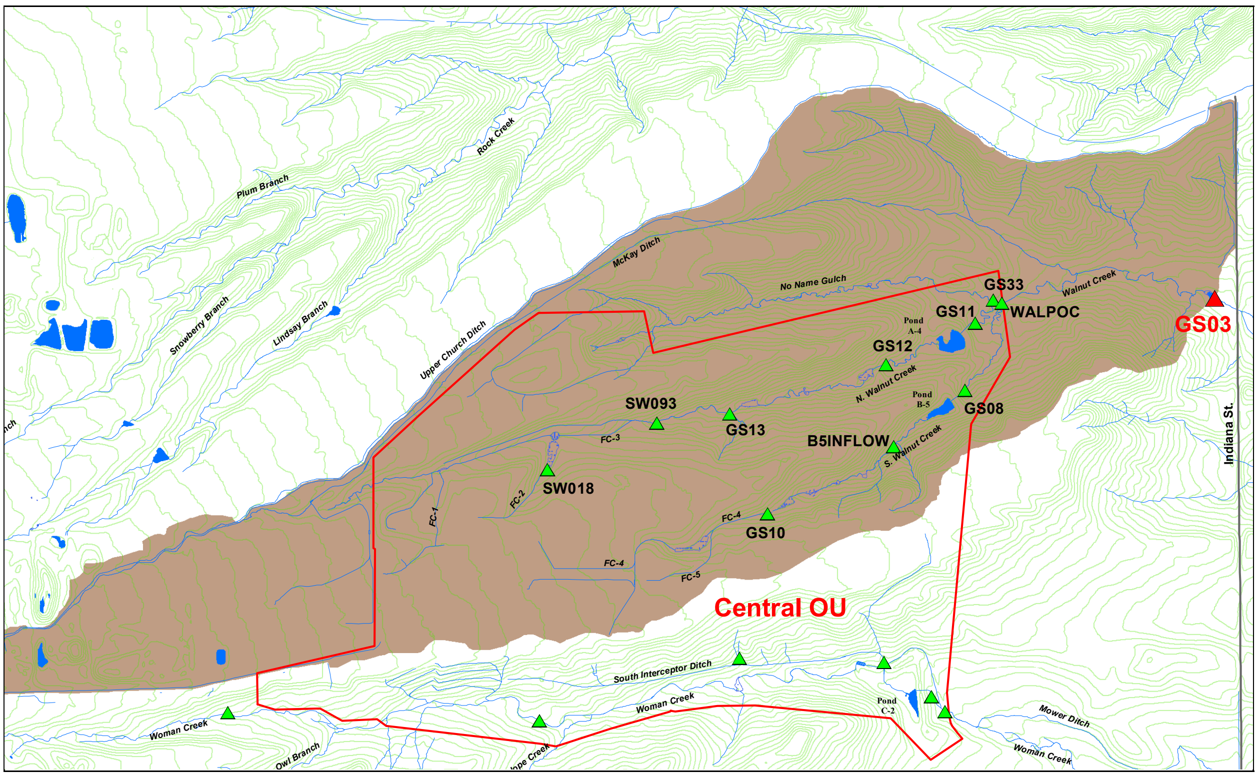


Figure 54. GS03 Drainage Area

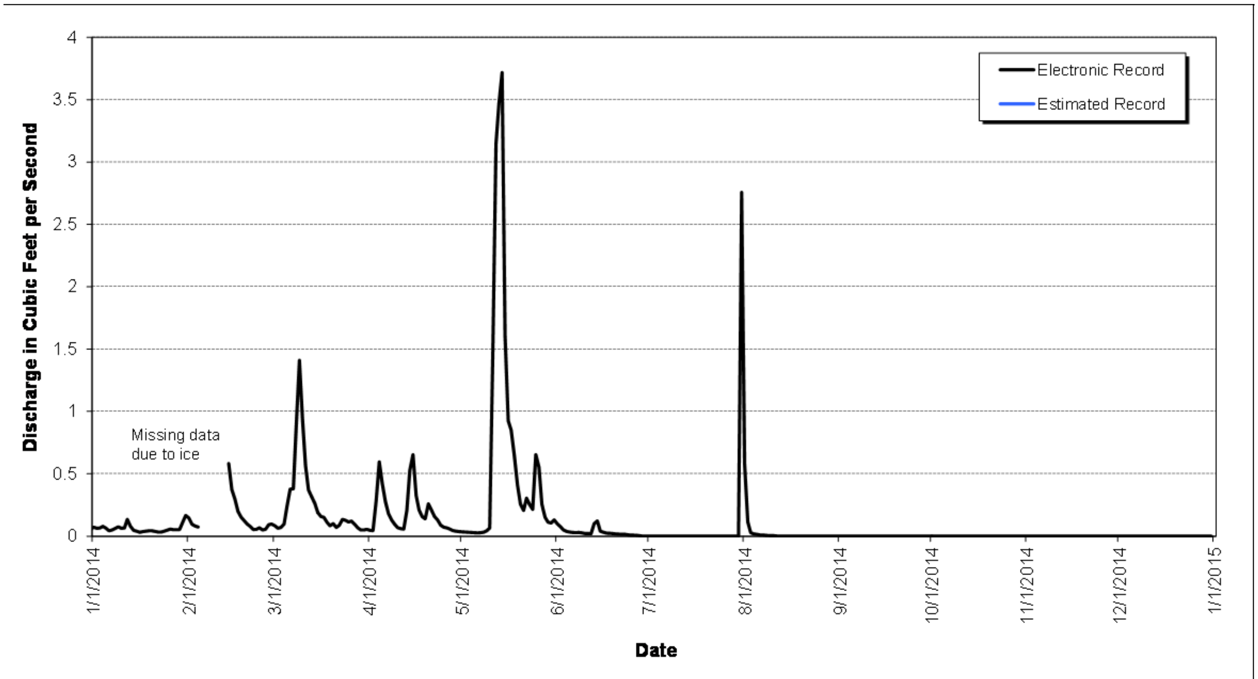


Figure 55. CY 2014 Mean Daily Hydrograph at GS03: Walnut Creek at Indiana Street

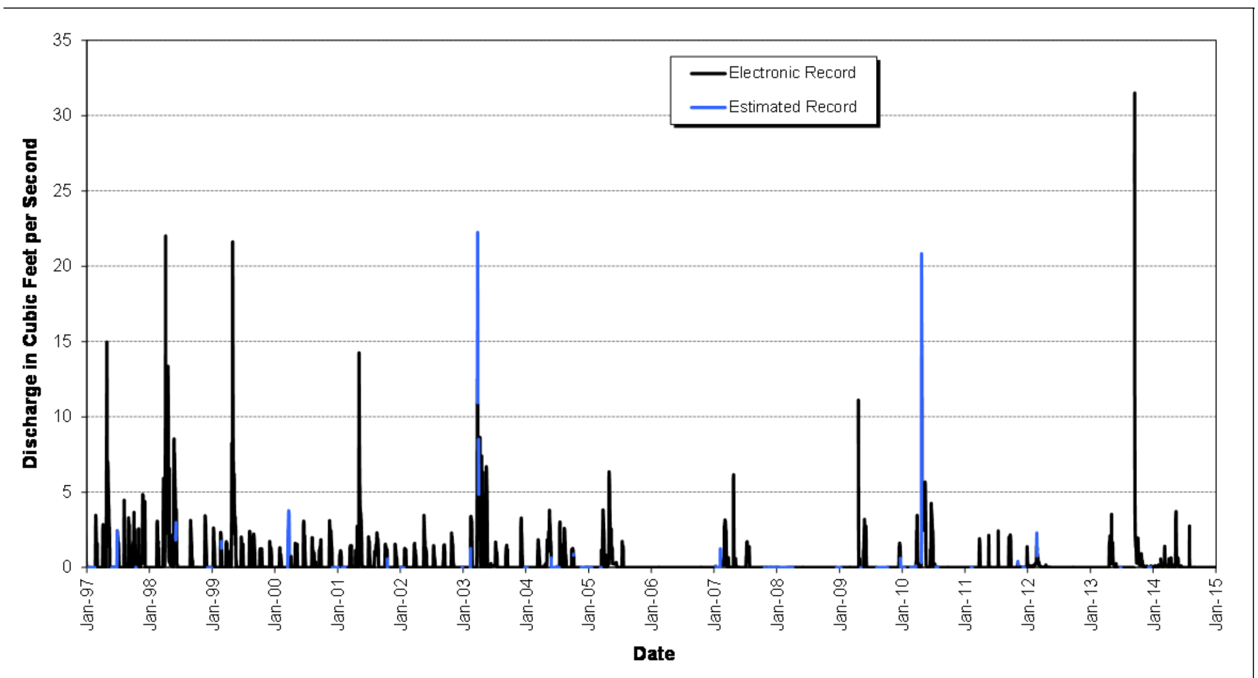


Figure 56. CY 1997–2014 Mean Daily Hydrograph at GS03: Walnut Creek at Indiana Street

WOMPOC: Woman Creek at Eastern COU Boundary

Location: Woman Creek 60 feet upstream of the eastern COU boundary; State Plane: E2089468, N747282.

Drainage Area: The basin includes the Woman Creek drainage and southern portions of the COU; areas west of Highway 93 also contribute runoff (total drainage acreage undetermined).

Period of Record: September 28, 2011, to current year.

Gage: Water-stage recorder and 3-foot HL flume.

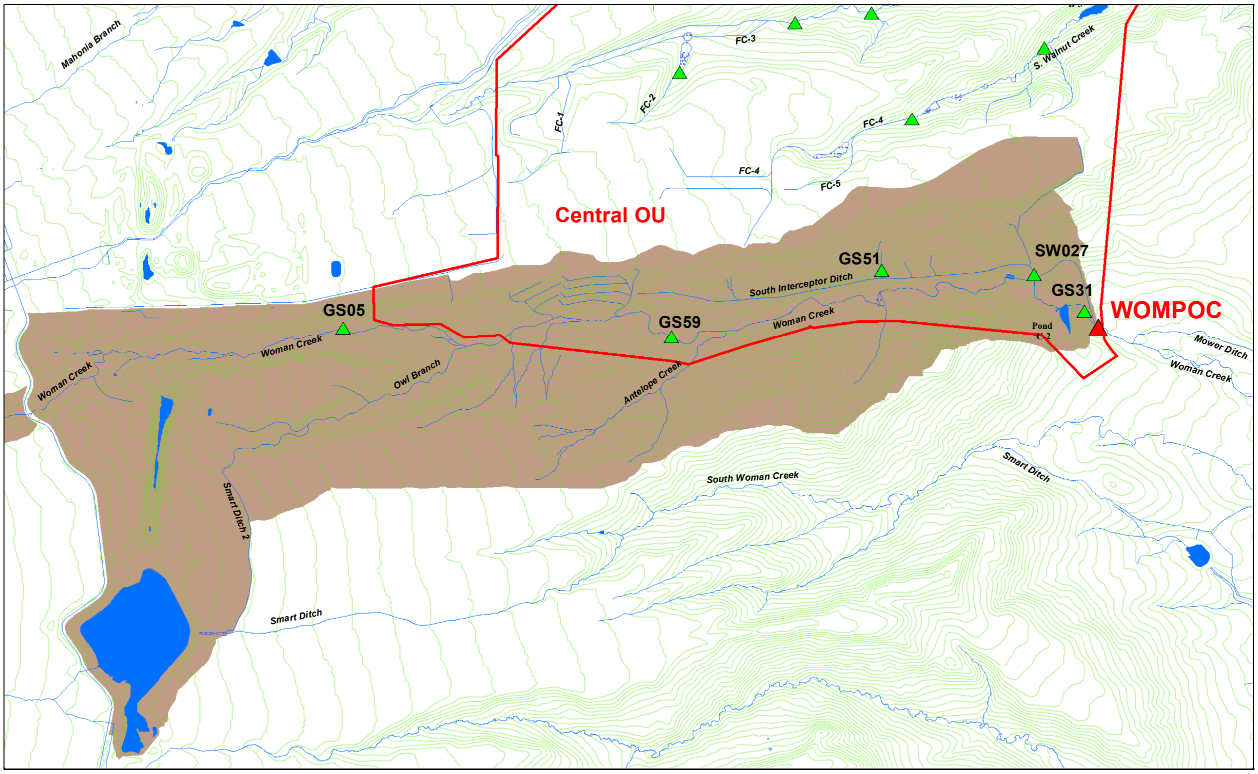


Figure 57. WOMPOC Drainage Area

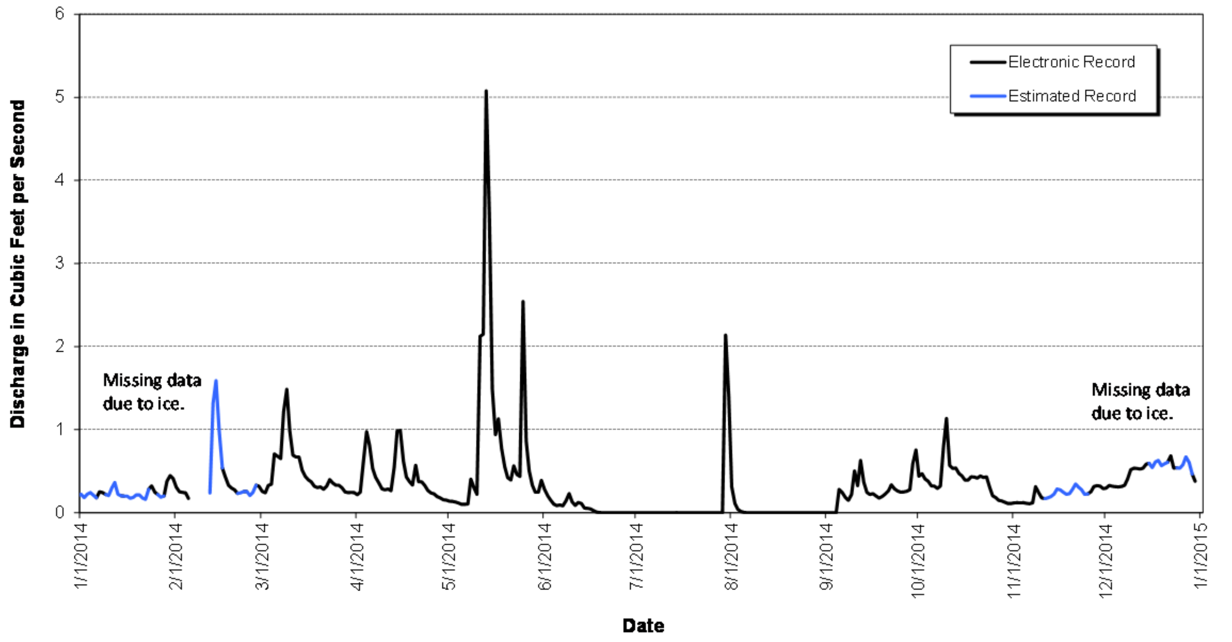


Figure 58. CY 2014 Mean Daily Hydrograph at WOMPOC: Woman Creek at Eastern COU Boundary

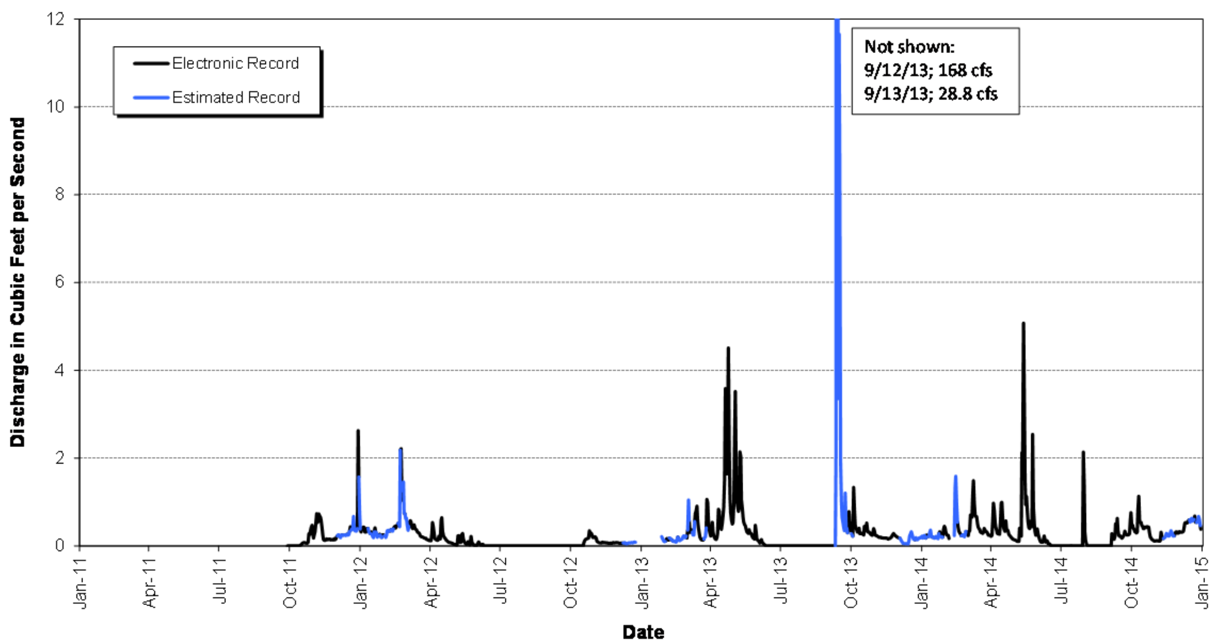


Figure 59. CY 2011–2014 Mean Daily Hydrograph at WOMPOC: Woman Creek at Eastern COU Boundary

WALPOC: Walnut Creek at Eastern COU Boundary

Location: Walnut Creek 15 feet upstream of the eastern COU boundary; State Plane: E2090341, N753574.

Drainage Area: The basin includes the No Name Gulch, North Walnut Creek, and South Walnut Creek drainages, including a majority of the COU (total of 1,051.6 acres).

Period of Record: September 9, 2011, to current year.

Gage: Water-stage recorder and 3-foot HL flume.

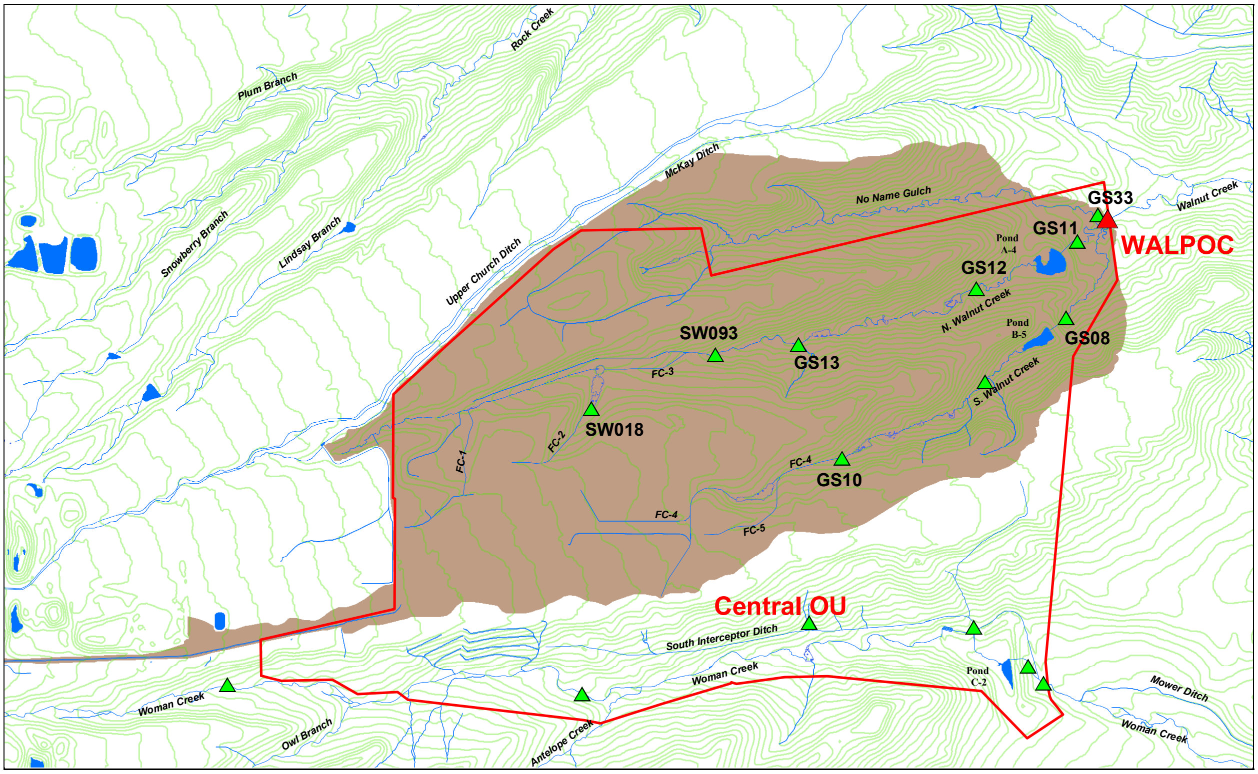


Figure 60. WALPOC Drainage Area

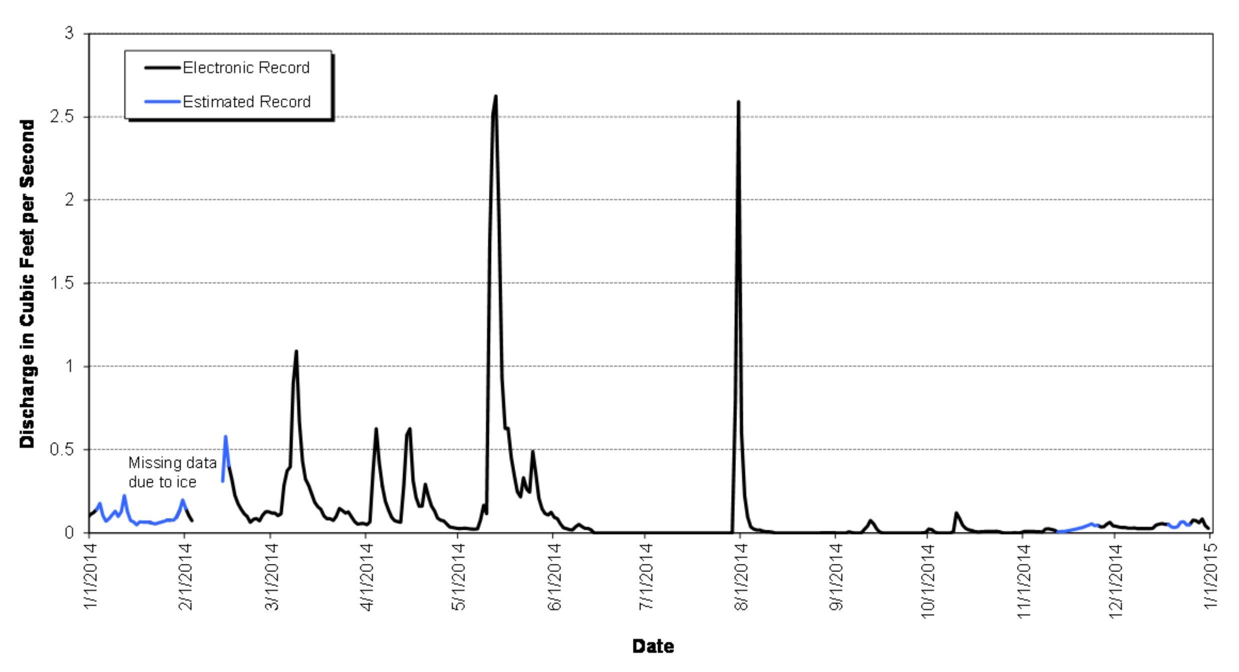


Figure 61. CY 2014 Mean Daily Hydrograph at WALPOC: Walnut Creek at Eastern COU Boundary

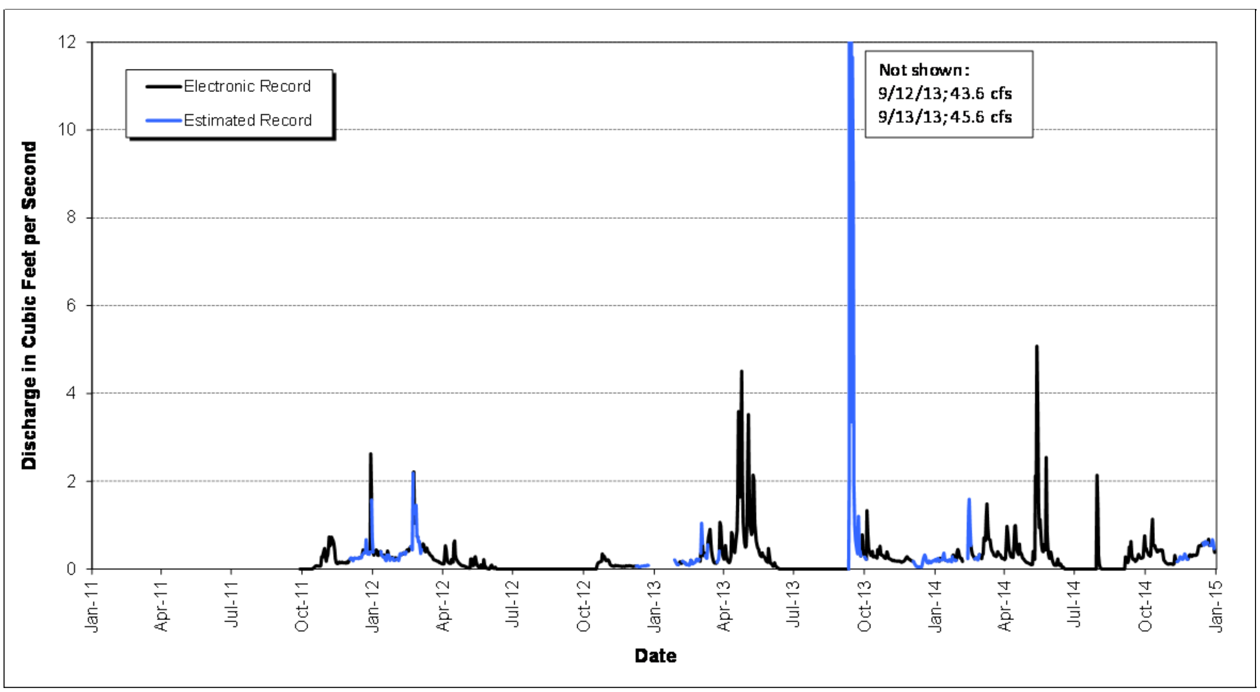


Figure 62. CY 2011–2014 Mean Daily Hydrograph at WALPOC: Walnut Creek at Eastern COU Boundary

GS05: North Woman Creek at West Fence Line

Location: Woman Creek east of the western COU boundary; State Plane: E2078429, N747264.

