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 2009. 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. Surface-water flow across the Site is primarily from west to east, with three major drainages traversing the Site. Five ponds within the COU collect and manage surface-water runoff.[15] The Site drainages and ponds, including their respective pertinence to this report, are described below and shown on Figure 3–47.

In March 2009, the Site completed the reconfiguration (Dam Breach Phase I) of Dams A-1 and A-2 in North Walnut Creek and Dams B-1, B-2, B-3, and B-4 in South Walnut Creek. The reconfiguration eliminates the dams from ongoing monitoring and maintenance as required by the Colorado Office of the State Engineer and returns the stream reaches to a more natural system, while preserving existing wetlands and habitat. (see Section 2.3).

The major stream drainages leading out of the Refuge, from north to south, are Rock Creek, Walnut Creek, and Woman Creek. North Walnut Creek flows through the A-Series Ponds and South Walnut Creek flows through the B-Series Ponds; both are tributaries to Walnut Creek. The hydrologic routing diagram (as of December 31, 2009) for the locations included in this report is shown on Figure 3–48.

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 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 locally diverted toward 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 subcrop or are sufficiently shallow to be included in

[15] Former Dams A-1, A-2, B-1, B-2, B-3, and B-4 were breached during 2008−2009.