Drainage Area: The basin includes a portion of the Woman Creek drainage; areas west of Highway 93 also contribute runoff (total drainage acreage undetermined).

Period of Record: September 23, 1991, to current year.

Gage: Water-stage recorder and 9-inch Parshall flume with weir insert.

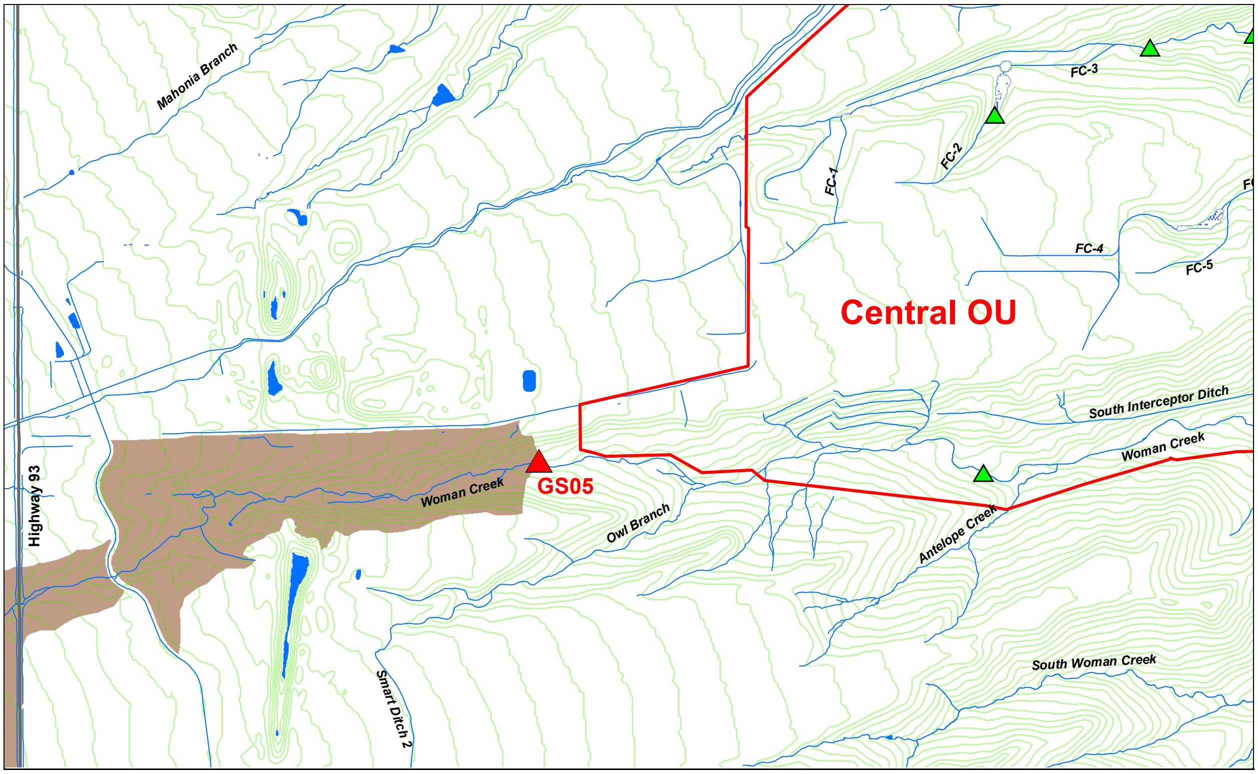


Figure 63. GS05 Drainage Area

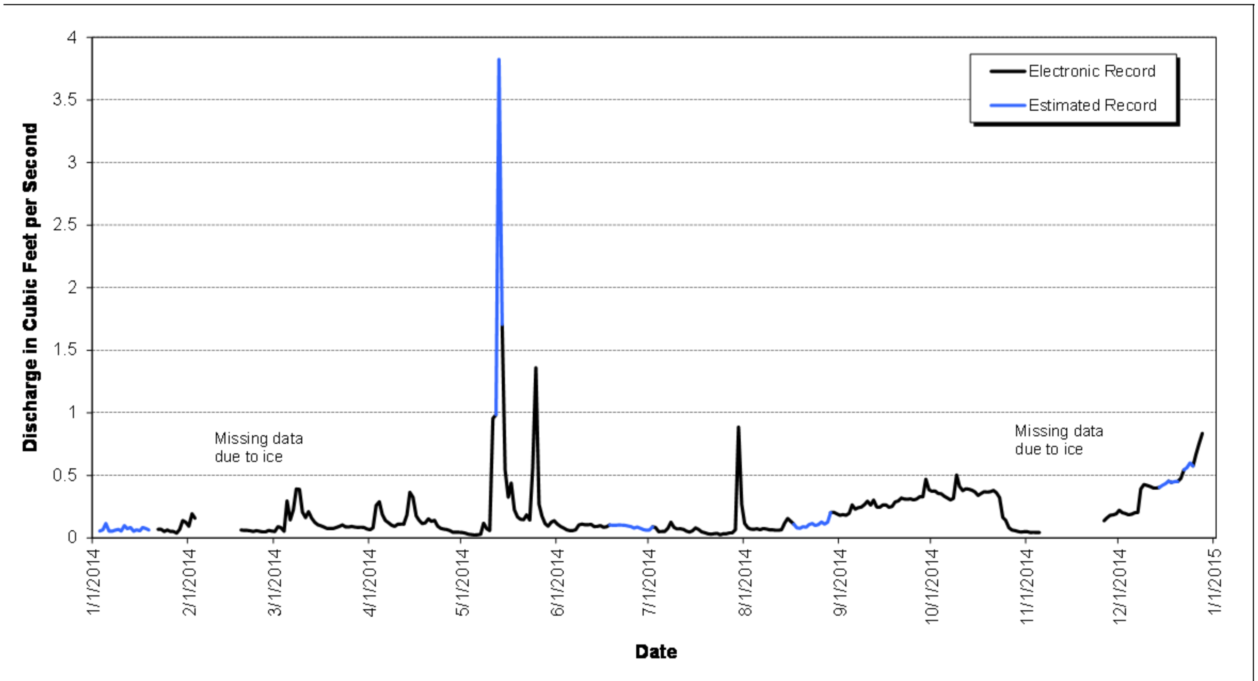


Figure 64. CY 2014 Mean Daily Hydrograph at GS05: North Woman Creek at West Fence Line

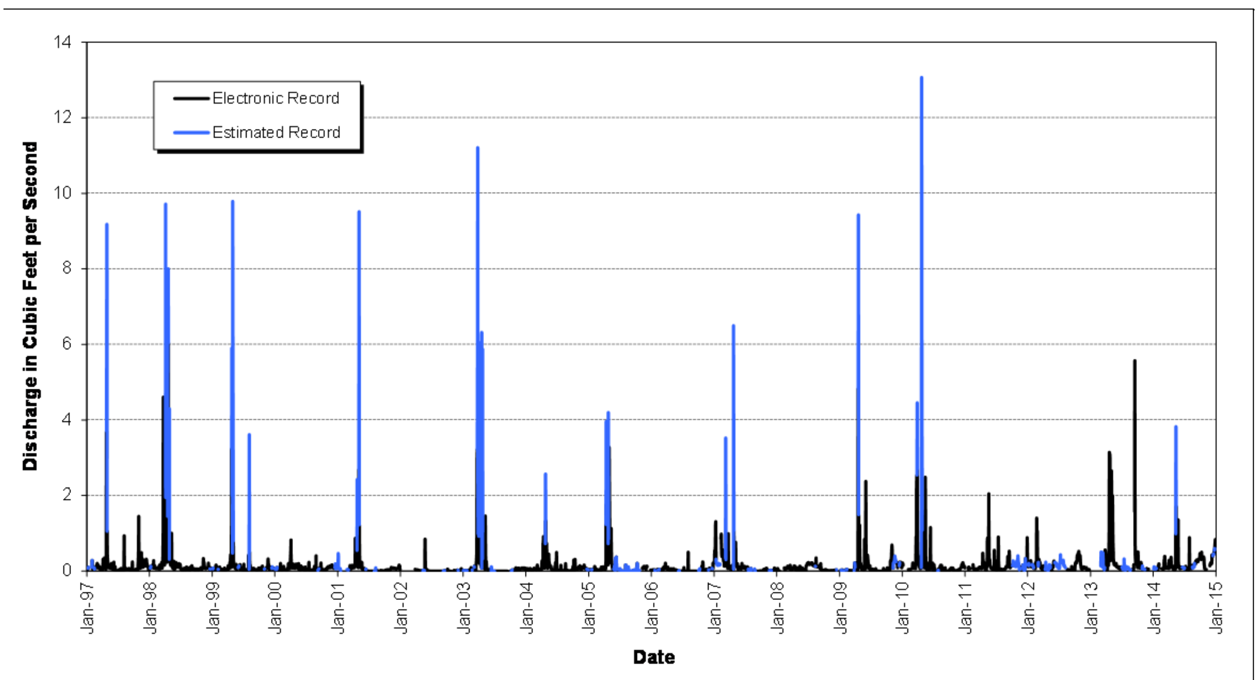


Figure 65. CY 1997–2014 Mean Daily Hydrograph at GS05: North Woman Creek at West Fence Line

GS08: South Walnut Creek at Pond B-5 Outlet

Location: South Walnut Creek at Pond B-5 outlet; State Plane: E2089778, N752231.

Drainage Area: The basin includes the South Walnut Creek drainage and central portions of the COU (total of 311.0 acres).

Period of Record: March 23, 1994, to current year.

Gage: Water-stage recorder and 24-inch Parshall flume with weir insert.

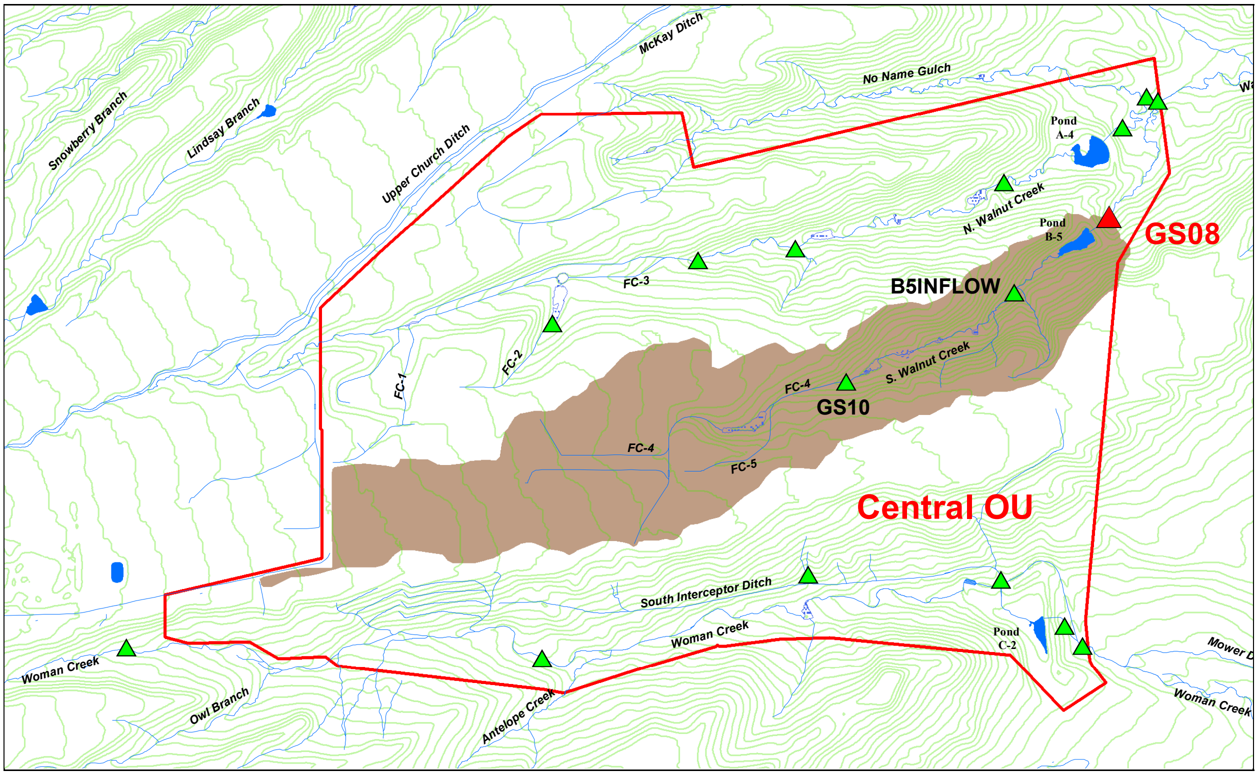


Figure 66. GS08 Drainage Area

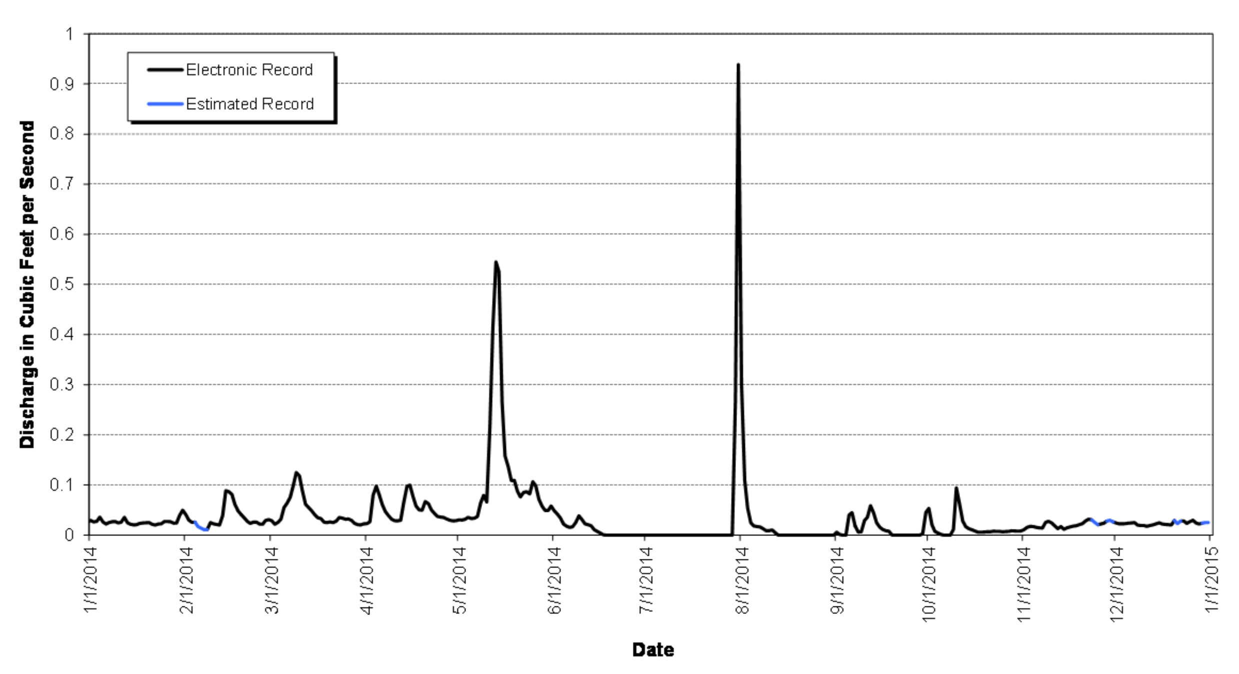


Figure 67. CY 2014 Mean Daily Hydrograph at GS08: South Walnut Creek at Pond B-5 Outlet

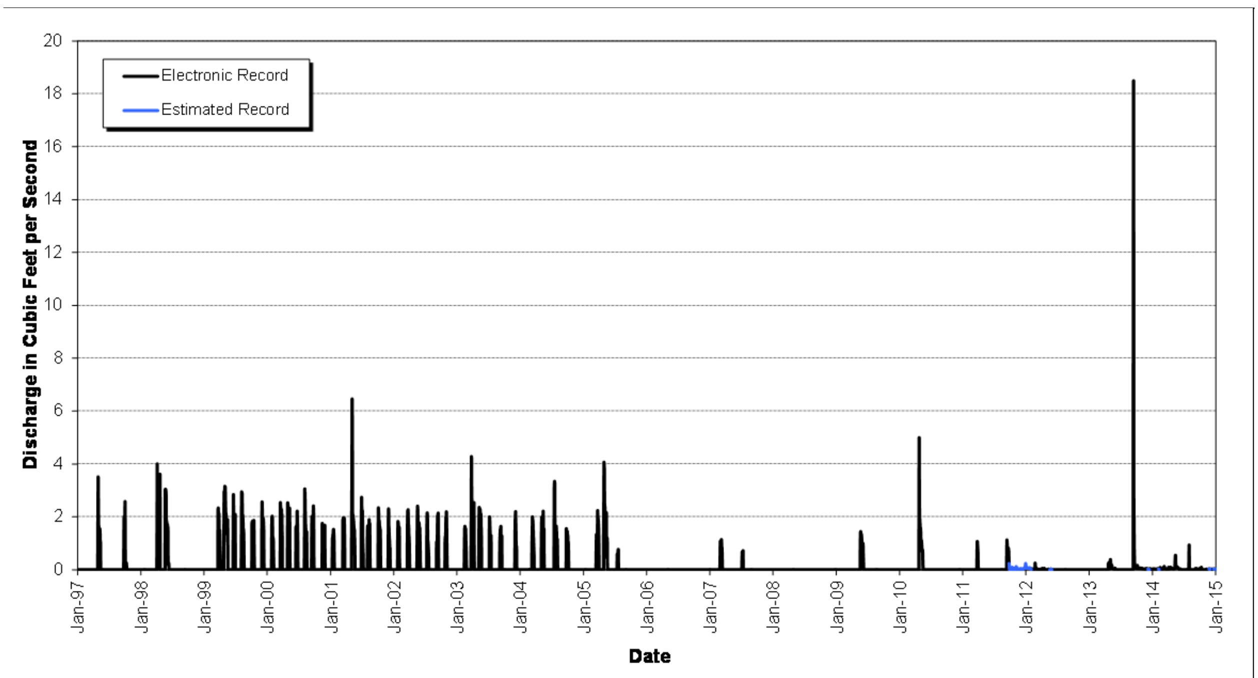


Figure 68. CY 1997–2014 Mean Daily Hydrograph at GS08: South Walnut Creek at Pond B-5 Outlet

GS10: South Walnut Creek at Former Pond B-1

Location: South Walnut Creek above former Pond B-1; State Plane: E2086741, N750329.

Drainage Area: The basin includes the central portion of the COU (total of 206.0 acres).

Period of Record: April 1, 1993, to current year.

Gage: Water-stage recorder and 9-inch Parshall flume with weir insert through August 26, 2013. H flume (2.5-foot) after August 27, 2013.

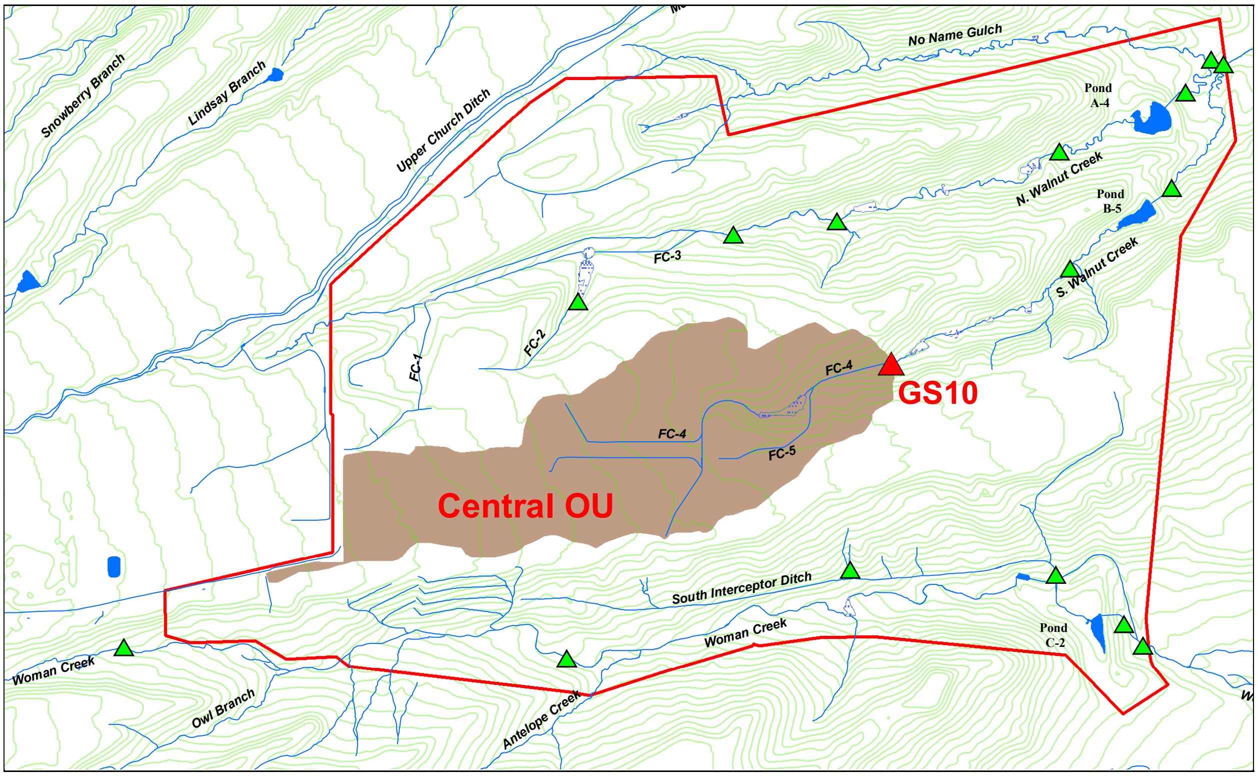


Figure 69. GS10 Drainage Area

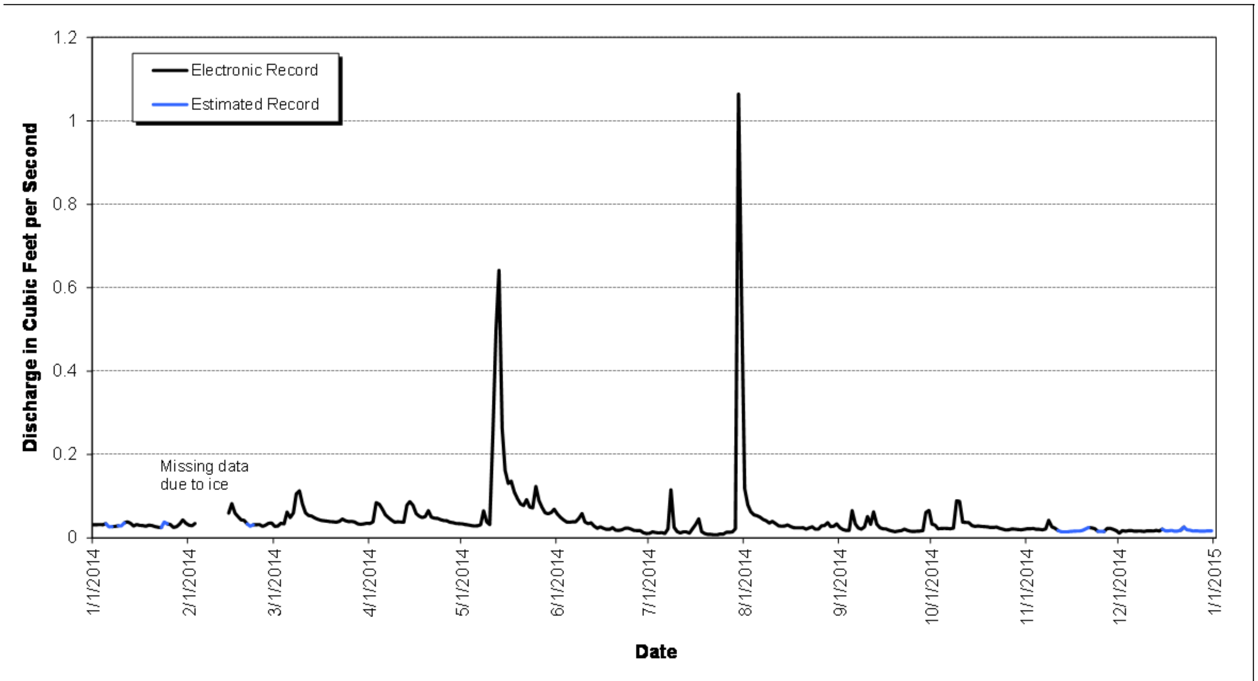


Figure 70. CY 2014 Mean Daily Hydrograph at GS10: South Walnut Creek at Former Pond B-1

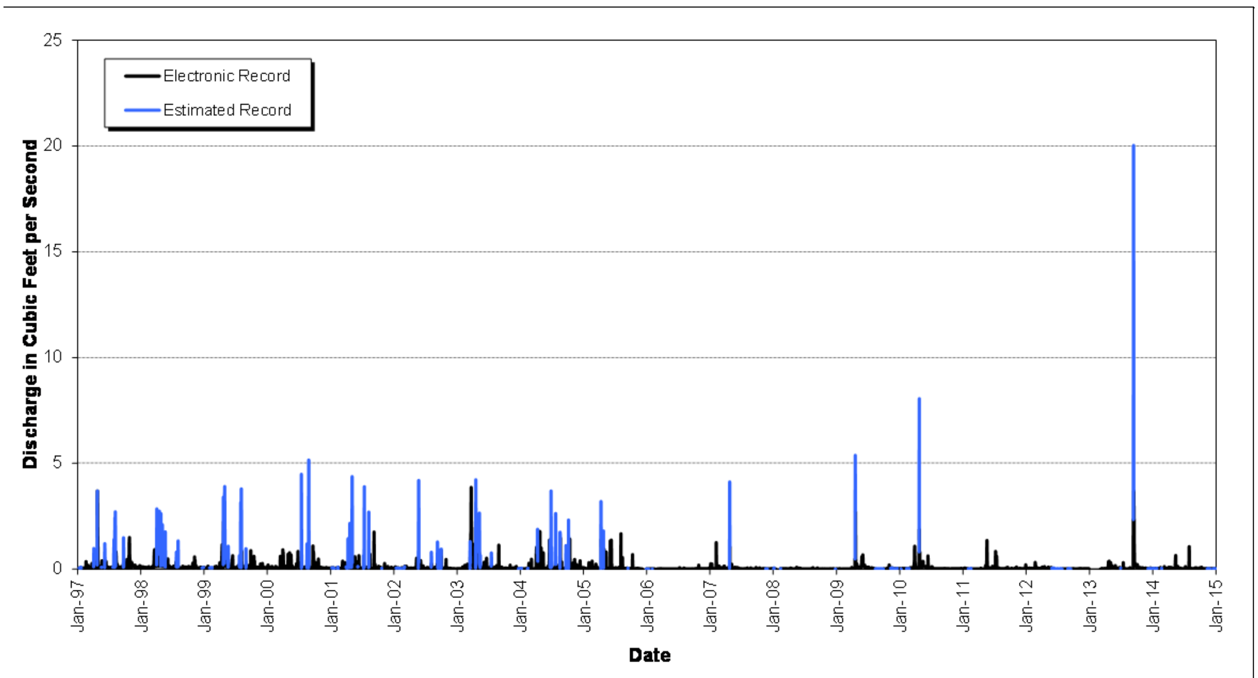


Figure 71. CY 1997–2014 Mean Daily Hydrograph at GS10: South Walnut Creek at Former Pond B-1

GS11: North Walnut Creek at Pond A-4 Outlet

Location: North Walnut Creek at Pond A-4 outlet; State Plane: E2089930, N753265.

Drainage Area: The basin includes the North Walnut Creek drainage and northern portions of the COU (total of 395.0 acres).

Period of Record: May 12, 1992, to current year.

Gage: Water-stage recorder and 24-inch Parshall flume with weir insert.

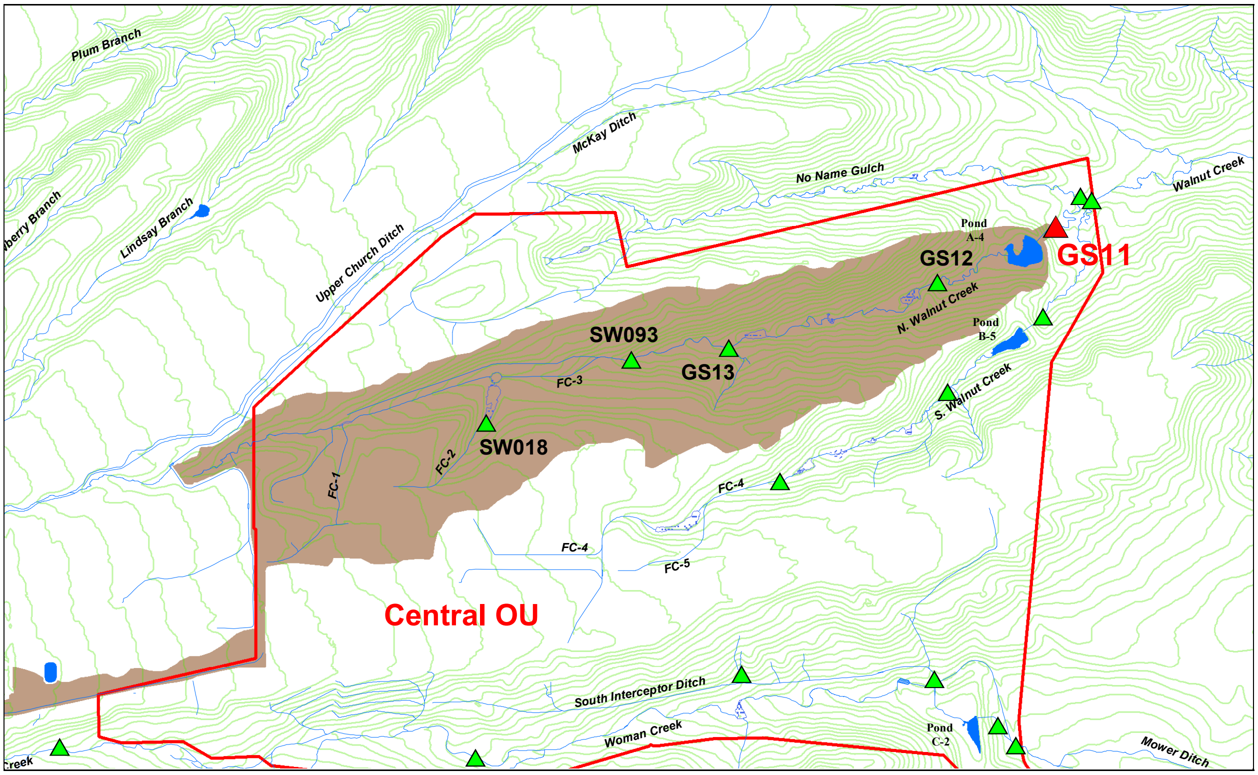


Figure 72. GS11 Drainage Area

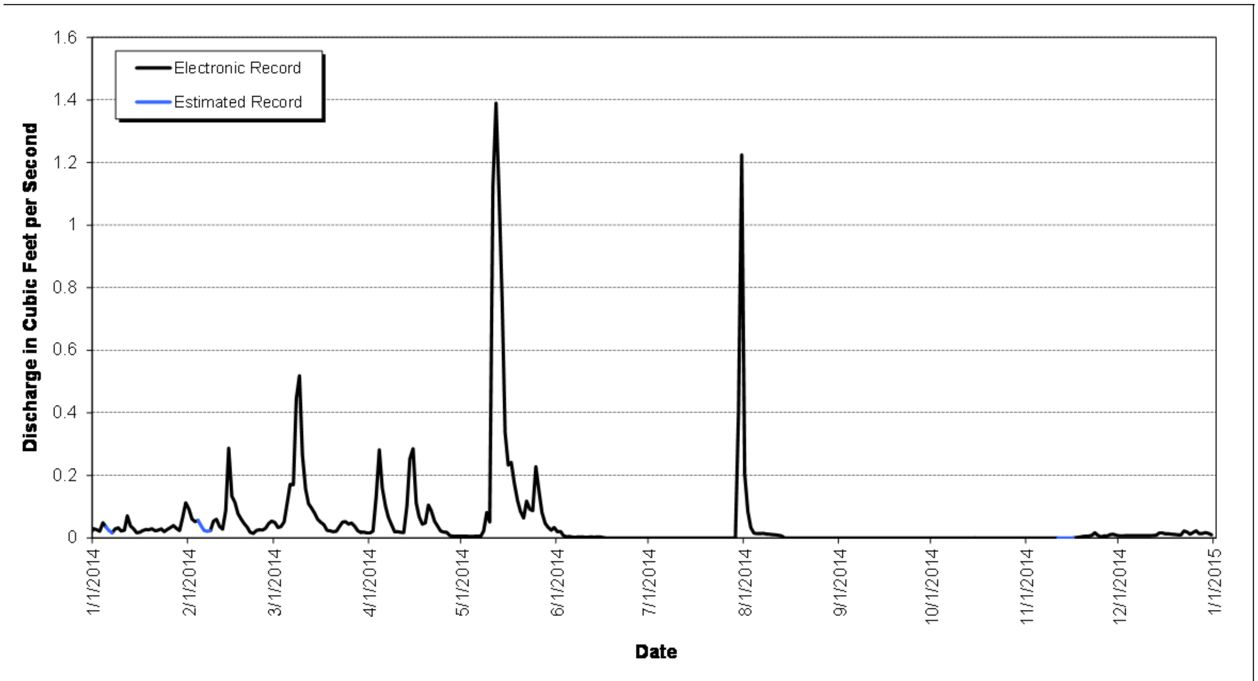


Figure 73. CY 2014 Mean Daily Hydrograph at GS11: North Walnut Creek at Pond A-4 Outlet

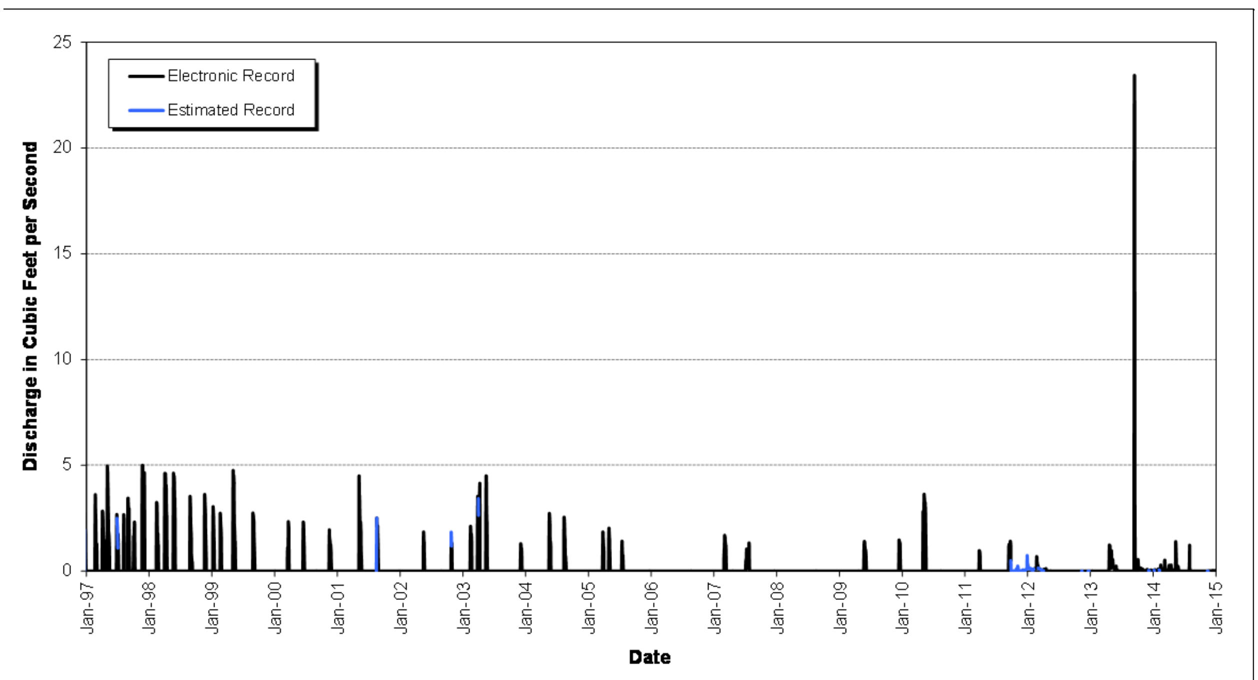


Figure 74. CY 1997–2014 Mean Daily Hydrograph at GS11: North Walnut Creek at Pond A-4 Outlet

GS12: North Walnut Creek at Former Pond A-3 Outlet

Location: North Walnut Creek at former Pond A-3 outlet; State Plane: E2088564, N752629.

Drainage Area: The basin includes the North Walnut Creek drainage and northern portions of the COU (total of 361.7 acres).

Period of Record: May 13, 1992, to current year.

Gage: Water-stage recorder and 30-inch Parshall flume.

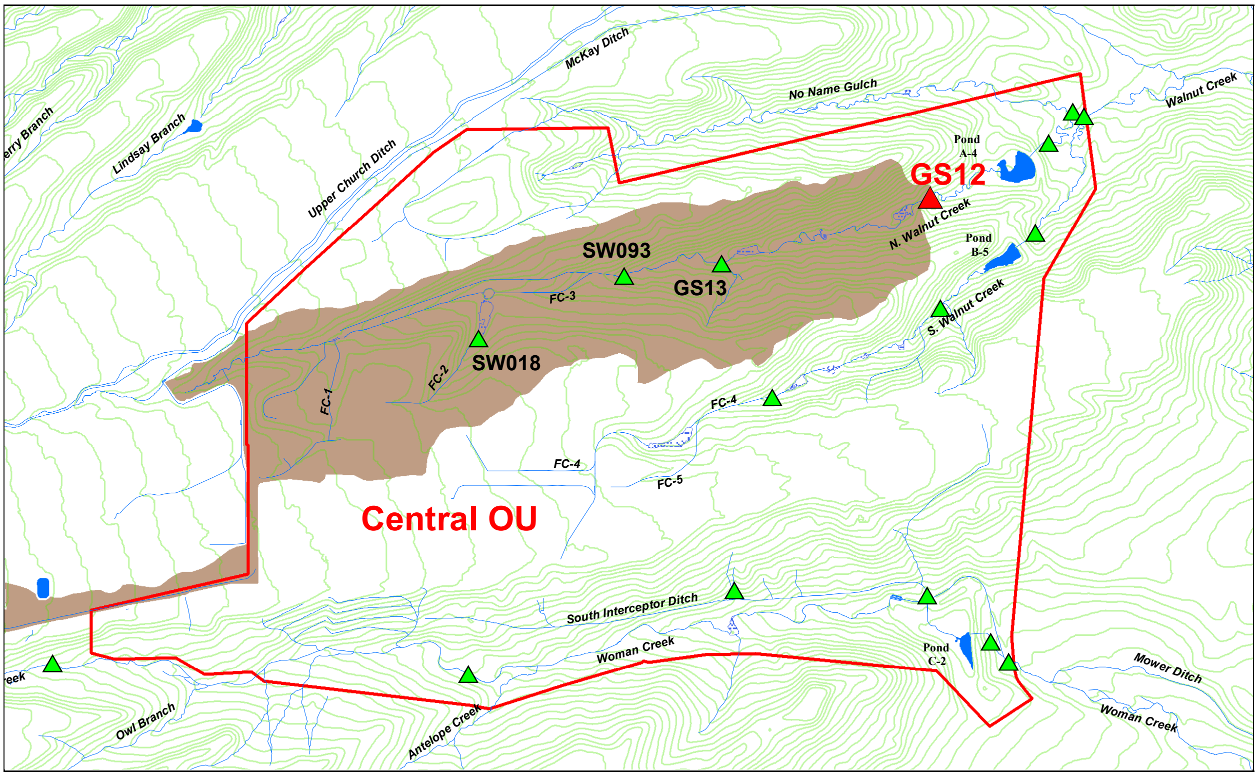


Figure 75. GS12 Drainage Area

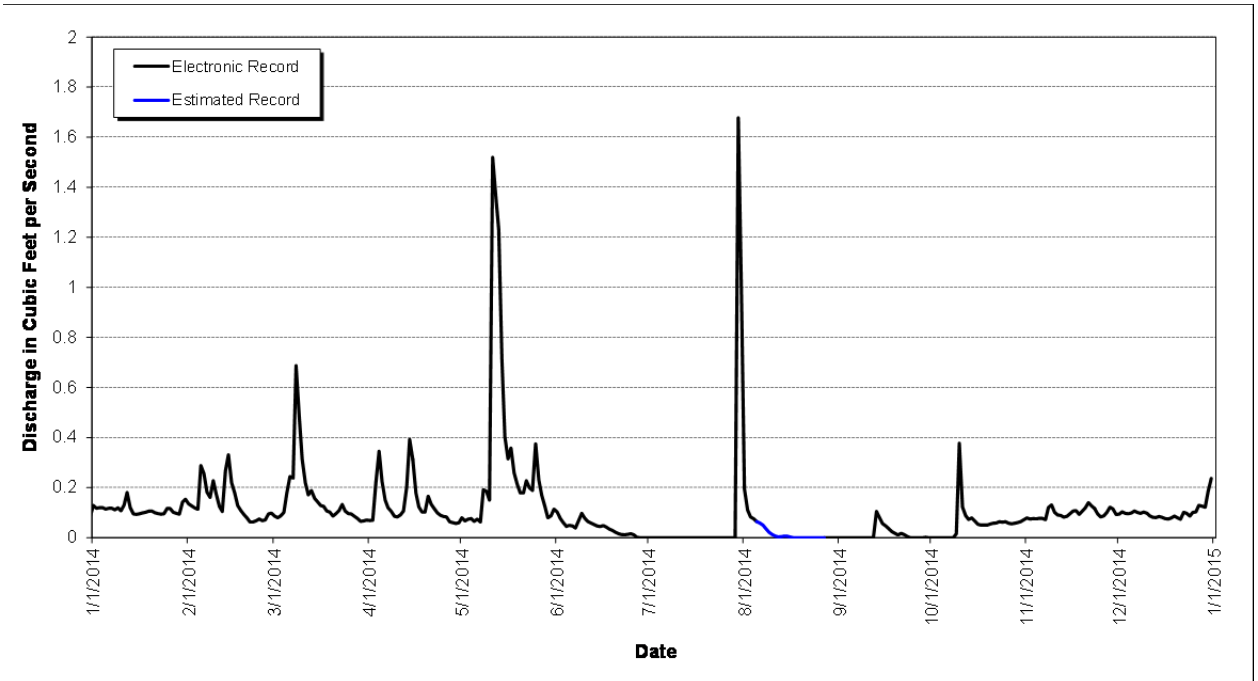


Figure 76. CY 2014 Mean Daily Hydrograph at GS12: North Walnut Creek at Former Pond A-3 Outlet

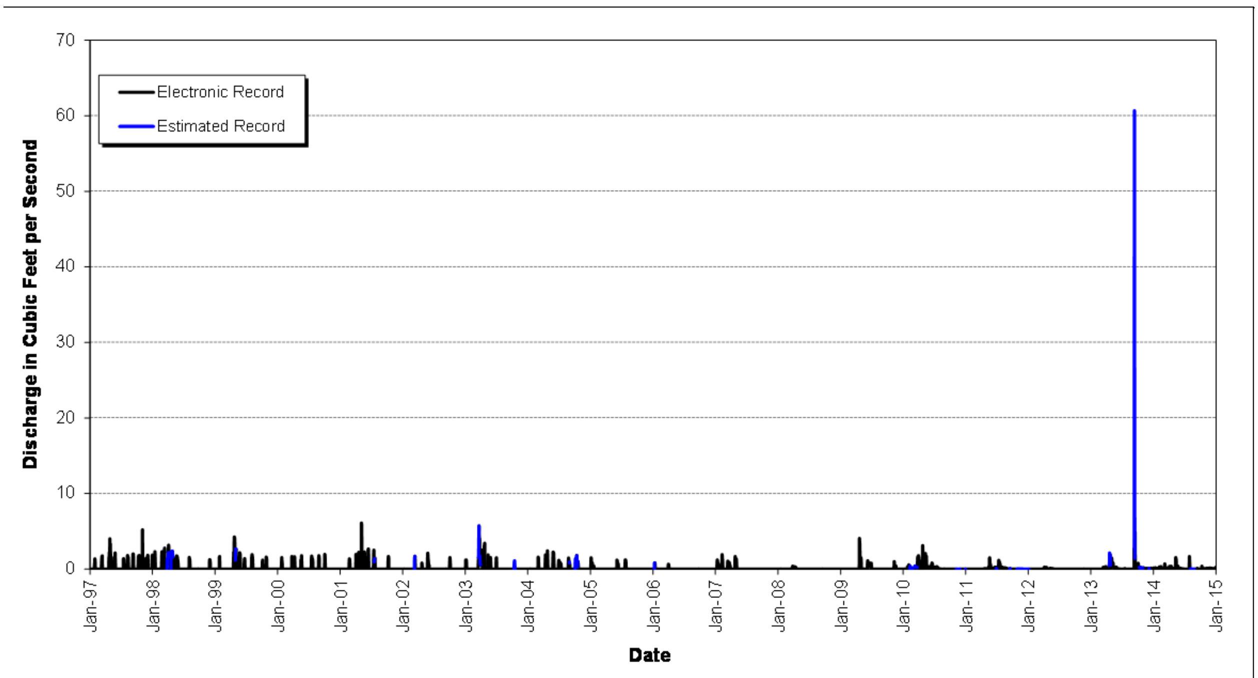


Figure 77. CY 1997–2014 Mean Daily Hydrograph at GS12: North Walnut Creek at Former Pond A-3 Outlet

GS13: North Walnut Creek at Former Pond A-1

Location: North Walnut Creek at former Pond A-1; State Plane: E2086153, N751870.

Drainage Area: The basin includes the North Walnut Creek drainage and northwestern portions of the COU (total of 260.8 acres).

Period of Record: October 1, 2005, to current year.

Gage: Water-stage recorder and 6-inch Parshall flume.

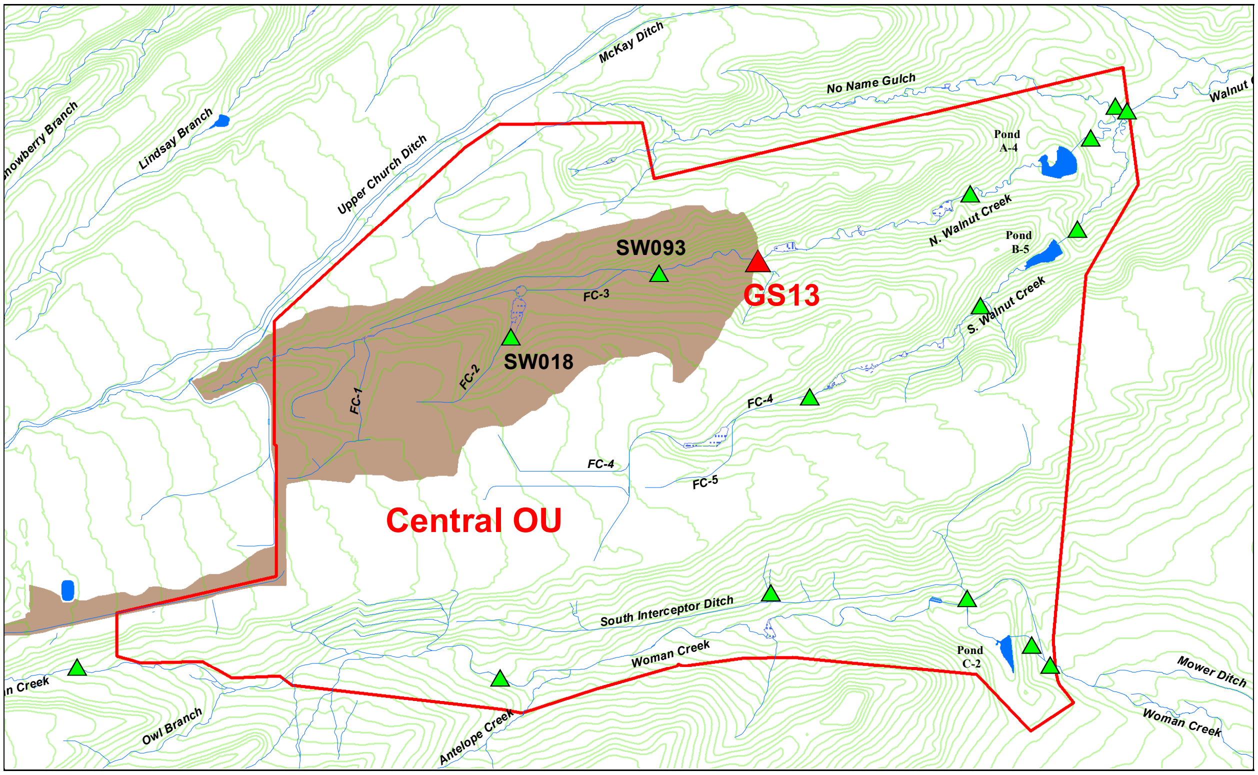


Figure 78. GS13 Drainage Area

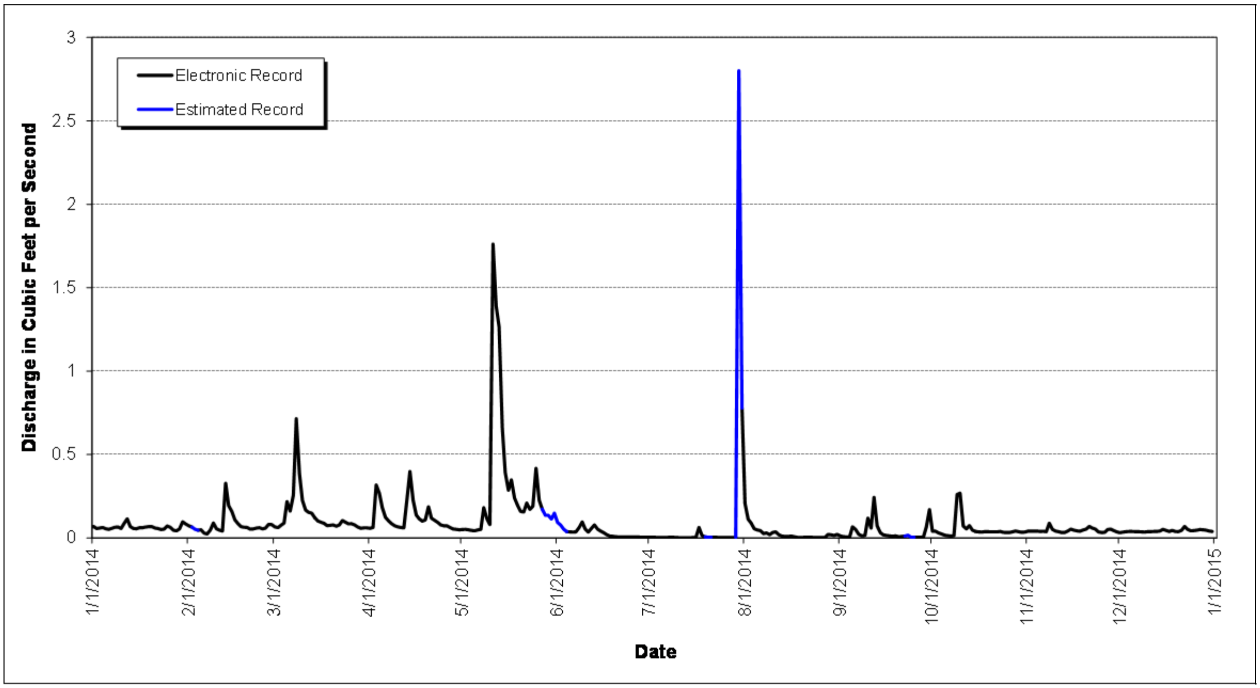


Figure 79. CY 2014 Mean Daily Hydrograph at GS13: North Walnut Creek at Former Pond A-1

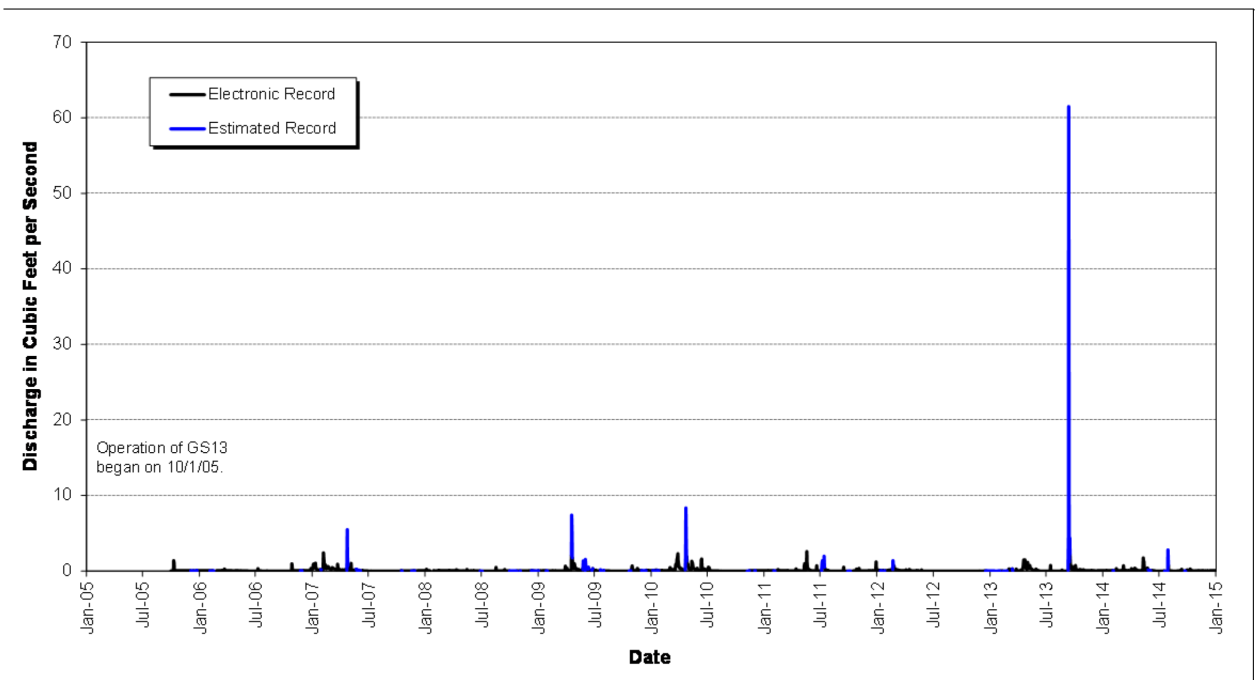


Figure 80. CY 2005–2014 Mean Daily Hydrograph at GS13: North Walnut Creek at Former Pond A-1

GS31: Woman Creek at Pond C-2 Outlet

Location: Pond C-2 outlet; State Plane: E2089261, N747512.

Drainage Area: The basin includes a portion of the southern COU draining to the SID and the area surrounding Pond C-2 (total of 204.1 acres).

Period of Record: October 1, 1996, to current year.

Gage: Water-stage recorder and 24-inch Parshall flume; weir insert installed March 6, 2014.

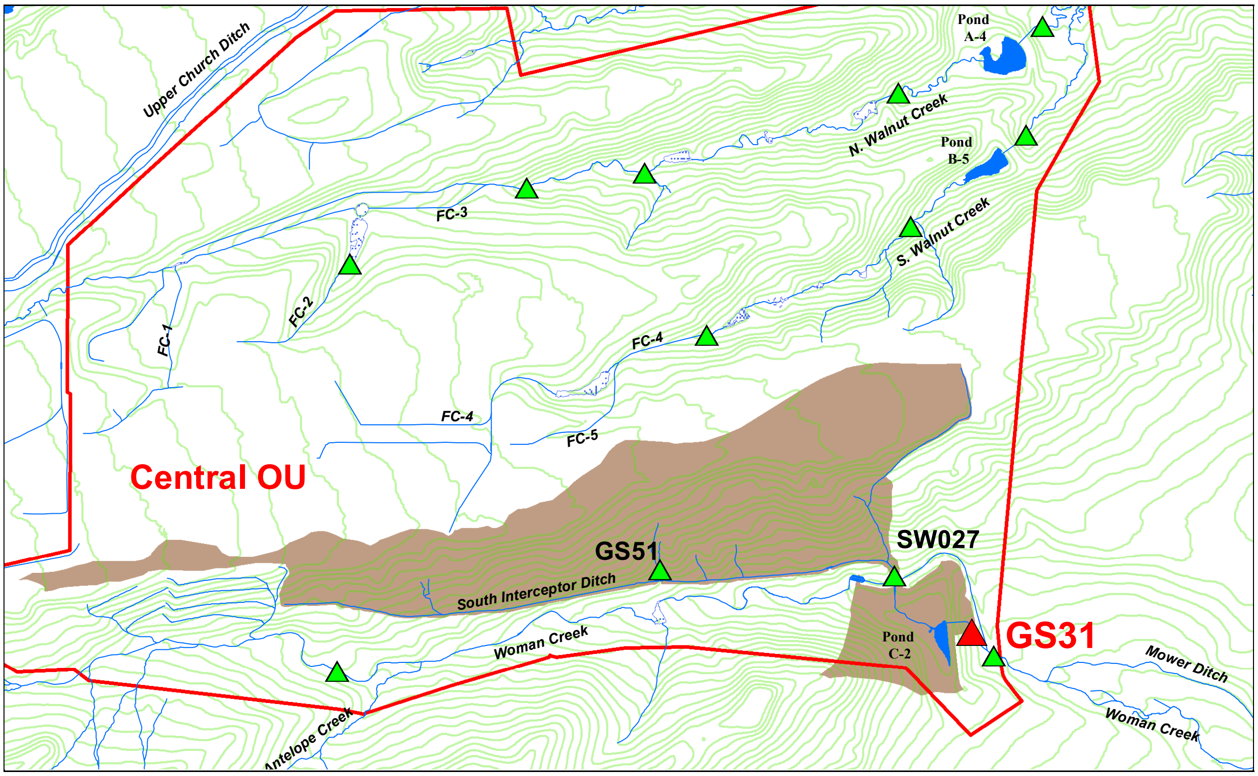


Figure 81. GS31 Drainage Area

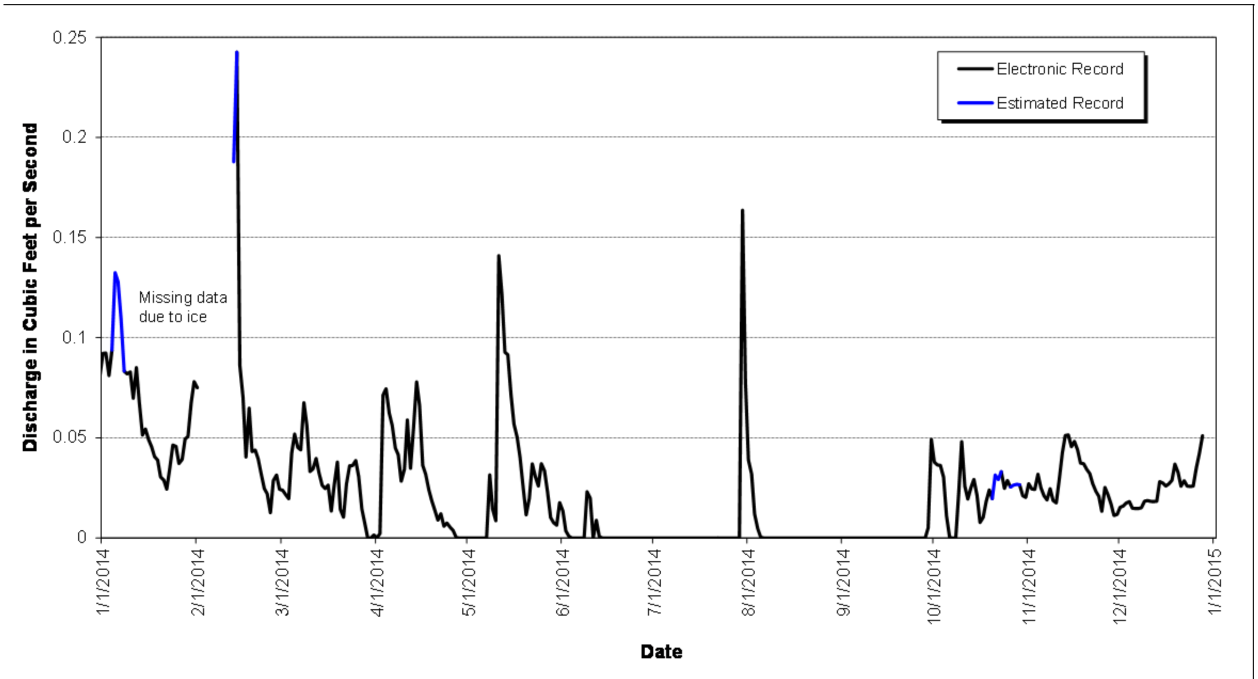


Figure 82. CY 2014 Mean Daily Hydrograph at GS31: Woman Creek at Pond C-2 Outlet

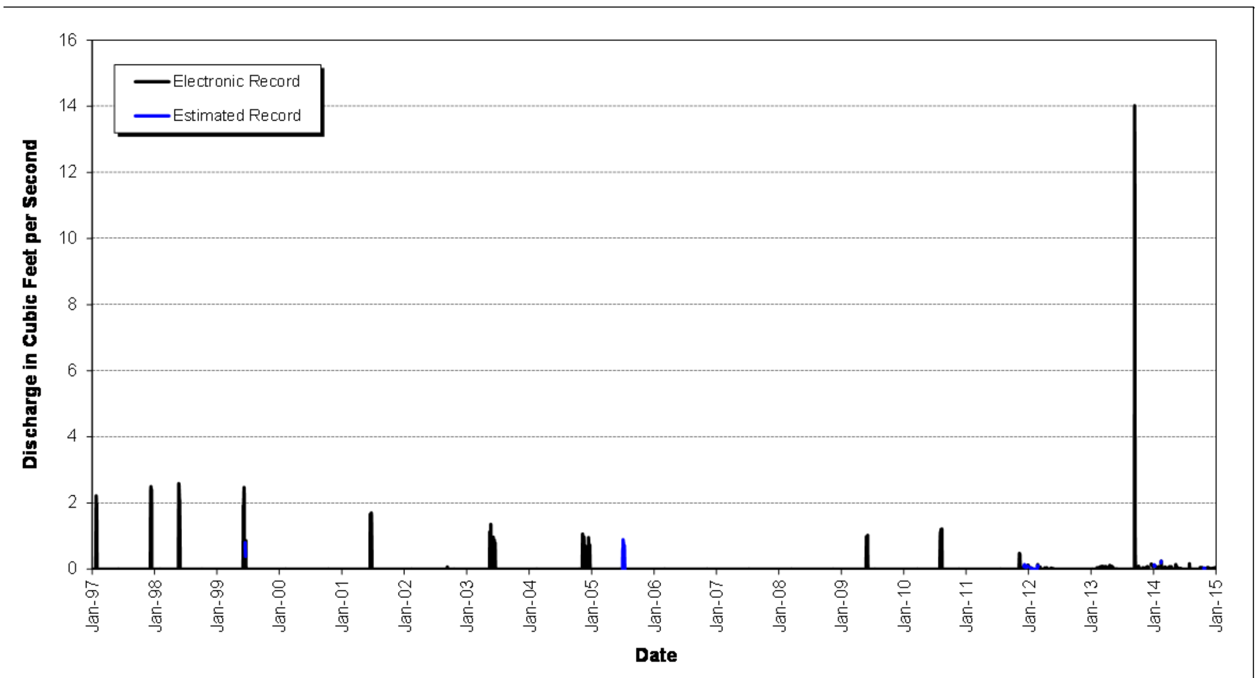


Figure 83. CY 1997–2014 Mean Daily Hydrograph at GS31: Woman Creek at Pond C-2 Outlet

GS33: No Name Gulch at Walnut Creek

Location: No Name Gulch at Walnut Creek; State Plane: E2090210, N753623.

Drainage Area: The basin is the No Name Gulch drainage (total of 295.3 acres).

Period of Record: September 16, 1997, to current year.

Gage: Water-stage recorder and 9.5-inch Parshall flume.

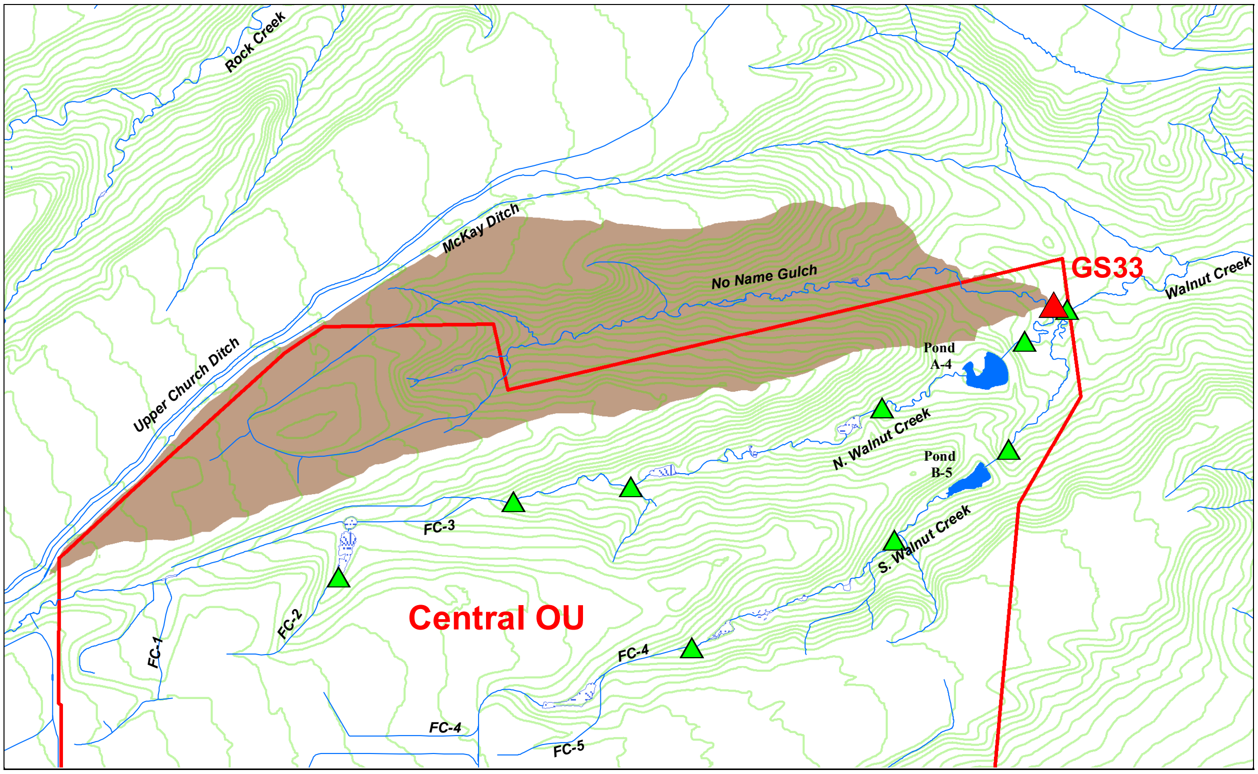


Figure 84. GS33 Drainage Area

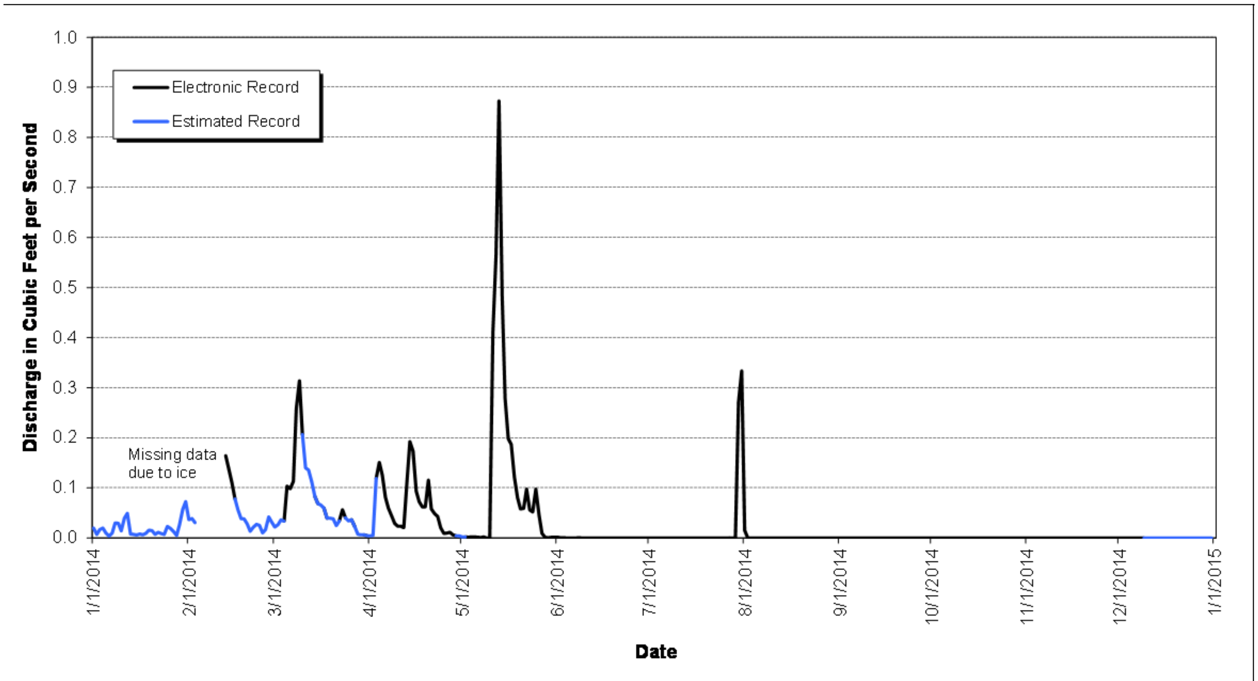


Figure 85. CY 2014 Mean Daily Hydrograph at GS33: No Name Gulch at Walnut Creek

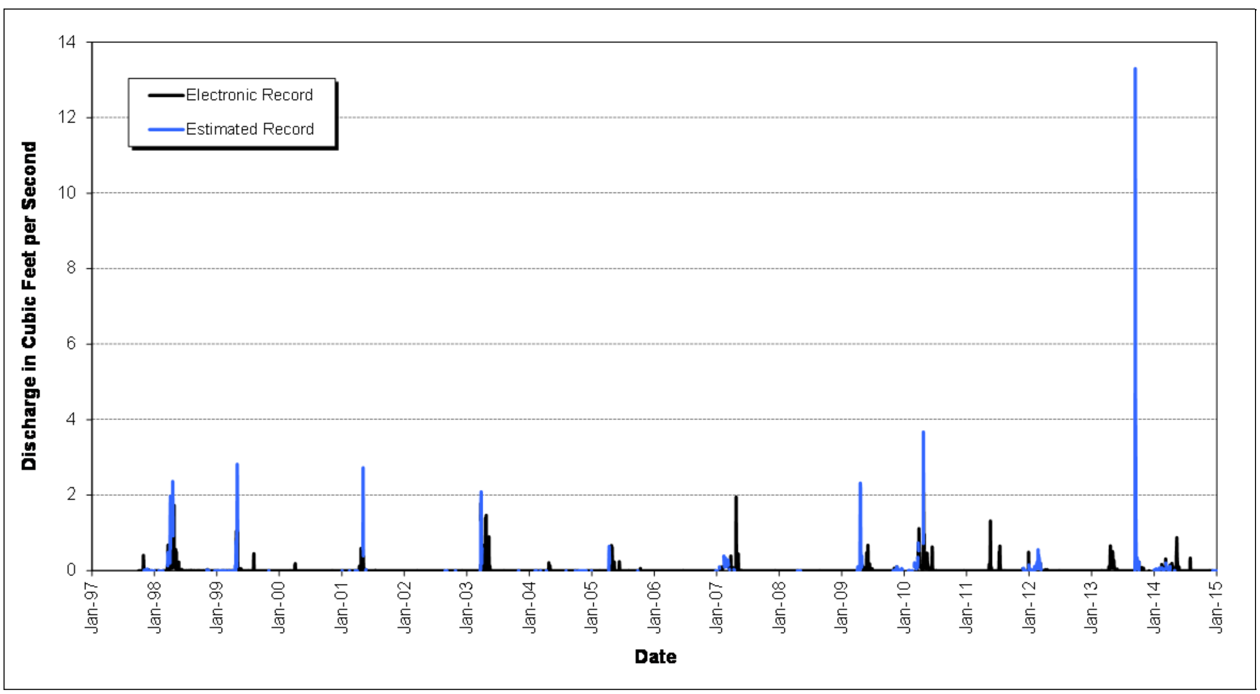


Figure 86. CY 1997–2014 Mean Daily Hydrograph at GS33: No Name Gulch at Walnut Creek

GS51: Ditch South of Former 903 Pad

Location: Ditch south of former 903 Pad; State Plane: E2086300, N748102.

Drainage Area: The basin includes an area south and west of the former 903 Pad (total of 16.0 acres).

Period of Record: August 13, 2001, to current year.

Gage: Water-stage recorder and 0.75-foot H flume.

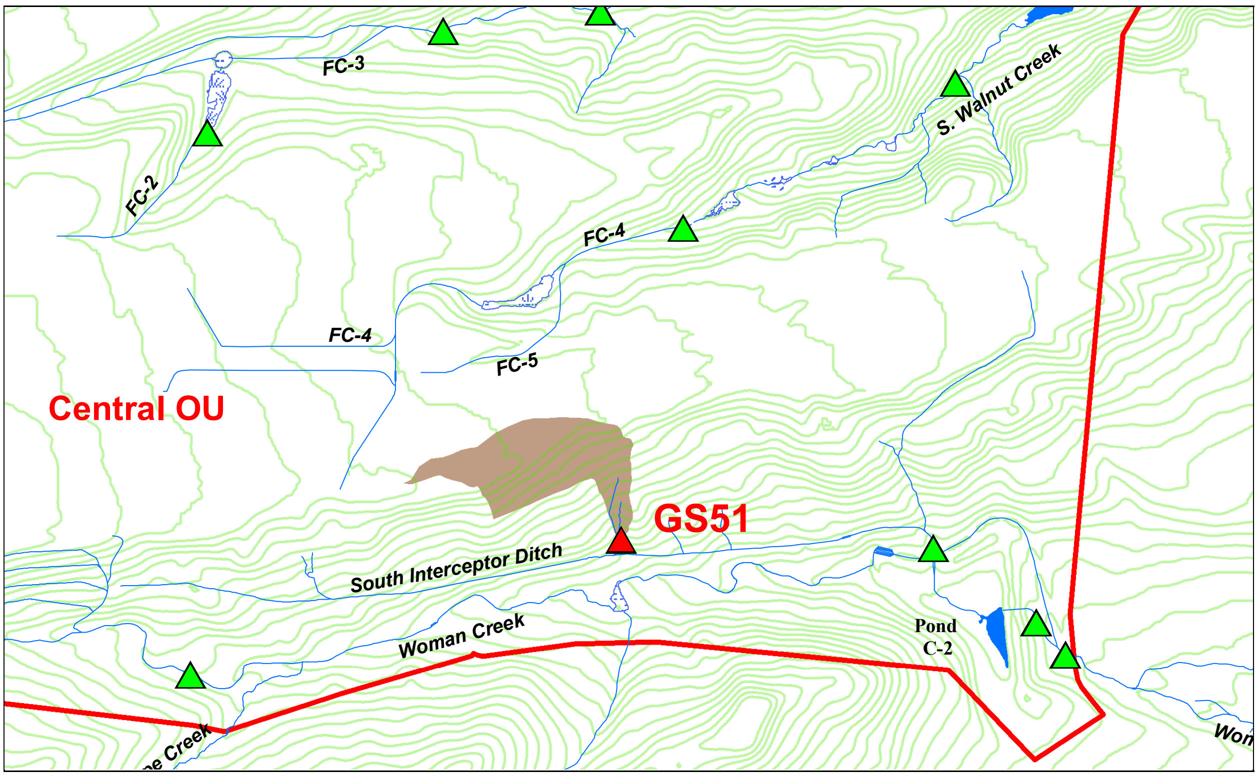


Figure 87. GS51 Drainage Area

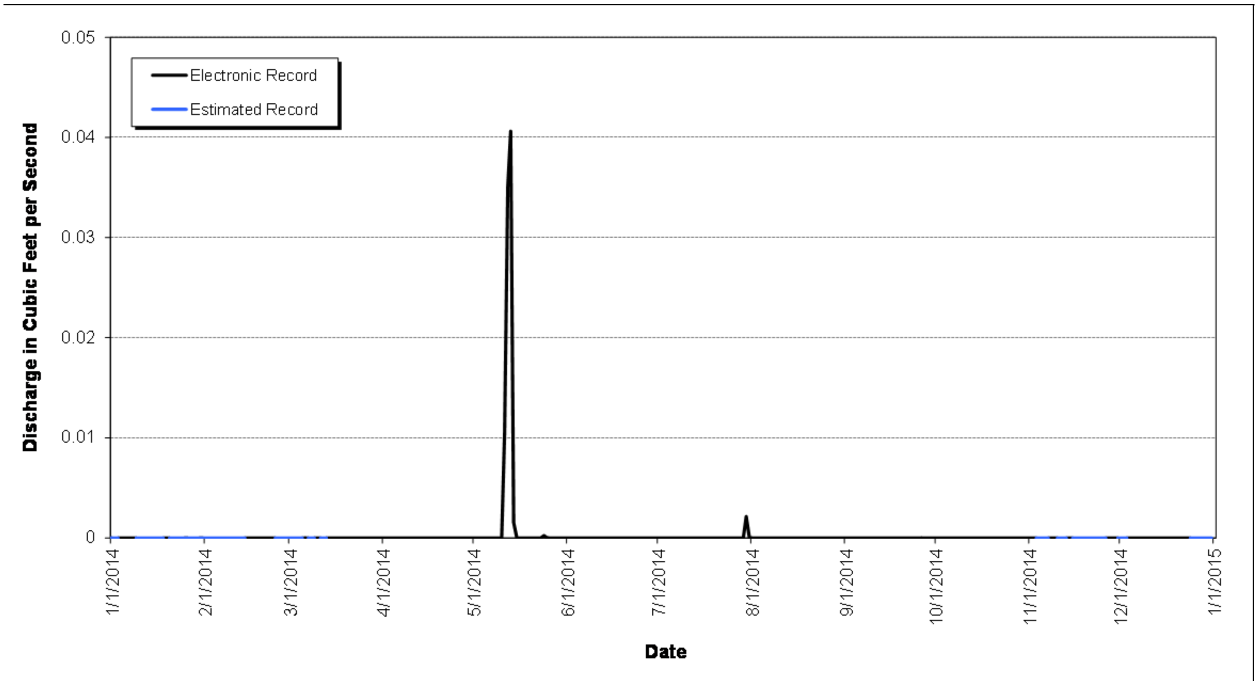


Figure 88. CY 2014 Mean Daily Hydrograph at GS51: Ditch South of Former 903 Pad

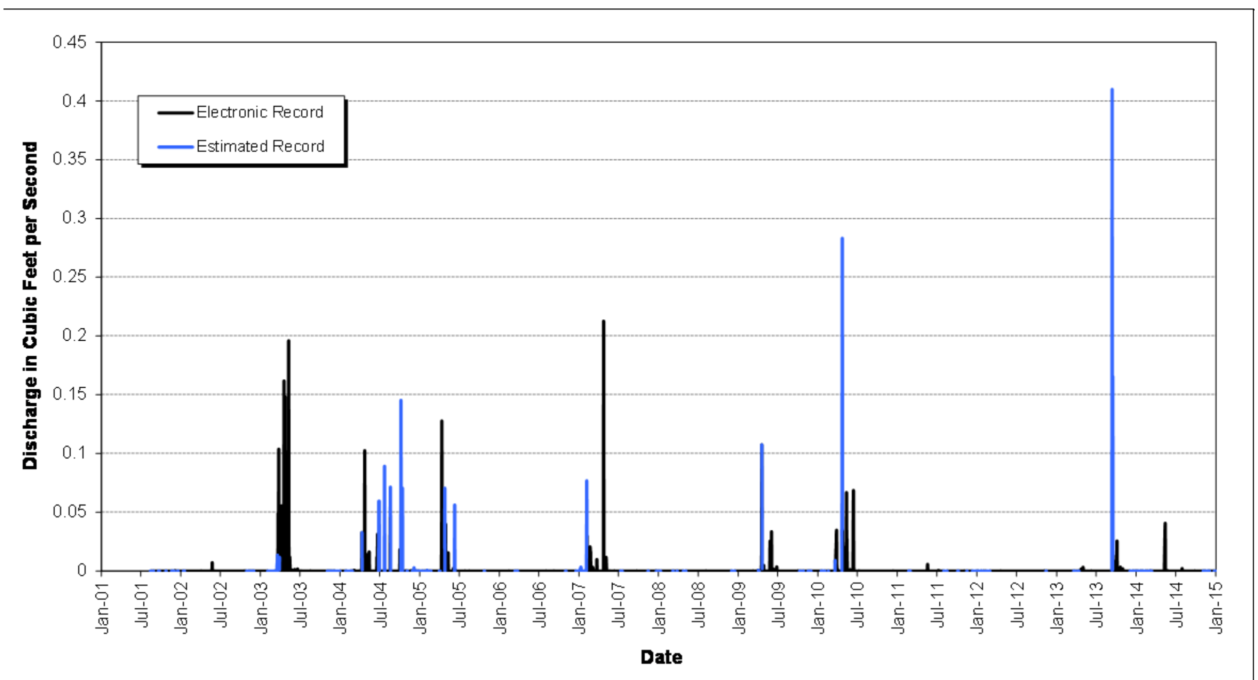


Figure 89. CY 2001–2014 Mean Daily Hydrograph at GS51: Ditch South of Former 903 Pad

GS59: Woman Creek Upstream of Antelope Springs Confluence

Location: Woman Creek 900 feet upstream of Antelope Springs confluence; State Plane: E2083228, N747139.

Drainage Area: The basin includes upstream reaches of Woman Creek; areas west of Highway 93 also contribute runoff (total drainage acreage undetermined).

Period of Record: November 20, 2002, to current year.

Gage: Water-stage recorder and 1.5-foot Parshall flume.

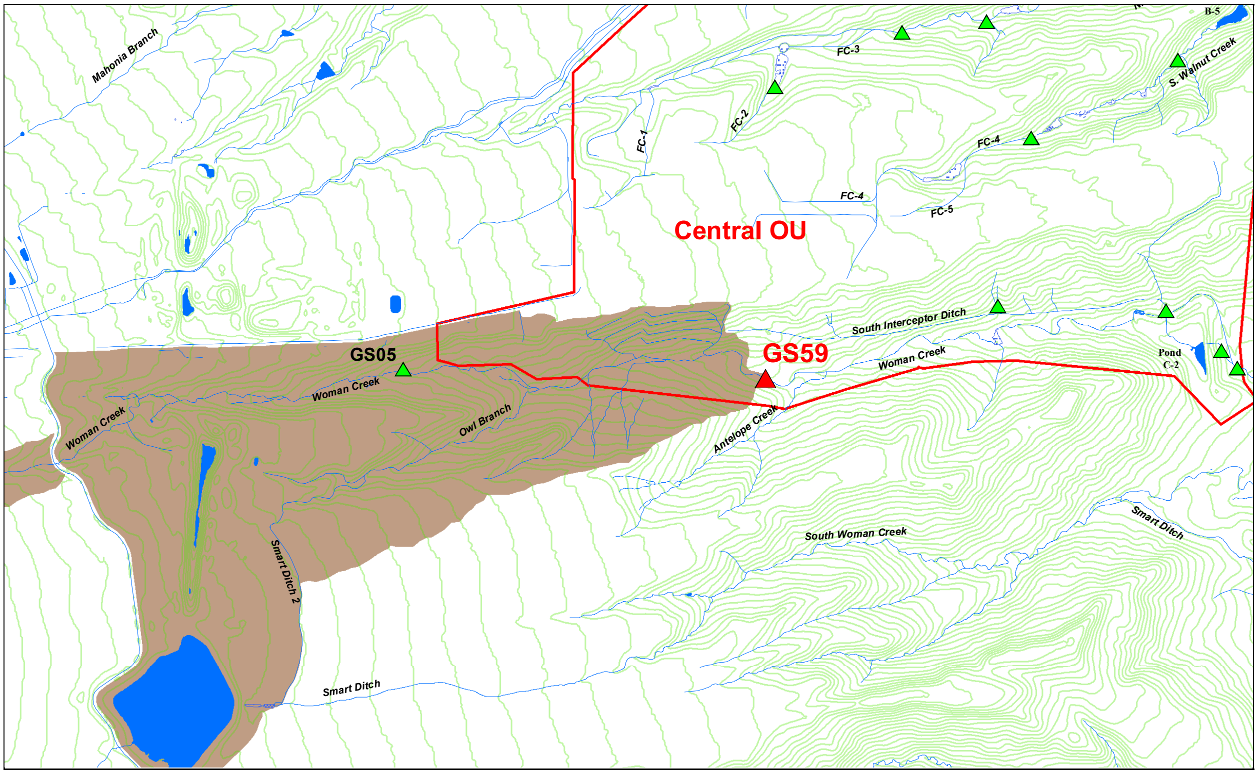


Figure 90. GS59 Drainage Area

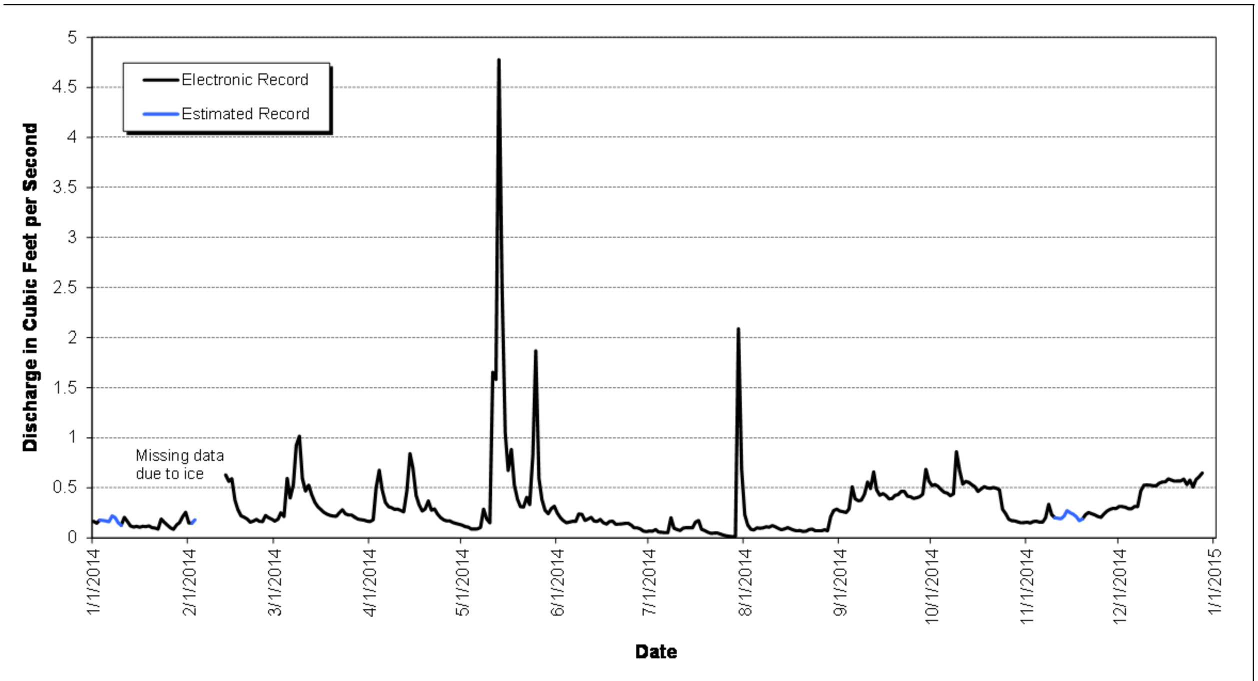


Figure 91. CY 2014 Mean Daily Hydrograph at GS59: Woman Creek Upstream of Antelope Springs Confluence

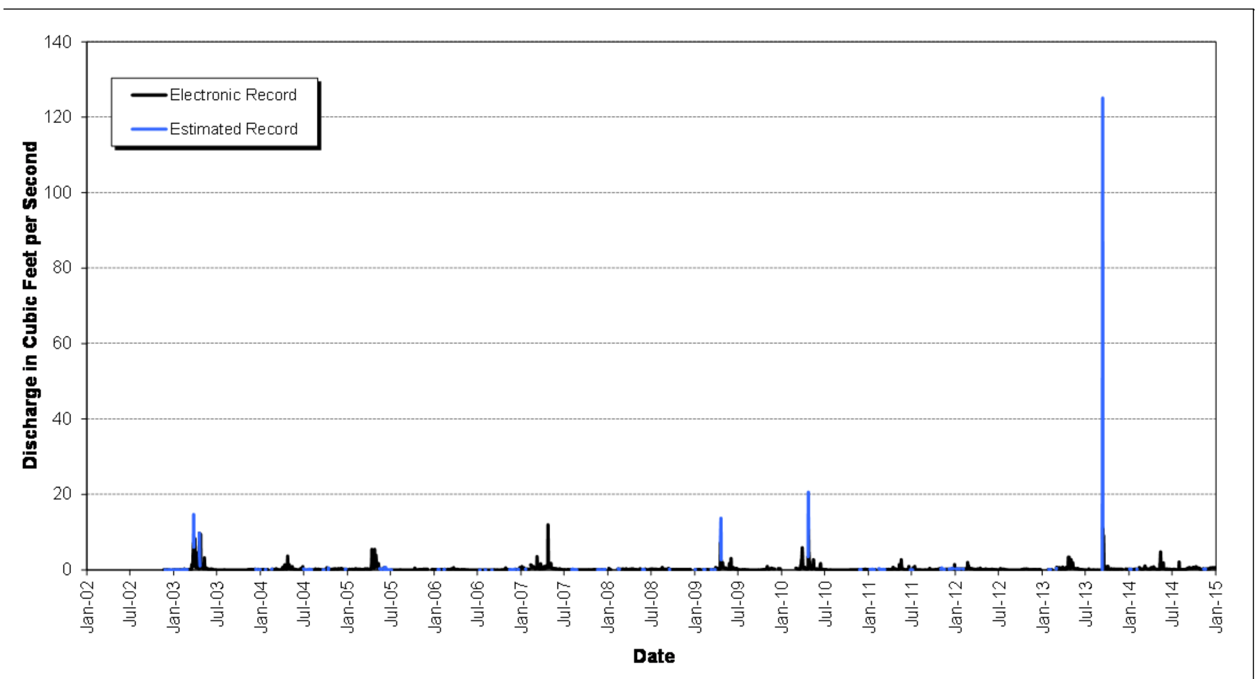


Figure 92. CY 2002–2014 Mean Daily Hydrograph at GS59: Woman Creek Upstream of Antelope Springs Confluence

B5INFLOW: South Walnut Creek Upstream of Pond B-5

Location: South Walnut Creek 500 feet upstream of Pond B-5; State Plane: E2088676, N751358.

Drainage Area: The basin includes the central portion of the COU and the former B-Series Ponds (total of 260.3 acres).

Period of Record: June 17, 2010, to current year.

Gage: Water-stage recorder and 9-inch Parshall flume.

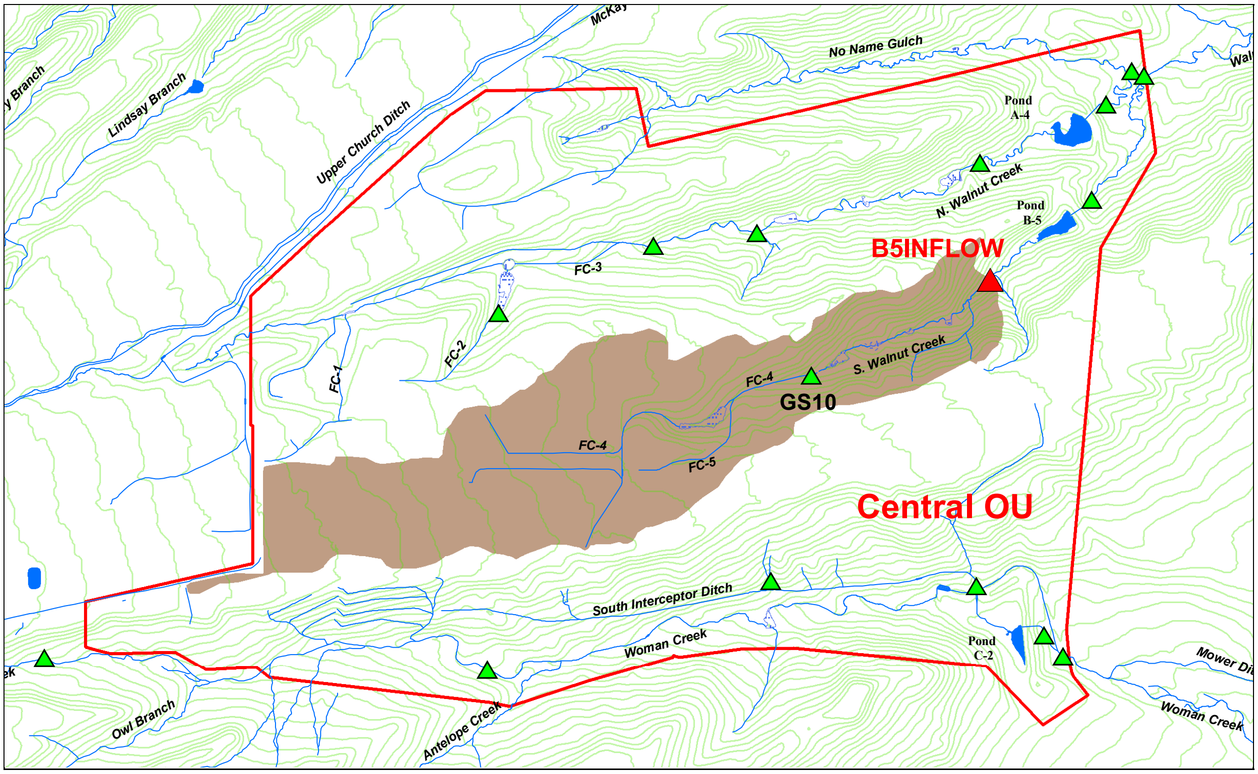


Figure 93. B5INFLOW Drainage Area

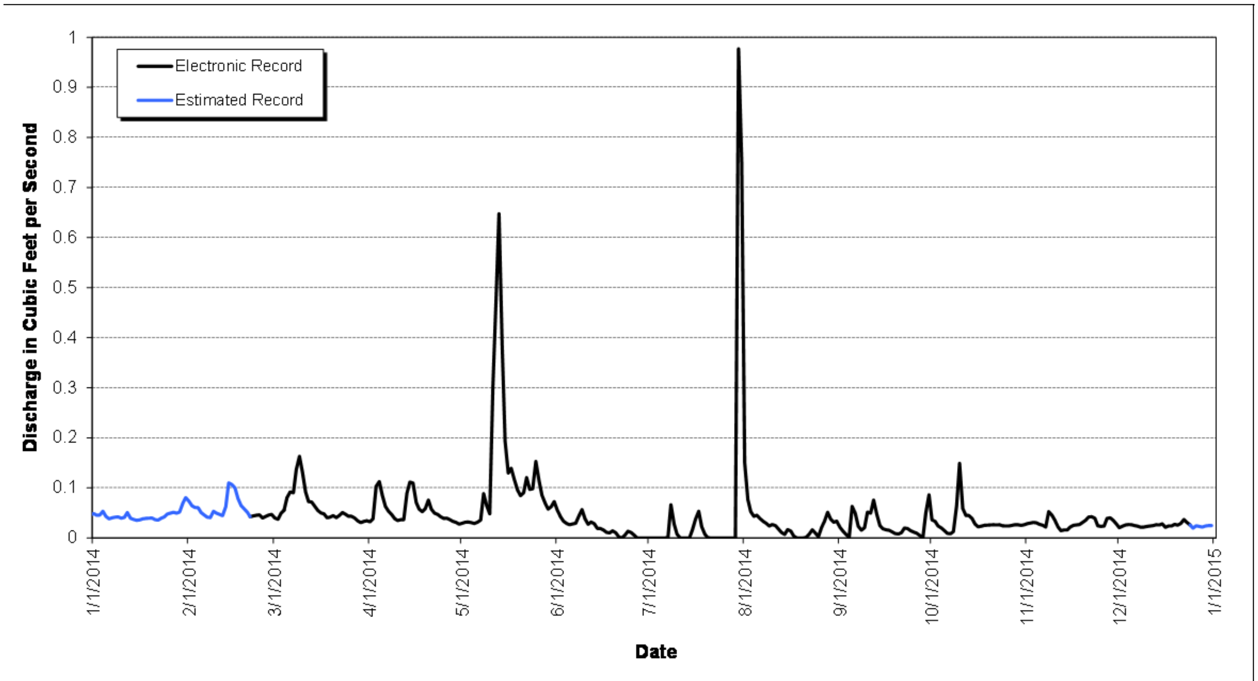


Figure 94. CY 2014 Mean Daily Hydrograph at B5INFLOW: South Walnut Creek Upstream of Pond B-5

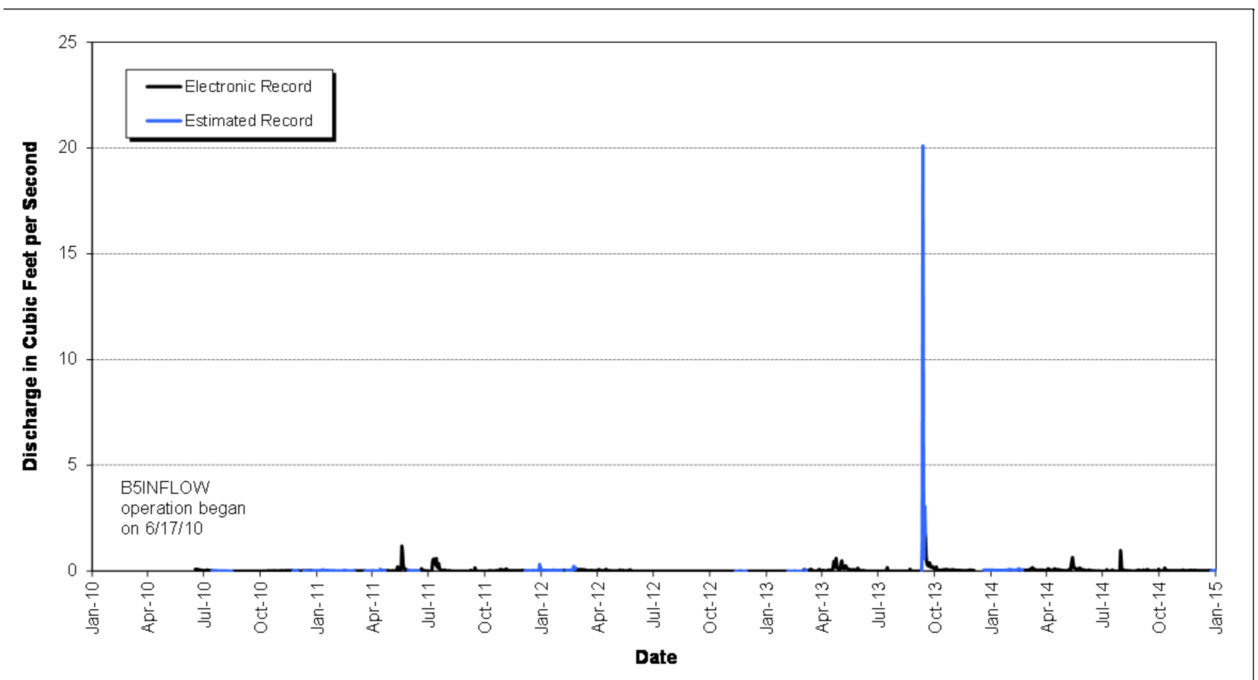


Figure 95. CY 2010–2014 Mean Daily Hydrograph at B5INFLOW: South Walnut Creek Upstream of Pond B-5

SW027: SID at Pond C-2

Location: East end of SID at Pond C-2; State Plane: E2088527, N748044.

Drainage Area: The basin includes a portion of the southern COU drained by the SID (total of 177.6 acres).

Period of Record: September 11, 1991, to current year.

Gage: Water-stage recorder and dual parallel 120° V-notch weirs.

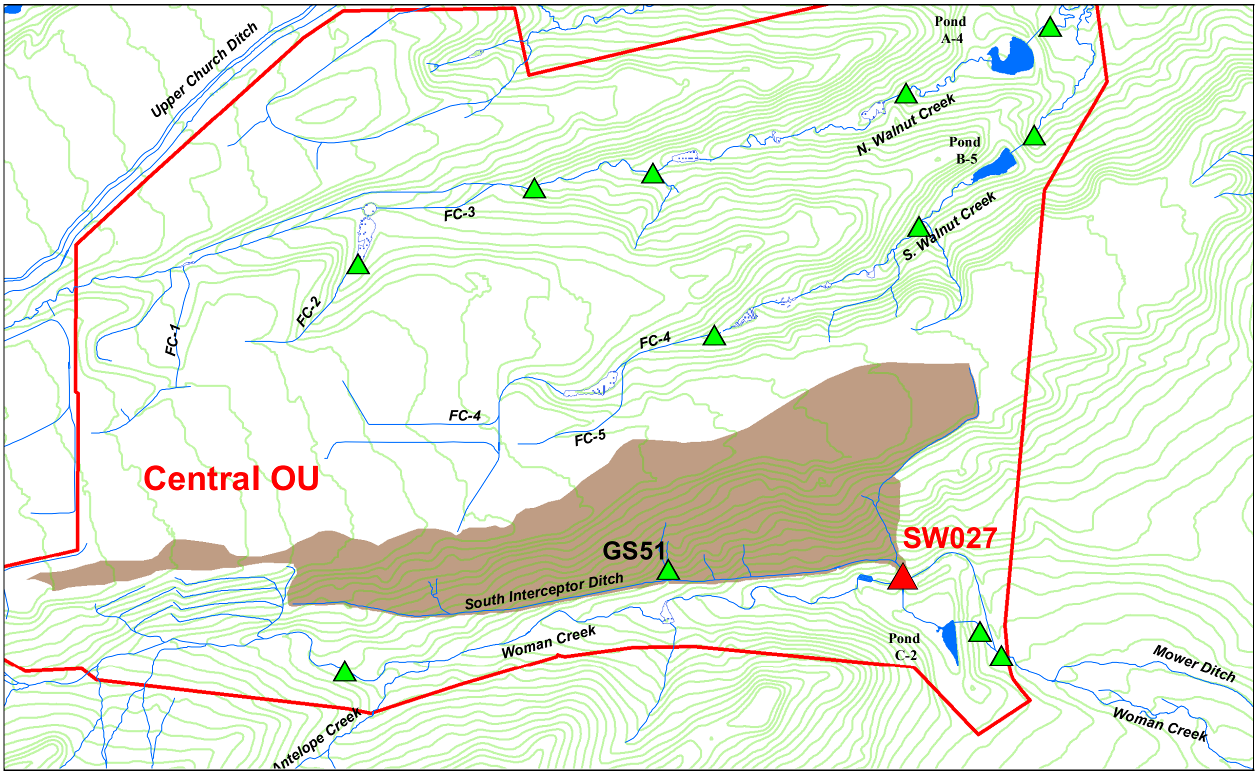


Figure 96. SW027 Drainage Area

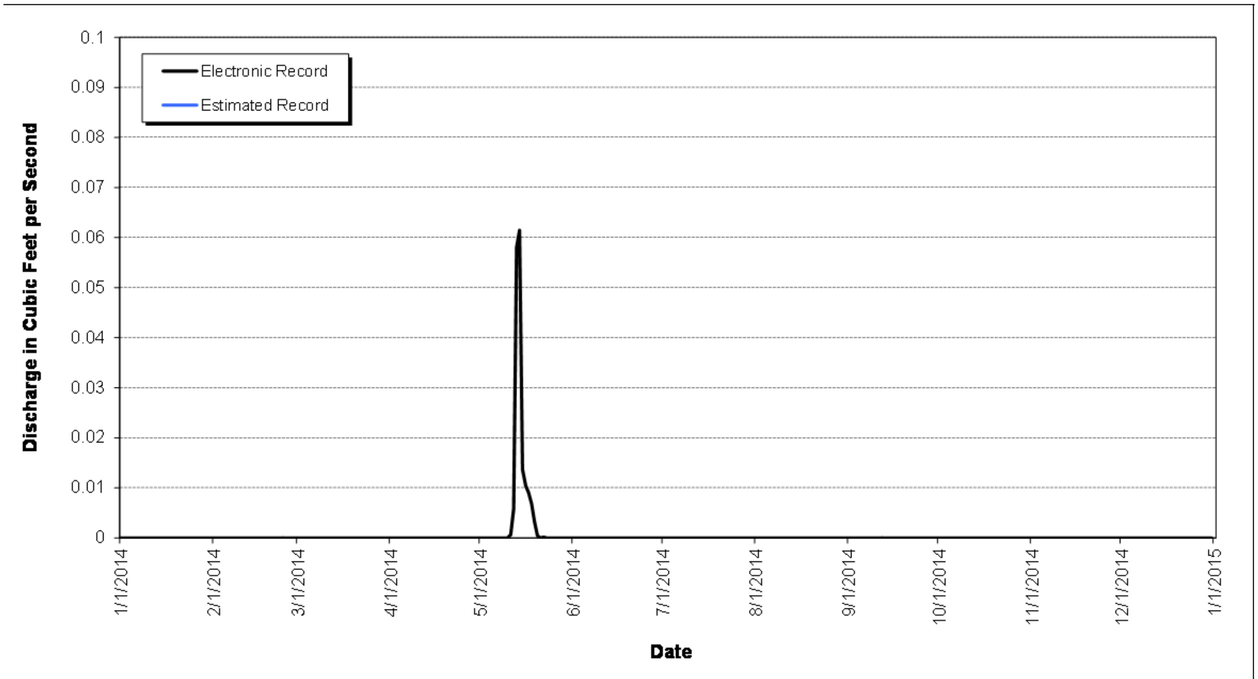


Figure 97. CY 2014 Mean Daily Hydrograph at SW027: SID at Pond C-2

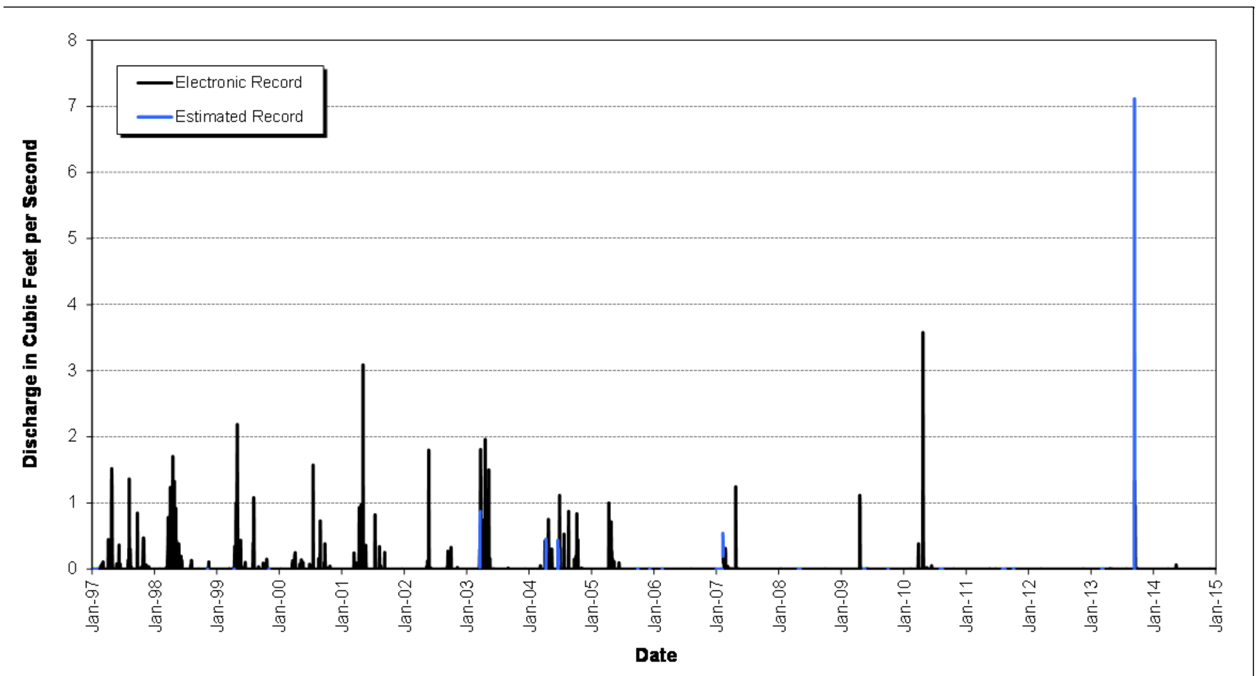


Figure 98. CY 1997–2014 Mean Daily Hydrograph at SW027: SID at Pond C-2

SW093: North Walnut Creek Upstream of Former Pond A-1

Location: North Walnut Creek 1,300 feet above former Pond A-1; State Plane: E2085030, N751730.

Drainage Area: The basin includes the northwestern portion of the COU drained by FC-3 (total of 220.0 acres).

Period of Record: September 11, 1991, to current year.

Gage: Water-stage recorder and 36-inch suppressed, rectangular, sharp-crested weir to January 27, 2003; rated stream section during new flume construction (SW093T; January 27, 2003–May 29, 2003). Three-foot H flume starting May 29, 2003.

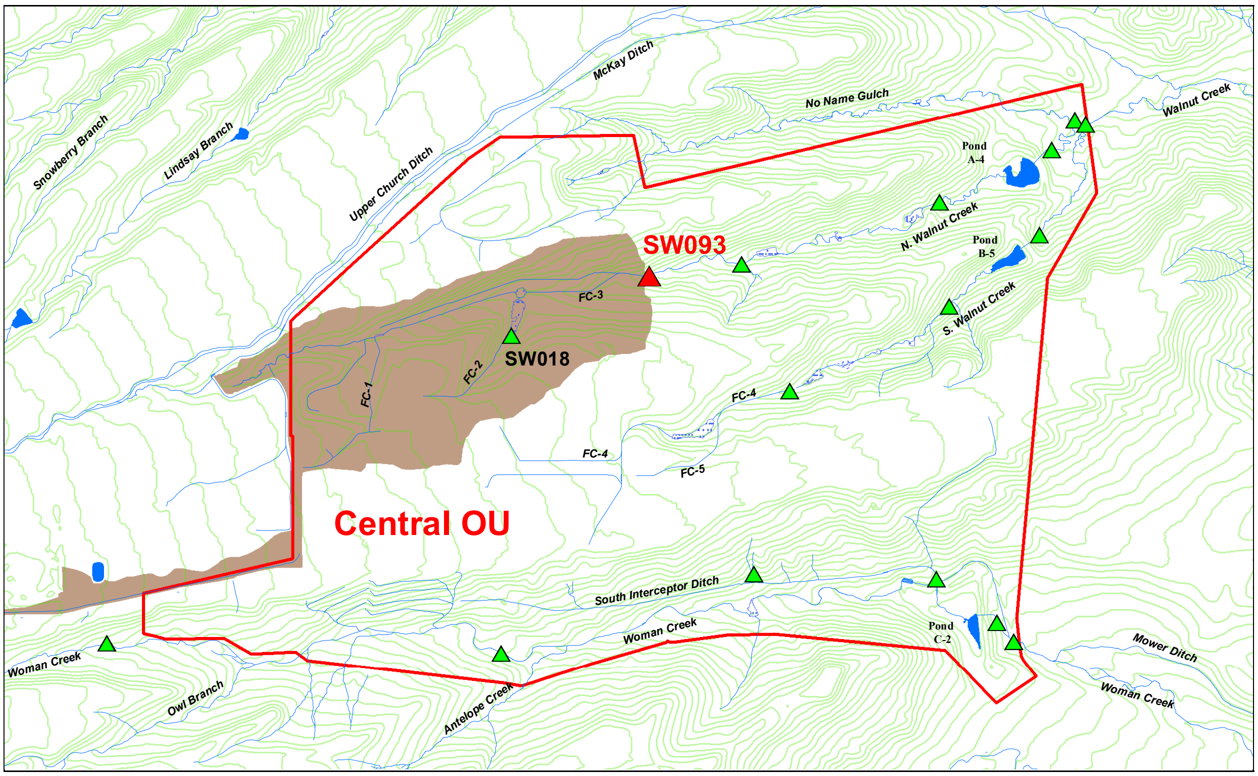


Figure 99. SW093 Drainage Area

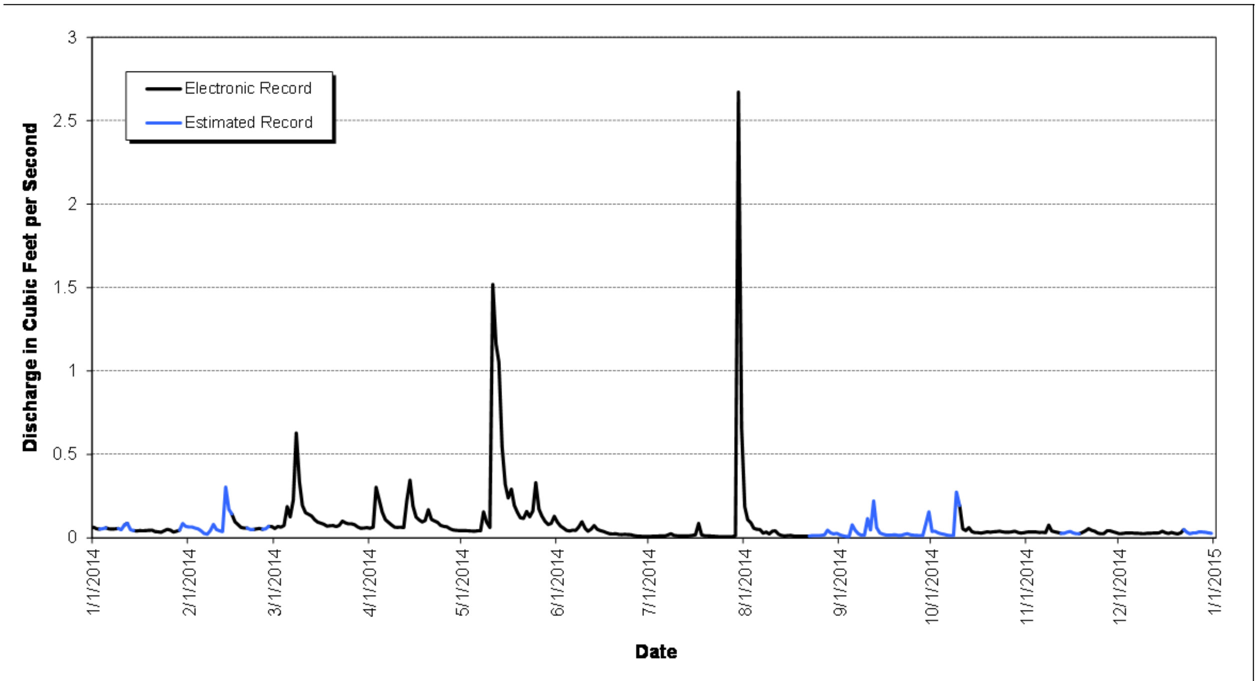


Figure 100. CY 2014 Mean Daily Hydrograph at SW093: North Walnut Creek Upstream of Former Pond A-1 Bypass

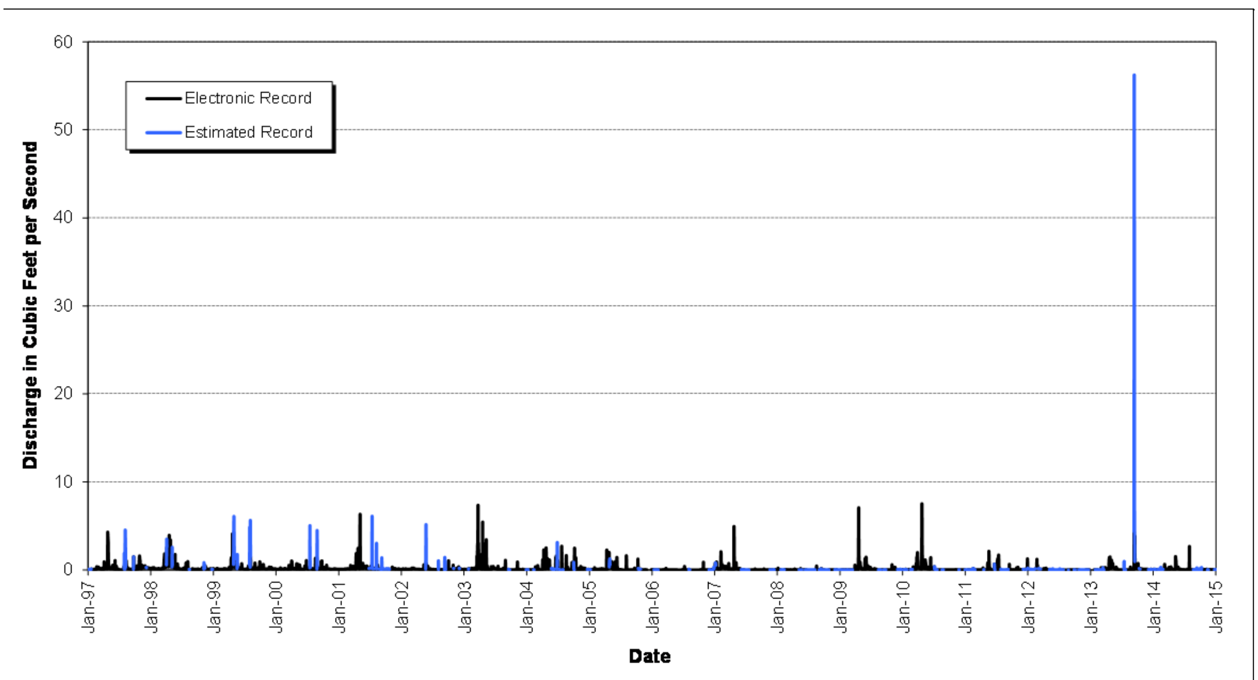


Figure 101. CY 1997–2014 Mean Daily Hydrograph at SW093: North Walnut Creek Upstream of Former Pond A-1 Bypass

3.1.3.4 Precipitation Data

During CY 2014, 11 precipitation gages were operated as part of the automated surface-water monitoring network (Table 32 and Figure 102). The locations employ tipping-bucket rain gages generally mounted at ground level. Precipitation totals are logged on 5-minute intervals. The gages are not heated and will not accurately record equivalent precipitation for all snowfall events. The following sections present several figures (Figure 103, Figure 104, Figure 105, Figure 106, Figure 107, and Figure 108) summarizing the precipitation data collected for CY 1997–2014.

Table 32. Monitoring Network Precipitation Gage Information

Location Code (Surface-Water Gage)	Easting (State Plane)	Northing (State Plane)	Period of Operation
PG58 [GS01]	2093835.22	744921.16	10/11/1996–current year
PG59 [GS03]	2093598.99	753629.51	4/1/1996–current year
PG61 [GS05]	2078432.10	747285.45	4/1/1996–current year
PG73 [GS13]	2086169.70	751862.47	9/27/2005–current year
PG74 [GS59]	2083245.00	747172.00	9/5/2006–current year
PG76 [NA]	2091963.00	752705.00	3/28/2007–current year
PG77 [NA]	2087329.00	746937.00	8/23/2007–current year
PG78 [WALPOC]	2090350.00	753546.00	9/9/2011–current year
PG79 [WOMPOC]	2089488.00	747308.00	9/27/2011–current year
PG80 [MetTower]	2082875.00	749877.00	10/31/2014–current year

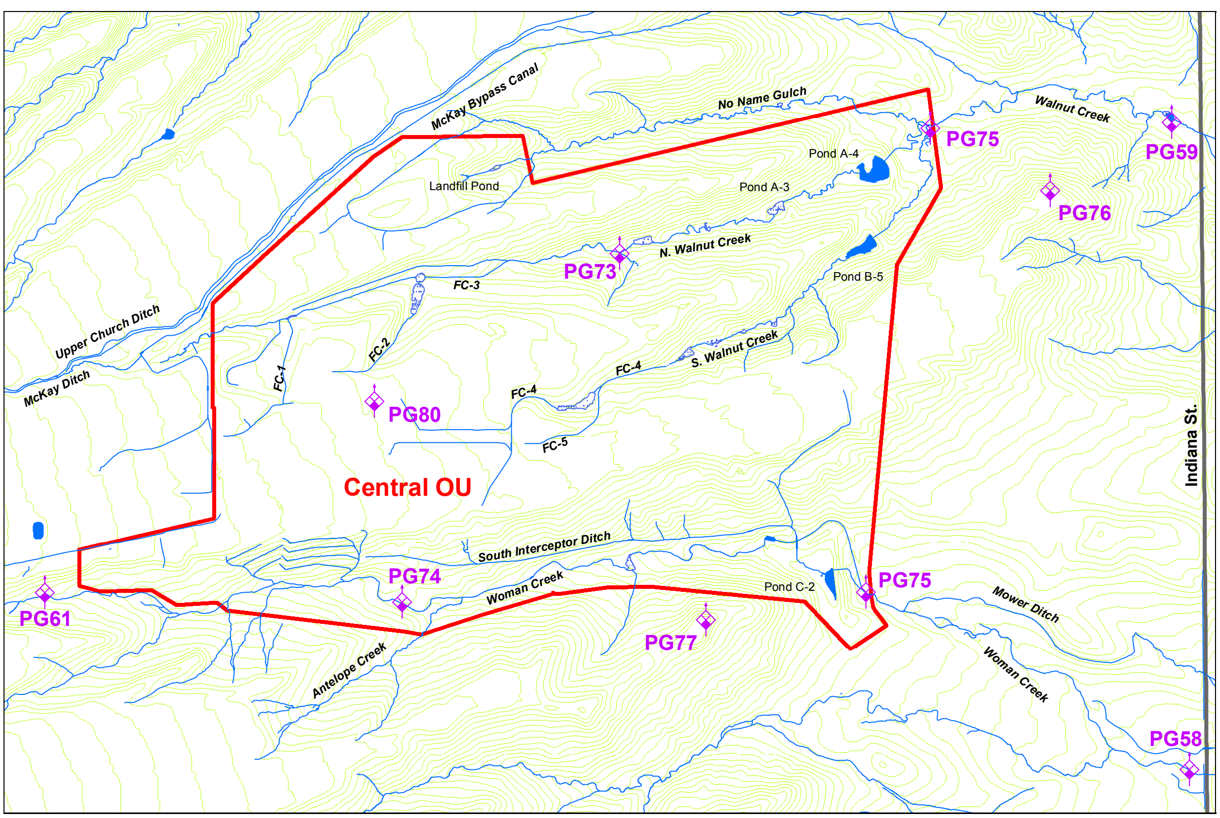
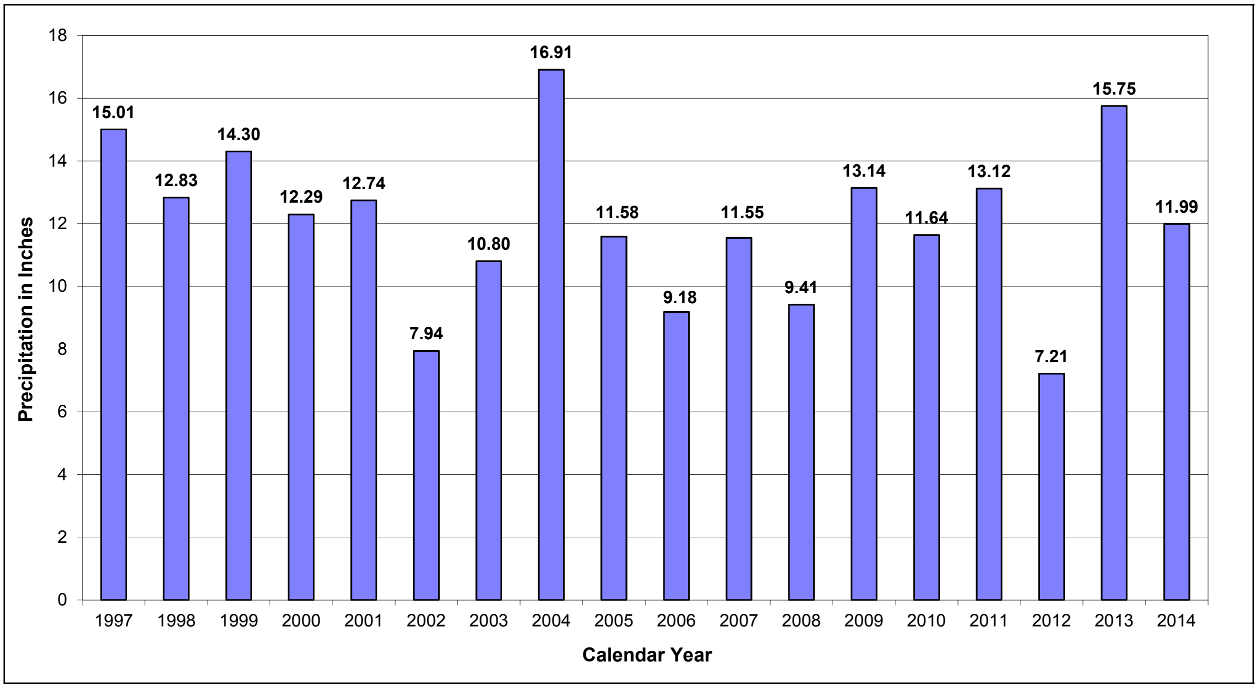


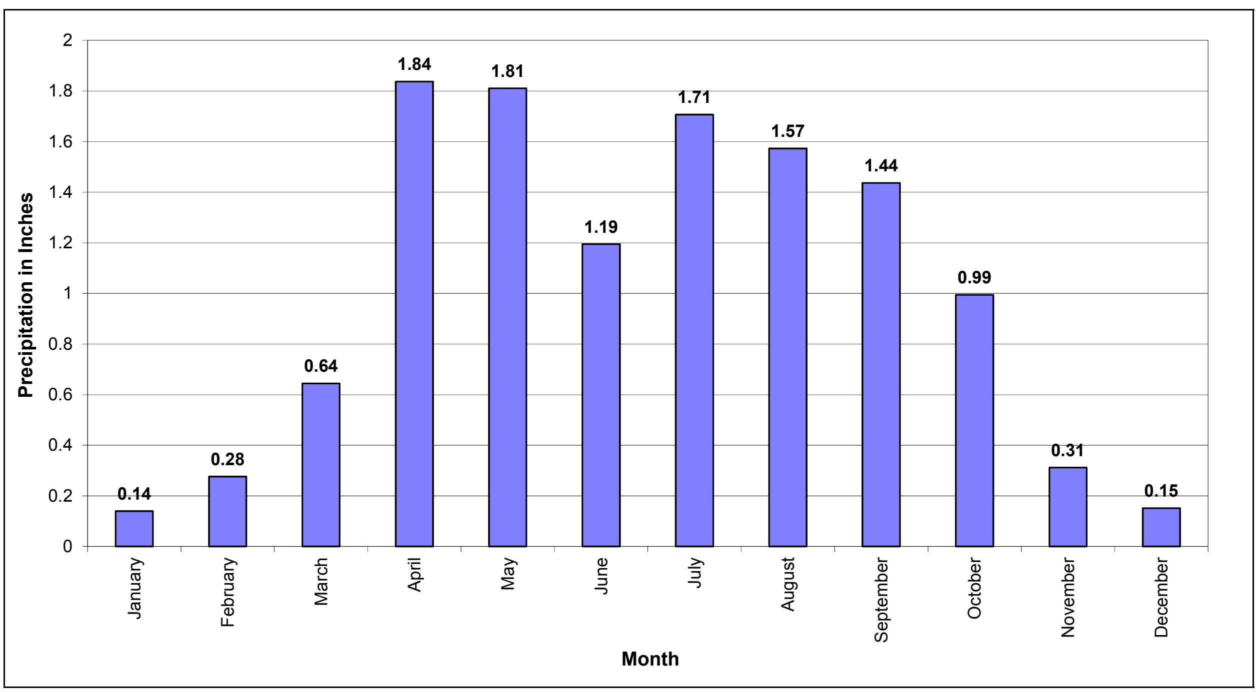
Figure 102. Site Precipitation Gages: CY 2014

CY 1997–2014 Summary



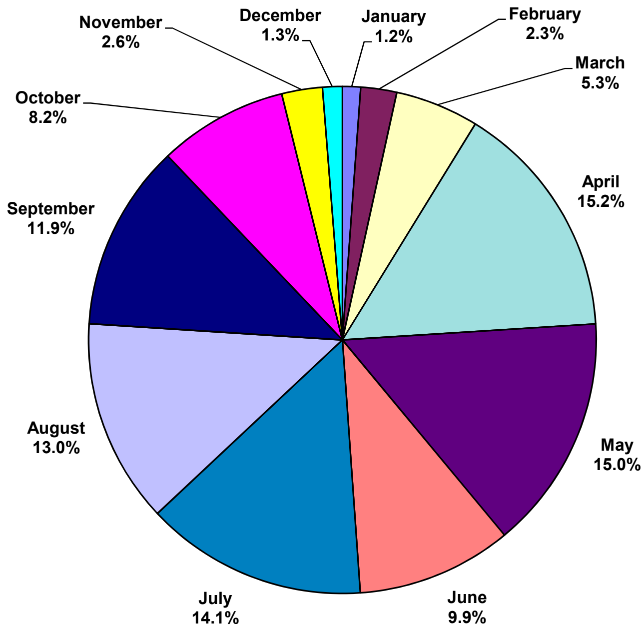
Notes: Arithmetic average of gages in operation.

Figure 103. Annual Total Precipitation for CY 1997–2014



Notes: Arithmetic average of gages in operation.

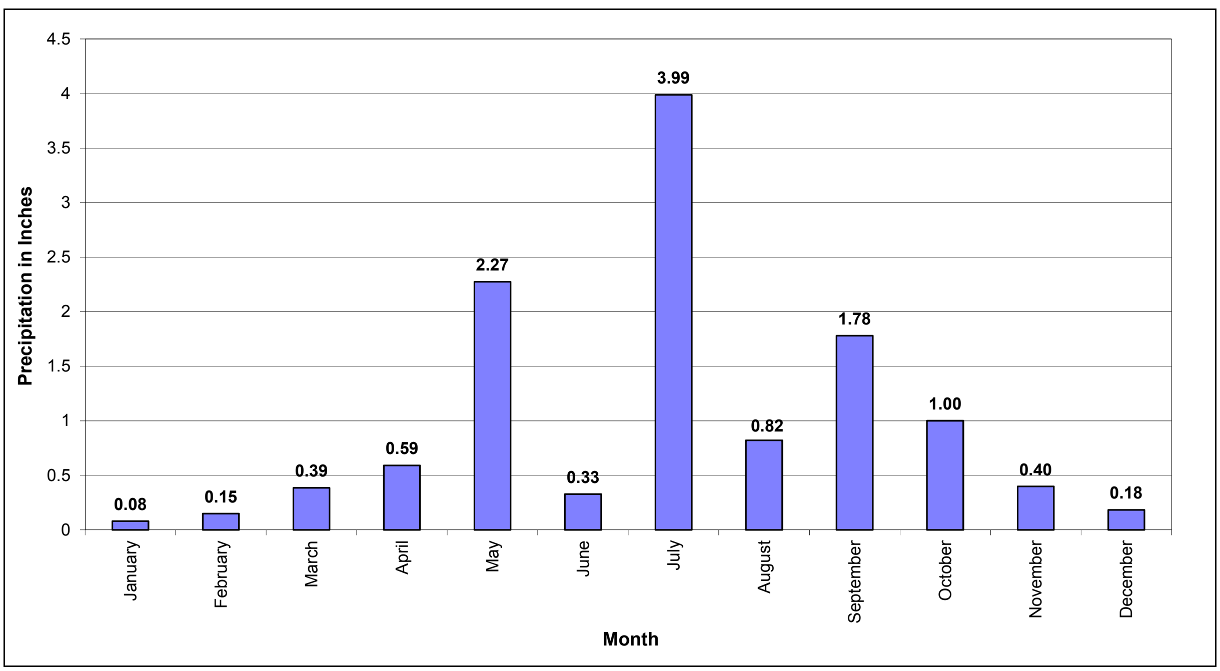
Figure 104. Average Monthly Precipitation for CY 1997–2014



Notes: Arithmetic average of gages in operation.

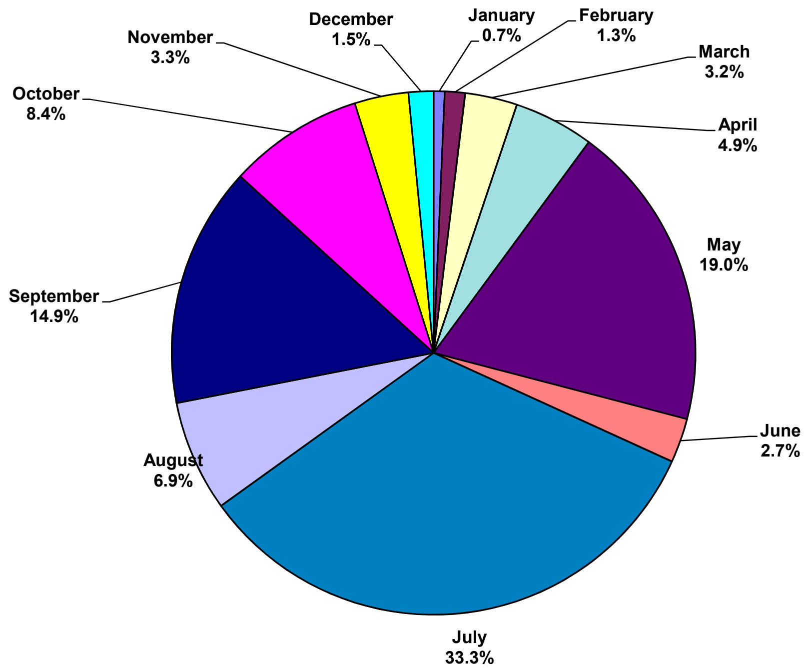
Figure 105. Relative Monthly Precipitation Totals for CY 1997–2014

CY 2014 Summary



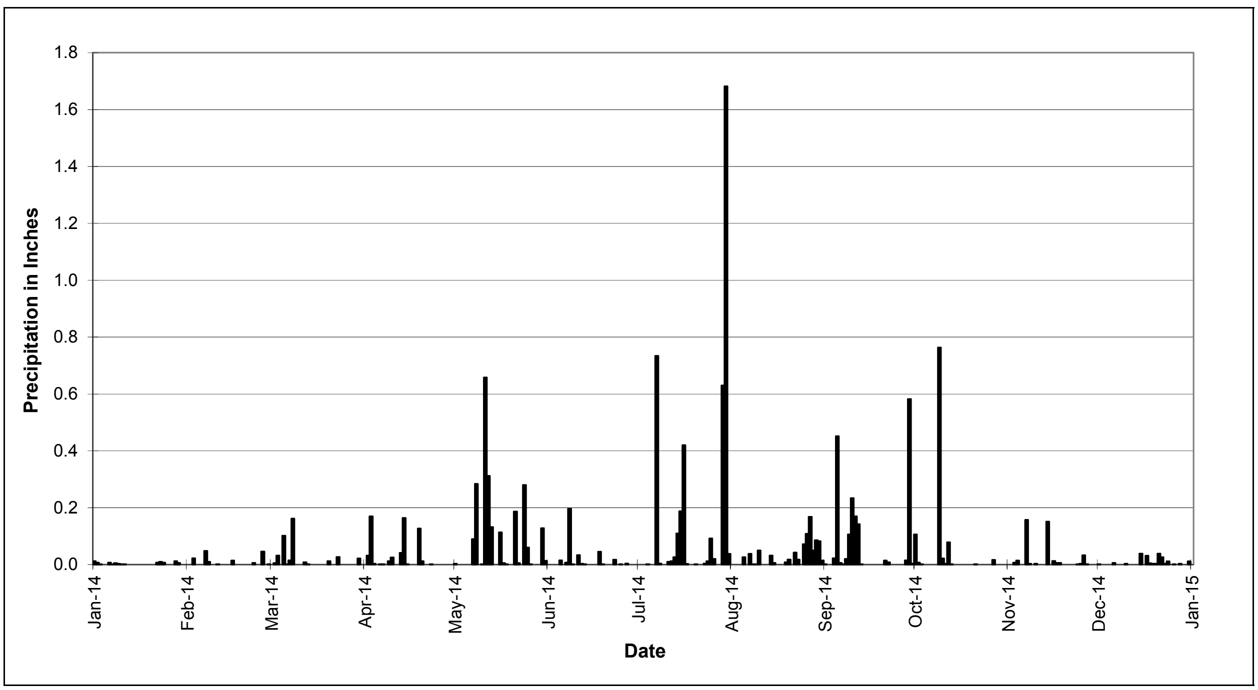
Notes: Arithmetic average of gages in operation.

Figure 106. Monthly Precipitation for CY 2014



Notes: Arithmetic average of gages in operation.

Figure 107. Relative Monthly Precipitation Volumes for CY 2014



Notes: Arithmetic average of gages in operation.

Figure 108. Daily Precipitation Totals for CY 2014

3.1.3.5 Groundwater Flow

Measurement of the depth of the groundwater in monitoring wells can provide fundamental indicators of the groundwater regime and are critical to a meaningful evaluation of groundwater quantity, quality, and flow. These measurements are converted to elevations and compared among the various wells across the Rocky Flats Site.

This section summarizes groundwater elevations and flow characteristics. Groundwater elevation data are evaluated through the construction of potentiometric surface maps and hydrographs. Results of this evaluation are presented below, together with an assessment of groundwater flow characteristics.

Groundwater Elevations

Groundwater elevation data were manually collected at the start of each quarter in 2014; these data are included in Appendix A. The second and fourth quarter groundwater elevation data were plotted and hand-contoured to create potentiometric surface maps. The potentiometric surface map for second quarter CY 2014 is included as Figure 109. The map for the fourth quarter of CY 2014 is included as Figure 110.

All of the monitoring wells at Rocky Flats are screened within the UHSU. The UHSU encompasses unconsolidated surface materials such as Rocky Flats Alluvium, hillslope colluvium, valley-fill alluvium, and artificial fill (all of which are often referred to as “alluvium”), and underlying weathered bedrock (the Cretaceous-age Laramie Formation or the Cretaceous-age Arapahoe Formation). A well screened entirely within the weathered bedrock may yield different water levels than an adjacent well screened entirely within the alluvium.

Potentiometric surface maps for 2014 are based on many fewer locations than maps from pre-closure years and are, therefore, less detailed in comparison. Due to the distribution of groundwater contamination, the areas of interest in post-closure years are the former IA and adjacent areas; groundwater monitoring data are no longer collected from the unimpacted former Buffer Zone, as they provide no meaningful data.

Wells are labeled as “dry” on the potentiometric surface maps if there is no water measured or if the water level measured is below the bottom of the screened interval (water below the screen is stagnant and may not reflect the actual groundwater level). The locations labeled as dry may indicate areas where the UHSU is unsaturated. These areas are a result of limited groundwater, caused by a reduction in recharge from precipitation (e.g., droughts, such as that in 2002), or local conditions that may result from an engineered structure such as the groundwater intercept trenches that collect groundwater and route it to the associated treatment systems. (Effects from the reduction in contributions from artificial sources—such as removal of water lines, foundation drains, and dust suppression water—were recognized in early post-closure years, but are no longer evident.) However, some wells in the monitoring network do not fully penetrate the UHSU; therefore, a location that is depicted as dry does not necessarily indicate that it is in an area of unsaturated UHSU, as the UHSU may be saturated at depths greater than that of the dry well.

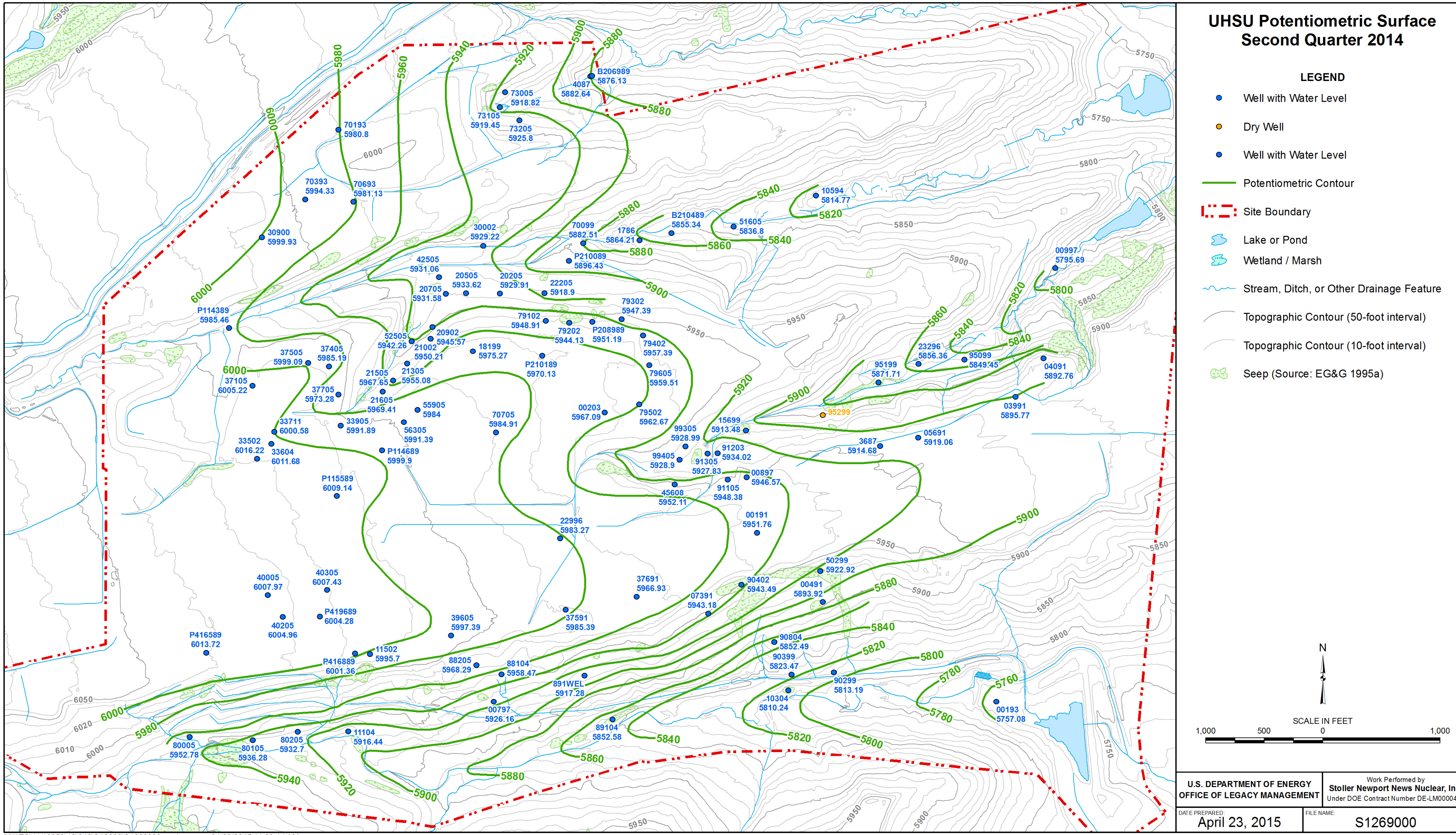


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Figure 109. UHSU Potentiometric Contours: Second Quarter CY 2014

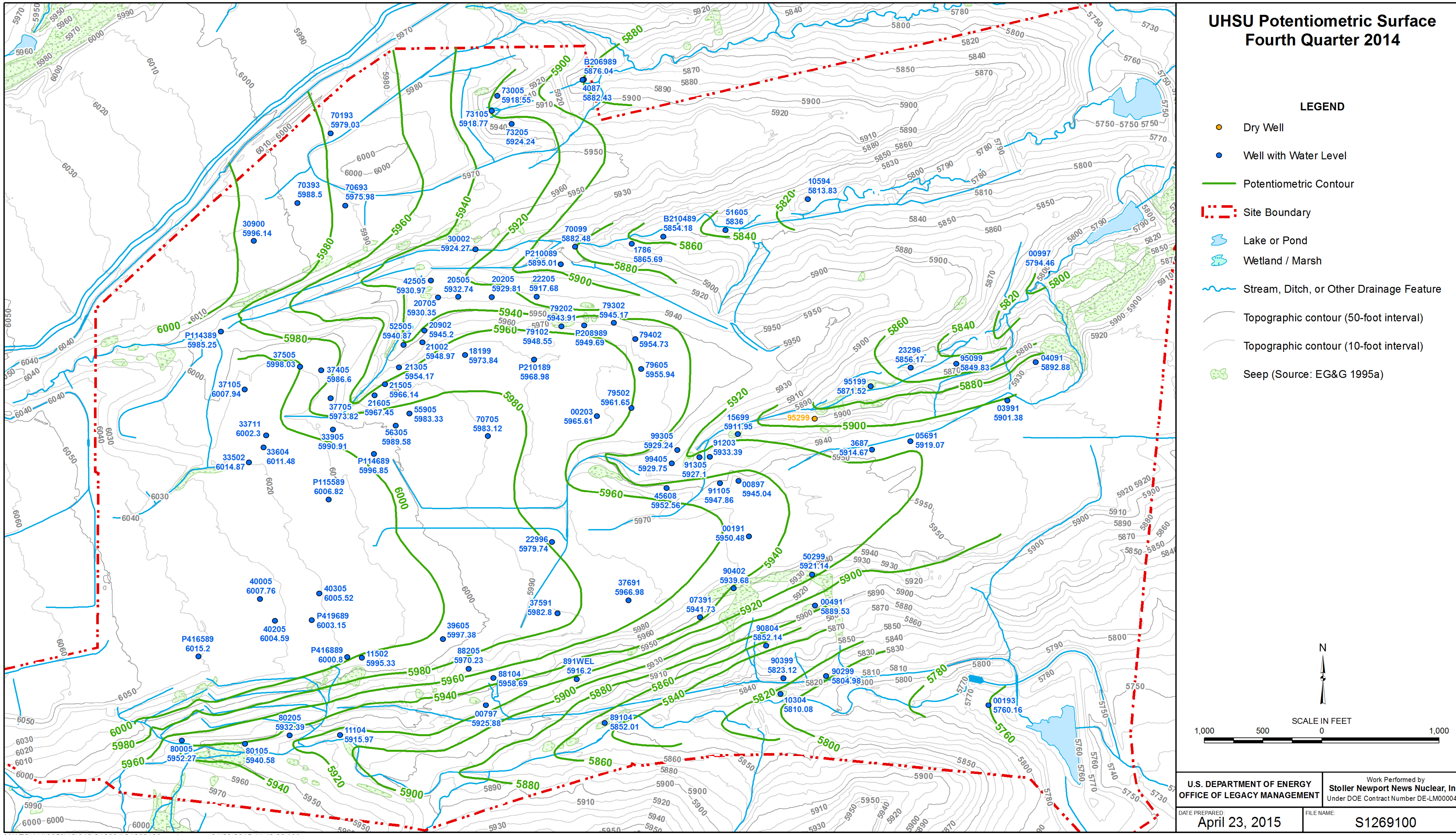

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Figure 110. UHSU Potentiometric Contours: Fourth Quarter CY 2014

Unsaturated areas were generally unchanged from those observed in recent years. For example, well 95299, which is located adjacent to and downgradient of the ETPTS groundwater intercept trench, was dry. This well has been dry (as monitored quarterly) since 2000 with one exception; water was encountered in the well in late 2006. This area is typically dry due to the dewatering effects of the trench. Conversely, well 90299, which had been observed to be dry since October 2007, recharged in the relatively moist year of 2010 and continued to present groundwater for sampling through the dry year of 2012. Although the well was dry during 2013 and the first quarter of 2014, it again recharged (presumably due to the heavy rains in September 2013) and contained water for the remainder of 2014.

Groundwater flow paths, which are estimated from the potentiometric surface maps (Figure 109 and Figure 110), are consistent in 2014 with conditions observed in recent years. As noted above, unsaturated areas in 2014 are very similar to those depicted in recent years. In most areas of the Site the fourth quarter of 2014 was noticeably drier than the second quarter, as illustrated by the lower water levels measured in wells during the fourth quarter. While this is a typical seasonal pattern, the abundance of water observed during second quarter 2014 is likely due to the continued effects of the significant precipitation received during September 2013, when the Site received over 7 inches of rain.

Hydrographs

Hydrographs are used to evaluate the groundwater levels at Rocky Flats and are included in Appendix A. Selected hydrographs are discussed here, but it may be helpful to refer to the referenced hydrographs throughout the following discussion.

As in previous annual reports issued since the Site was closed, water level data for original and replacement wells are combined into a single hydrograph under the assumption that the corresponding data are continuous, or that any discontinuities that may be present do not meaningfully affect decisions that may be based on these hydrographs. However, before any important decisions based on hydrographs are made, details of well replacement should be considered.

Water level data used for these hydrographs include routine, pre-sampling, and any nonroutine measurements that may have been made at RFLMA wells and other groundwater locations. These data were reviewed and prepared for display by merging the data with water level data used to generate hydrographs for the 2013 Annual Report. The resulting hydrographs show water levels for current (and predecessor, as applicable) wells together with historic water levels (i.e., dating to the start of 2000 or from the date of the original well's construction, if later than 2000).

Water level elevations were calculated by subtracting the measured depth to water from the surveyed elevation of the top of the well casing. When wells were found to be dry, the water level posted on the hydrograph is equivalent to the elevation of the bottom of the well casing. The bottom of the well casing is calculated from measurements of the total depth of the borehole and the total length of the well casing, which were recorded during its installation. The same process is followed when the measured water level is found to be below the bottom of the screened interval, because this water is not in hydraulic connection with saturated materials and is therefore likely not representative of groundwater in the surrounding formation. For those wells where the water level is below the top of the dedicated pump, the measurement cannot be made and the attempt is flagged with a "B" (for below top of pump). As above, the water level posted on the hydrograph for wells flagged as "B" is equivalent to the elevation of the bottom of the well casing.

Previous annual reports noted and discussed that water levels were unstable due to Site closure activities and that it would take several years for water levels to become stabilized. A high-level technical review was completed in 2011 by Hydro Systems LLC to analyze post-closure analytical and water level data. An increase in head had been predicted across most of the IA in the 2002 water balance report (K-H 2002a). As confirmed in the technical review of 2011 and as illustrated on the hydrographs, water levels generally do in fact display an increase in elevation from pre- to post-closure averages, agreeing with the direction of water level change (increase, static, decrease) predicted by this model. There are a number of reasons for the observed increases; one obvious major factor is the increased infiltration and groundwater recharge following removal of impervious surfaces.

The water balance model anticipated removal and disruption of facilities, but did not incorporate changes in sampling methods as an input; this change was not considered or implemented until after Site closure. However, it proved to be a significant factor in the rising water levels measured at several locations over the past years. This is discussed in detail in previous reports, such as the annual reports for 2011 (DOE 2012) and 2012 (DOE 2013a).

Measured total precipitation for 2014 was close to normal, but the first half was drier and the second half wetter than average. Precipitation in CY 2014 was recorded at 10 gage locations across the site and Refuge (see Section 3.1.3.4 for more information on this subject). Table 33 provides monthly totals for the Site. The estimated "total" precipitation recorded in 2014 was 12.29 inches (as measured by unheated rain gages, which do not accurately reflect precipitation totals related to snowfall; therefore, this value typically under-represents the actual amount of precipitation received). This total value is approximately 102 percent of the historic (1997–2013) average precipitation of 12.08 inches per year. As summarized in Table 34, precipitation historically has been greatest during the second and third calendar quarters (9.55 inches total) of each year. During CY 2014 the precipitation measured in the second and third quarters (9.83 inches) was essentially equivalent to the average over this historical period (1997–2013). However, the first half of 2014 only received about 69 percent of average (4.16 inches in 2014 versus 6.02 inches on average), while the latter half of 2014 received 134 percent of the average precipitation (8.13 inches versus an average of 6.06 inches).

The initial effects of the significant rain event in September 2013 were reported in the corresponding annual report (DOE 2014c), and were still evident through the first part of 2014 in many areas across the site. Wells in these areas show a sharp water level rise in the fourth quarter of 2013; in some cases, a rise of more than 5 feet is evident. Average water levels in these wells gradually fell after that event but remained higher than normal across much of the Site through the first several months of 2014.

Table 33. Total CY 2014 Monthly Precipitation Data for the Site

Month	Precipitation (inches)
January	0.11
February	0.17
March	0.51
April	0.70
May	2.32
June	0.35
July	3.96
August	0.78
September	1.72
October	1.02
November	0.42
December	0.23
Total Annual	**12.29**

Notes: Values are averaged from 10 tipping bucket rain gages across the Site. This total does not include snowfall totals.

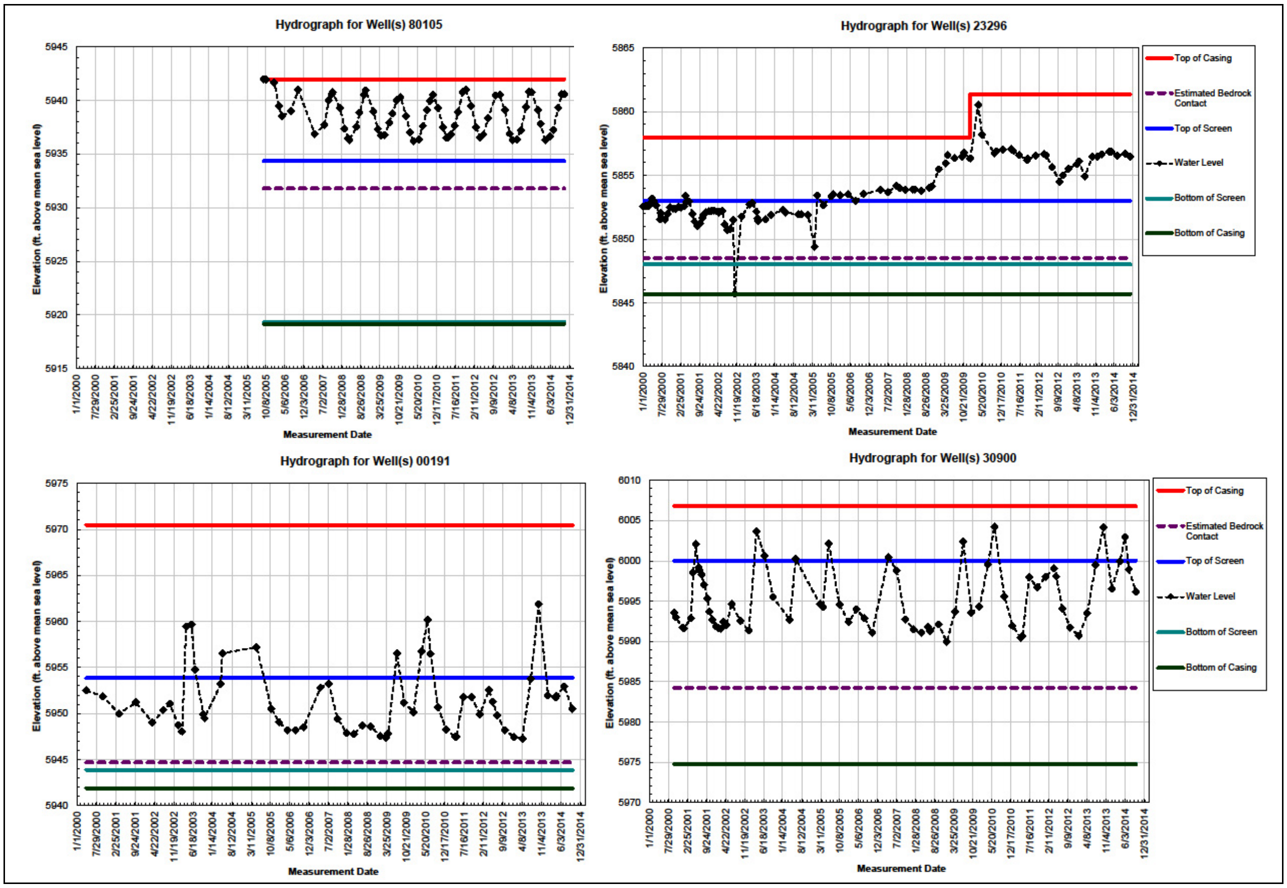
Table 34. Precipitation in CY 2014 Compared with Average Precipitation for Prior Years, by Quarter

Period	CY 2014	Historical Average (1997–2013)
1st Quarter (January–March)	0.79	1.08
2nd Quarter (April–June)	3.37	4.94
3rd Quarter (July–September)	6.46	4.61
4th Quarter (October–December)	1.67	1.45
Total Annual	**12.29**	**12.08**

Notes: This table includes precipitation values for 2003 that incorporate March data from the Site's former 61-meter meteorology tower, which included a heated precipitation gage that recorded precipitation from the multi-foot March 2003 snowstorm more accurately than did the unheated gages operated by the Water Programs Group.

The wells most strongly affected by this recharge event are located on a pediment surface rather than in a drainage, as illustrated in Figure 111. Wells located immediately adjacent to Woman Creek and Walnut Creek show very slight increases in their saturated intervals in response to that event. The best example of this response by far is well 80105, located south (downgradient) of the OLF in the willows adjacent to Woman Creek. This well shows essentially no response to the 2013 flood, instead displaying its normal seasonal behavior. Well 23296 is also situated in a drainage, in this case the South Walnut Creek valley downgradient of the ETPTS groundwater intercept trench. As such, this well is cut off from subsurface flow from the hillside to the south (the East Trenches source area), but does reflect groundwater availability in the valley. The dry conditions preceding the 2013 rains are evident in the hydrograph for this well, but afterwards the water level remained relatively uniform through 2014. (Refer to the annual report for 2010, [DOE 2011] for a discussion of the rising water levels here from 2008 through 2010.)

Conversely, wells located on a pediment surface (such as upgradient of the PLF, in the former B444 area, and in the former 903 Pad and East Trenches area) show the most significant increases. Well 00191, located adjacent to the former 903 Pad, provides a good example of such a response (Figure 111). The higher water levels caused by heavy precipitation in 2013 continued into mid-2014, with some seasonal fluctuation. Many of these wells are represented by hydrographs that show a sharp dip in water levels at the end-2013/beginning-2014 time frame (as illustrated on Figure 111 via the hydrograph for well 30900). However, as can be seen in these examples, the average water level through the first portion of 2014 at these pediment surface wells remained higher than usual.



Notes: Top row includes hydrographs of wells located in drainages, bottom row includes wells located on pediment surfaces. (See Figure 2 for well locations.) These hydrographs are excerpted from Appendix A. Note that the scales for elevation are not the same for all four hydrographs. See text for discussion.

Figure 111. Hydrographs for Selected Wells in Drainages and on Pediment Surfaces

The heavy precipitation in late 2013 that is apparent on many of the hydrographs may have affected contaminant concentrations and distributions. For example, rising groundwater can flush residual contamination from the normally unsaturated vadose zone and transport it downgradient. Discussion of this topic is presented in the context of the respective contaminant plumes in Section 3.1.5.3 of this report.

Groundwater Flow Velocities

Groundwater flow directions and velocities in 2014 are generally consistent with those reported in 2013. Flow directions, water level data, geological information, and completed well designs and locations support the selection of several well pairs for the calculation of linear groundwater flow velocities, also referred to as seepage velocities. In conjunction with the potentiometric surface maps, a pair of wells is potentially useful for these calculations if a line drawn between them is perpendicular (or nearly so) to the potentiometric contour lines between the two wells, and there are no intervening drainages or artificial groundwater control structures (such as the groundwater intercept trenches that are a component of three of the four treatment systems, and the GWIS at the PLF).

The seepage velocity (v) may be calculated using the Darcy equation:

$$v = \left(\frac{K}{n}\right)\left(\frac{dh}{dl}\right)$$

where

K = hydraulic conductivity
n = effective porosity
dh/dl = hydraulic gradient.

This calculation is most sensitive to the hydraulic gradient and value of K used, because for all calculations of v in this report a porosity of 0.1 (consistent with previous Annual RFCA Groundwater Monitoring Reports as well as post-closure RFLMA reports) is used.

The hydraulic gradients were calculated from groundwater elevation data collected in the second and fourth quarters of 2014. Results of the hydraulic gradient calculation typically differ slightly when data are used from different quarters, but the differences are typically not large. The majority of hydraulic gradient differences range from no difference to less than 0.006. As in 2013, the largest difference in hydraulic gradients among the two quarters evaluated (which amounts to 0.018) was calculated for Oil Burn Pit (OBP) #1 well pair 33604-33711, where the gradient was 0.107 for the second quarter and 0.089 for the fourth quarter. Compared to others at the Site in 2014, this is a relatively large difference. It is due to the larger difference in second-quarter water levels at the two wells, which is driven by the lower second-quarter water level in downgradient well 33711. Although the majority of wells experienced higher water levels during the second quarter of 2014 as a result of the September 2013 heavy precipitation, the lower water level in second quarter at well 33711 was not a unique occurrence, and was observed in several other wells. During the second quarter of 2014, the difference in the groundwater elevations measured at 33604 and 33711 was over 11 feet, while the fourth quarter difference was approximately 9 feet. This larger variation in water level observed during the second quarter is reflected in the steeper gradient in this area compared to fourth quarter.

As noted above, previous annual reports (e.g., DOE 2012, DOE 2013a) have discussed the change, formalized in 2009, that revised sampling methods implemented at low-producing wells to one that minimized dewatering. While removing water during sample collection may still affect water levels, of course, these impacts on measured water levels should be much less than those observed prior to this procedural modification.

Calculated seepage velocities are only useful as estimates. Table 35 presents the flow velocities calculated using the 2014 data for selected well pairs. These velocities are hypothetical and represent pure water; therefore, they are most often used to estimate the travel time of conservative (nonreactive) constituents. Reactive constituents tend to migrate more slowly than nonreactive constituents, and also more slowly than the calculated velocity. These calculated

Table 35. Calculated Flow Velocities for 2014

Well Pair	Area	2015 Quarter	Geological Unit	WL Elevation, Well 1	WL Elevation, Well 2	dh (ft)	dl (ft)	dh/dl (hydraulic gradient)	Calculated K (cm/s)	v (ft/yr)	Time to Traverse Transect (yr)
P115589-P114689	North IA	2	Qrf	6009.14	5999.9	9.24	550.14	0.017	4.18E-04	72.64	7.57
P115589-P114689	North IA	4	Qrf	6006.82	5996.85	9.97	550.14	0.018	4.18E-04	78.38	7.02
P114689-21605	North IA/B559	2	Qrf / Qrf/KaKlclst	5999.9	5969.41	30.49	503.78	0.061	3.14E-04	196.45	2.56
P114689-21605	North IA/B559	4	Qrf / Qrf/KaKlclst	5996.85	5967.45	29.4	503.78	0.058	3.14E-04	189.59	2.66
56305-21505	B559	2	Qrf/KaKlclst	5991.39	5967.65	23.74	368.91	0.064	2.09E-04	139.45	2.65
56305-21505	B559	4	Qrf/KaKlclst	5989.58	5966.14	23.44	368.91	0.064	2.09E-04	137.40	2.69
18199-20505	B771	2	KaNo.1ss / Qrf/KaKlclst	5975.27	5933.62	41.65	500.43	0.083	4.99E-04	429.46	1.17
18199-20505	B771	4	KaNo.1ss/ Qrf/KaKlclst	5973.84	5932.74	41.1	500.43	0.082	4.99E-04	423.79	1.18
P416589-80105	OLF	2	Qrf / Qrf/KaKlclst	6013.72	5936.28	77.44	846.63	0.091	3.14E-04	296.90	2.85
P416589-80105	OLF	4	Qrf / Qrf/KaKlclst	6015.2	5940.58	74.62	846.63	0.088	3.14E-04	286.34	2.96
40005-80205	OLF	2	Qrf/KaKlclst	6007.97	5932.7	75.27	1194.95	0.063	2.09E-04	136.50	8.75
40005-80205	OLF	4	Qrf/KaKlclst	6007.76	5932.39	75.37	1194.95	0.063	2.09E-04	136.68	8.74
40305-39605	South IA	2	Qrf/KaKlslt / KaKlclst	6007.43	5997.39	10.04	1126.39	0.009	1.12E-04	10.34	108.92
40305-39605	South IA	4	Qrf/KaKlslt / KaKlclst	6005.52	5997.38	8.14	1126.39	0.007	1.12E-04	8.37	134.51
40005-P419689	South IA	2	Qrf/KaKlclst / Qrf/KaNo.1ss	6007.97	6004.28	3.69	478.87	0.008	4.06E-04	32.39	14.79
40005-P419689	South IA	4	Qrf/KaKlclst / Qrf/KaNo.1ss	6007.76	6003.15	4.61	478.87	0.010	4.06E-04	40.46	11.84
P419689-11502	South IA	2	Qrf/KaNo.1ss/ KaKlclst	6004.28	5997.48	6.8	535.27	0.013	3.02E-04	39.69	13.49
P419689-11502	South IA	4	Qrf/KaNo.1ss/ KaKlclst	6003.15	5997.11	6.04	535.27	0.011	3.02E-04	35.25	15.18

Table 35 (continued). Calculated Flow Velocities for 2014

Well Pair	Area	2015 Quarter	Geological Unit	WL Elevation, Well 1	WL Elevation, Well 2	dh (ft)	dl (ft)	dh/dl (hydraulic gradient)	Calculated K (cm/s)	v (ft/yr)	Time to Traverse Transect (yr)
40305-22996	South IA/ 800 Area	2	Qrf/KaKlclst / Qrf	6007.43	5981.73	25.7	2037.05	0.013	3.14E-04	40.95	49.74
40305-22996	South IA/ 800 Area	4	Qrf/KaKlclst / Qrf	6005.52	5978.2	27.32	2037.05	0.013	3.14E-04	43.53	46.79
88205-00797	881 Hillside	2	Qrf/KaKlclst / Qrf	5968.29	5925.84	42.45	343.12	0.124	3.14E-04	401.93	0.85
88205-00797	881 Hillside	4	Qrf/KaKlclst / Qrf	5970.23	5925.56	44.67	343.12	0.130	3.14E-04	422.95	0.81
00191-00491	903 Pad-Lip	2	Qrf/ Qrf/KaKlclst	5951.76	5894.22	57.54	816.98	0.070	3.14E-04	228.61	3.57
00191-00491	903 Pad-Lip	4	Qrf/KaKlclst	5950.48	5889.83	60.65	816.98	0.074	2.09E-04	160.87	5.08
07391-10304	Ryan's Pit/ Woman Ck.	2	Qrf/KaKlclst / Qc/KaKlclst	5943.3	5810.24	133.06	948.74	0.140	1.28E-04	186.12	5.10
07391-10304	Ryan's Pit/ Woman Ck.	4	Qrf/KaKlclst / Qc/KaKlclst	5941.85	5810.08	131.77	948.74	0.139	1.28E-04	183.94	5.16
33502-33711	Oil Burn Pit #1	2	Qrf/ Qrf/KaKlclst	6016.22	6000.58	15.64	271.46	0.058	3.14E-04	187.01	1.45
33502-33711	Oil Burn Pit #1	4	Qrf/ Qrf/KaKlclst	6014.87	6002.3	12.57	271.46	0.046	3.14E-04	150.30	1.81
33502-33604	Oil Burn Pit #1	2	Qrf / Qrf/KaKlclst	6016.22	6011.68	4.54	177.63	0.026	3.14E-04	82.96	2.14
33502-33604	Oil Burn Pit #1	4	Qrf / Qrf/KaKlclst	6014.87	6011.48	3.39	177.63	0.019	3.14E-04	61.95	2.87
33604-33711	Oil Burn Pit #1	2	Qrf/KaKlclst	6011.68	6000.58	11.1	103.49	0.107	2.09E-04	232.42	0.45
33604-33711	Oil Burn Pit #1	4	Qrf/KaKlclst	6011.48	6002.3	9.18	103.49	0.089	2.09E-04	192.22	0.54
P210189-79102	SEPs	2	KaKlslt / KaKlclst	5970.13	5948.78	21.35	301.98	0.071	1.48E-05	10.86	27.82
P210189-79102	SEPs	4	KaKlslt / KaKlclst	5968.98	5948.42	20.56	301.98	0.068	1.48E-05	10.45	28.89
79102-22205	North of SEPs	2	KaKlclst / KaKlslt	5948.78	5918.9	29.88	235.62	0.127	1.48E-05	19.47	12.10
79102-22205	North of SEPs	4	KaKlclst / KaKlslt	5948.42	5917.68	30.74	235.62	0.130	1.48E-05	19.98	11.79
79502-99305	SEPs/B991	2	Qrf/KaKlclst	5961.99	5928.99	33	532.37	0.062	2.09E-04	134.32	3.96

Table 35 (continued). Calculated Flow Velocities for 2014

Well Pair	Area	2015 Quarter	Geological Unit	WL Elevation, Well 1	WL Elevation, Well 2	dh (ft)	dl (ft)	dh/dl (hydraulic gradient)	Calculated K (cm/s)	v (ft/yr)	Time to Traverse Transect (yr)
79502-99305	SEPs/B991	4	KaKlclst / Qrf/KaKlclst	5960.97	5929.24	31.73	532.37	0.060	1.05E-04	64.85	8.21
70393-70693	PU&D/PLF	2	Qrf	5994.33	5981.13	13.2	410.48	0.032	4.18E-04	139.08	2.95
70393-70693	PU&D/PLF	4	Qrf	5988.5	5975.98	12.52	410.48	0.031	4.18E-04	131.91	3.11
30900-30002	PU&D/ N. Walnut Ck.	2	Qrf/KaNo.1ss / KaKlclst	6000.32	5928.18	72.14	1890.74	0.038	3.02E-04	119.19	15.86
30900-30002	PU&D/ N. Walnut Ck.	4	Qrf/KaNo.1ss / KaKlclst	5996.53	5923.23	73.3	1890.74	0.039	3.02E-04	121.14	15.61

Abbreviations:
cm/s = centimeters/second
ft = feet
ft/yr = feet per year
SEP = Solar Evaporation Pond
WL =
yr = years

velocities do not take into account properties such as sorption and chemical reactions (e.g., precipitation, abiotic and biologically driven degradation, and volatilization) that can strongly influence the transport of dissolved constituents including groundwater contaminants.

For each well pair, the value of K, the hydraulic conductivity, selected for this calculation was based on the predominant lithologic unit(s) comprising the saturated materials screened by each member of the well pair. This is based on the core logs for the respective wells and the published geology (EG&G 1995b), as well as information from the hydrographs (i.e., whether the saturated interval is typically restricted to the bedrock or includes surficial materials). If more than one lithology is represented in the screened interval of a well and, based on the hydrographs, the multiple lithologies appear to comprise a meaningful fraction of the saturated interval, then an average K was calculated from the corresponding lithologies. K values used for these calculations are from the EG&G hydrogeologic report (EG&G 1995a), Table G-2, with subsequently modified values for Rocky Flats Alluvium and valley-fill alluvium (RMRS 2000a; Safe Sites 2001, 2002).

One factor that may cause significant error in estimated seepage velocities is the presence of artificial fill in many portions of the former IA. The K value for Rocky Flats Alluvium is used because the source of the fill was typically deposits of Rocky Flats Alluvium. However, other materials (such as concrete rubble) were also used, and it is unlikely that the backfilled and reworked alluvium has the internal structure of or is as compacted as the original deposits, resulting in a higher effective porosity and K value than the published values for Rocky Flats Alluvium. Where well pairs cross former buildings that were backfilled with concrete rubble and alluvium, the effective porosity and K values may be higher still. For this report, well pairs crossing areas of sufficiently thick backfill deposits may use the K value for Rocky Flats Alluvium rather than that for the original lithology, under the assumption that the entire area of backfill/regrading has a hydraulic conductivity closer to that of Rocky Flats Alluvium than to a lower-permeability unit.

As stated above, these calculated velocities are based in part on data displayed on the hydrographs: if water is shown and the screened interval extends above the bedrock contact, then the calculations include hydraulic conductivities for the unconsolidated surficial material (e.g., Rocky Flats Alluvium or colluvium), as well as for bedrock to account for water flowing through the unit. If the hydrographs show that water is typically restricted to the bedrock, the K value for the generalized bedrock type at that well is selected. Note that, similar to the highly heterogeneous alluvial deposits, the bedrock lithologies are also variable (e.g., from claystone to silty claystone to clayey siltstone to siltstone), as is often reflected in cores from the screened interval of a given well; however, a single K value is selected to represent the well.

Estimated seepage velocities in 2014 (Table 35) range from (1) a low of 8.37 feet per year (ft/yr) within the artificial fill and bedrock from well 40305 to well 39605, in the vicinity of the former Industrial Area (southern portion) and across an area of VOC contamination, to (2) a high of 429.46 ft/yr within the artificial fill and bedrock (including the Arapahoe No. 1 Sandstone) from well 18199 (near the source area of the Individual Hazardous Substance Site (IHSS) 118.1 or Carbon Tetrachloride Plume) down the hill to well 20505 in the vicinity of the former Building 771 area. Refer to Figure 2 for the locations of the wells listed in Table 35.

The corresponding travel time between each well in a well pair ranges from approximately 5 months (from well 33604 to well 33711 in the vicinity of former OBP #1 and within the

VC Plume) to over 134 years (from well 40305 to well 39605 in the southern IA). However, as explained, these are estimated velocities for pure water, and the hydraulic gradients can be seen to change significantly from season to season between wells in some well pairs as a result of precipitation and seasonal recharge patterns. For example, the gradients between wells 33502 and 33711 (0.058 and 0.046 for second and fourth quarters, respectively) lead to corresponding calculated velocities of 187.01 ft/yr and 150.30 ft/yr—travel times of approximately 1.5 and almost 2 years, respectively. As illustrated, these estimates are very sensitive to measured water levels, again underscoring the potential importance of the change in sample collection procedures mentioned above and more thoroughly discussed in previous reports (e.g., DOE 2012, 2013a).

As in previous years, there are instances in which the estimated travel times for a given well pair vary widely between the second and fourth quarter. This is most often related to differences in gradient from one quarter to the other, as explained above; when groundwater elevations are very similar in both members of a well pair, a low gradient is calculated, which results in a slower travel time; when elevations are very different, the gradient is steeper, resulting in a higher calculated velocity. Differences in travel times can also be a result of differences in the hydraulic conductivity values used in the calculations, also discussed above. One well pair in which both conditions (different gradient, different conductivities) affected the estimated travel times is well pair 00191-00491 (Table 35). These wells are located in the vicinity of the 903 Pad-Lip Area in an area of VOC groundwater contamination. The gradients calculated for this well pair are 0.070 and 0.074 for second and fourth quarters, respectively. During the second quarter, the groundwater monitored at these wells was within Rocky Flats Alluvium (well 00191) and predominantly Rocky Flats Alluvium with some claystone bedrock (well 00491). The lower water levels observed in the fourth quarter resulted in groundwater at well 00491 flowing through just claystone bedrock rather than a mixture of alluvium and bedrock as in second quarter. Given that the claystone has a lower hydraulic conductivity than the Rocky Flats Alluvium, this lower water level during fourth quarter therefore effectively decreased the overall hydraulic conductivity and led to a significantly slower seepage velocity and total travel time in the fourth quarter. The results (Table 35) for second quarter are 228.61 ft/yr with an estimated total travel time of 3.57 years, and for fourth quarter are 160.87 ft/yr and 5.08 years. This points to the number of variables that are considered and the sensitivity of these seepage estimates, and further suggests caution be used when interpreting and applying them.

Velocities and travel times were also estimated for the nearby Ryan's Pit area, where the source area is monitored by Evaluation well 07391 and the pathway to surface water is monitored at its terminus by AOC well 10304. The travel times estimated in 2014 (just over 5 years in both second and fourth quarters) are equivalent to those estimated in previous years (for example, see DOE 2011, 2012, 2013a).

Other well pairs that may be of interest due to contaminants in the groundwater monitored by them include well pair 33502–33604 in the vicinity of the OBP #1. The travel times calculated for this well pair are similar in second and fourth quarters, and average roughly 2.5 years. Similarly, well pair 33604-33711, also in the vicinity of the OBP #1, have very similar travel times (5 and 6 months, respectively) (Table 35).

See Section 3.1.5 for additional discussion of groundwater quality in the various areas, including those described above. For a more detailed discussion of flow between well pairs by area, refer to the 2006 and 2007 Annual Reports [DOE 2007b, 2008].

In general, the estimated flow paths and velocities calculated for 2014 are comparable to those calculated prior to Site closure (e.g., K-H 2004b) and are also very similar to those presented in the 2013 Annual Report (DOE 2014c), as well as previous annual reports.

Based on the field data collected during 2014, it is apparent that the significant precipitation event in September 2013 continued to influence second quarter 2014 water levels. The effects of the flooding can be seen in the elevated levels, with fourth quarter water levels more closely resembling seasonal norms. Overall, the estimates of seepage velocities for 2014 are not much different from those calculated in previous post-closure years and the estimated groundwater flow paths also remain consistent with previous results.

3.1.3.6 Seeps

Seeps are common at the Rocky Flats Site. Seep distribution and occurrence are strongly controlled by geology and precipitation, and much of the discharge occurs at the contact between the Rocky Flats Alluvium and underlying claystone.

Seep locations posted on the second and fourth quarter CY 2014 potentiometric surface maps are slightly modified from those shown on the 1995 Hydrogeologic Characterization Report (EG&G 1995a). Although this 1995 depiction of seeps has been the best available map of the seeps for the Site for some time, it is no longer accurate, having been strongly affected by the removal of all artificial water sources and impermeable surfaces, as well as the overall land surface reconfiguration (e.g., excavations and placement of fill) in some areas. Thus, a new effort to identify locations of existing seeps in the COU began in 2010. Although not a rigorous investigation, this activity is designed to qualitatively establish the presence of seeps and document their general location.

One observation made during recent years is that seeps often occur where former building foundations, footer drains, and other features remain that contribute to groundwater reaching the surface. This observation supports the design of the monitoring network, which considered the anticipated post-closure groundwater flow directions.

Figure 112 presents the locations where seeps and wet areas were observed during July of CY 2014. Given that July was, by far, the wettest month of 2014, with almost 4 inches of precipitation, it is not surprising that numerous seeps and wet areas were scattered across the site during this time frame. Approximately one-third of the total precipitation for 2014 fell during July. Efforts to map seeps and wet areas across the Site will continue.

3.1.4 Surface-Water Data Interpretation and Evaluation

3.1.4.1 Surface-Water Quality Summaries

This section presents water quality summaries for selected analytes for the period January 1, 1997, through December 31, 2014 (CY 1997–2014) for the automated surface-water monitoring locations collecting flow-paced composite samples in CY 2014. Radionuclides summarized include Pu, Am,[10] and total U. Additionally, the POE metals (total beryllium [Be],

[10] In this report, "plutonium" or "Pu" refers to plutonium-239, 240; and "americium" or "Am" refers to americium-241.

dissolved Cd, total Cr, and dissolved silver [Ag]) and nitrate+nitrite as N[11] are also summarized. Additional analyses are also performed based on the specific monitoring objective. The results and evaluation for these additional analytes are presented in Section 3.1.2.1 through Section 3.1.2.9 by monitoring objective.

The summary values in this section should not be confused with the RFLMA required water-quality evaluations according to Attachment 2 in the RFLMA. The Pu, Am, and total U standards noted in this section apply only to POE (GS10, SW027, and SW093; Section 3.1.2.2) and POC (WALPOC and WOMPOC; Section 3.1.2.1) 30-day or 12-month rolling averages. Comparisons of standards to other summary statistics are noted in this section for reference only. POEs and POCs are highlighted in **bold** in the tables.

Radionuclides

The following summaries include all available results that were not rejected through the validation process.[12] Data are generally presented to decimal places as reported by the laboratories. Accuracy should not be inferred; minimum detectable concentrations, activities, and analytical errors are often greater than the precision presented. When a negative radionuclide result (e.g., –0.002 pCi/L) is reported by the laboratory due to blank correction, a value of 0.0 pCi/L is used for calculation purposes. When a sample has a corresponding field duplicate, the value used in calculations is the arithmetic average of the “real” and “duplicate” values.[13] When a sample has multiple “real” analyses (e.g., Site requested “reruns”), the value used in calculations is the arithmetic average of the multiple “real” analyses.

The Pu/Am ratio is calculated for each sample by dividing the Pu result by the corresponding Am result. Ratios are only calculated for samples where *both* the Pu and Am results are greater than 0.015 pCi/L (generally the minimum detectable activity for Pu and Am analyses) to exclude ratios for very low results with high relative error.

Each table includes only those locations where samples were collected that were analyzed for the referenced analyte. Maps are also included showing monitoring locations and the corresponding median values of the referenced parameter. Only locations that had four or more individual results are mapped.

[11] Due to hold time requirements, the nitrate+nitrite as N summaries are based on grab sample results.
[12] Summaries do not include supplemental post-closure grab samples for uranium from GS13 that were collected to assess modifications to the SPPTS; only routine continuous flow-paced samples are included.
[13] Arithmetic averaging of radionuclide pairs is performed only when the RER is less than or equal to 5. If the RER is greater than 5, the radionuclide results are determined to be nonrepresentative. These results are not used for the calculation of summary statistics. A more thorough discussion of data management is given in Appendix B.1, “Surface-Water Analytical Data Evaluation Methods.”

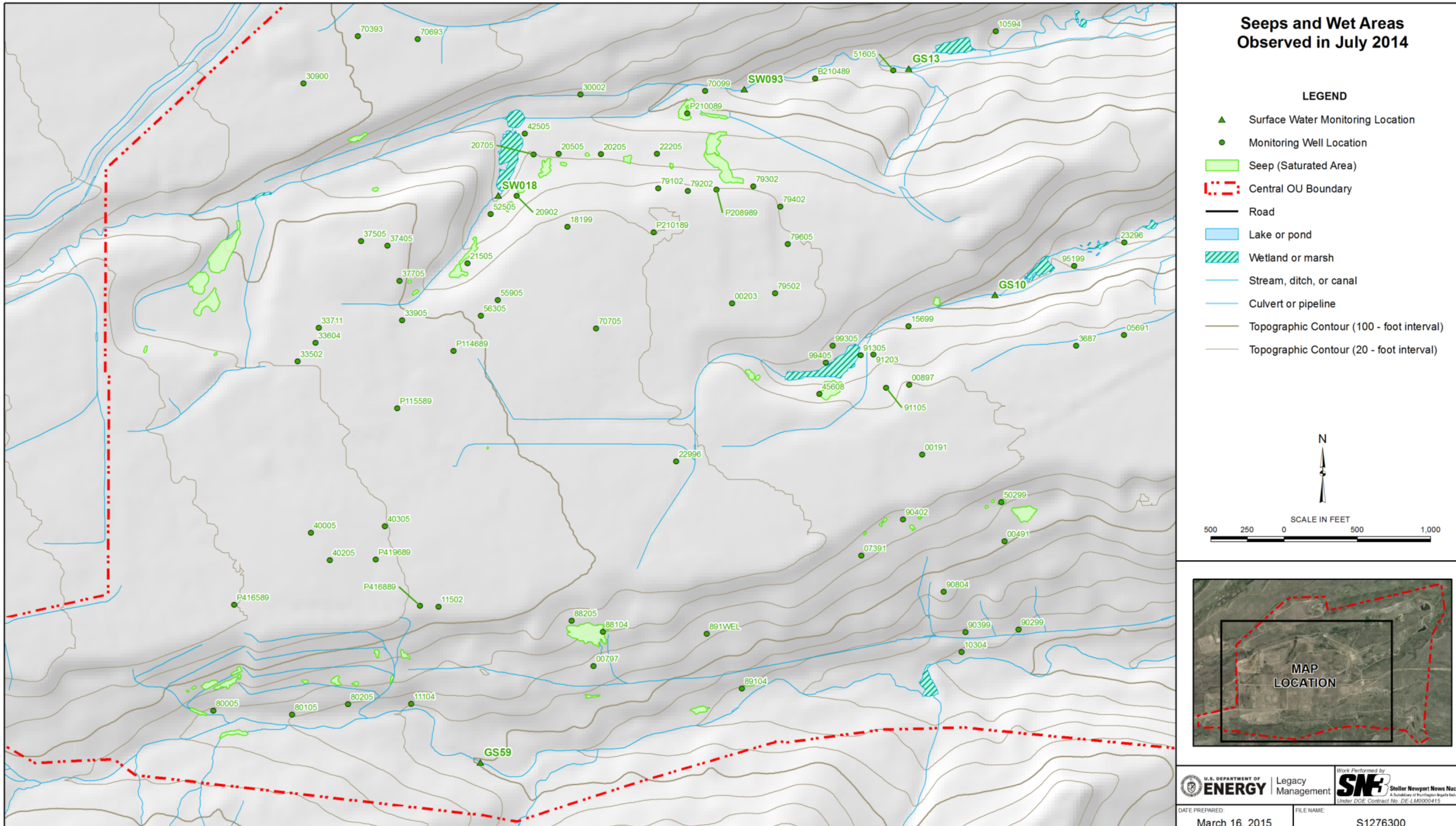


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Figure 112. Seeps and Wet Areas Observed in 2014

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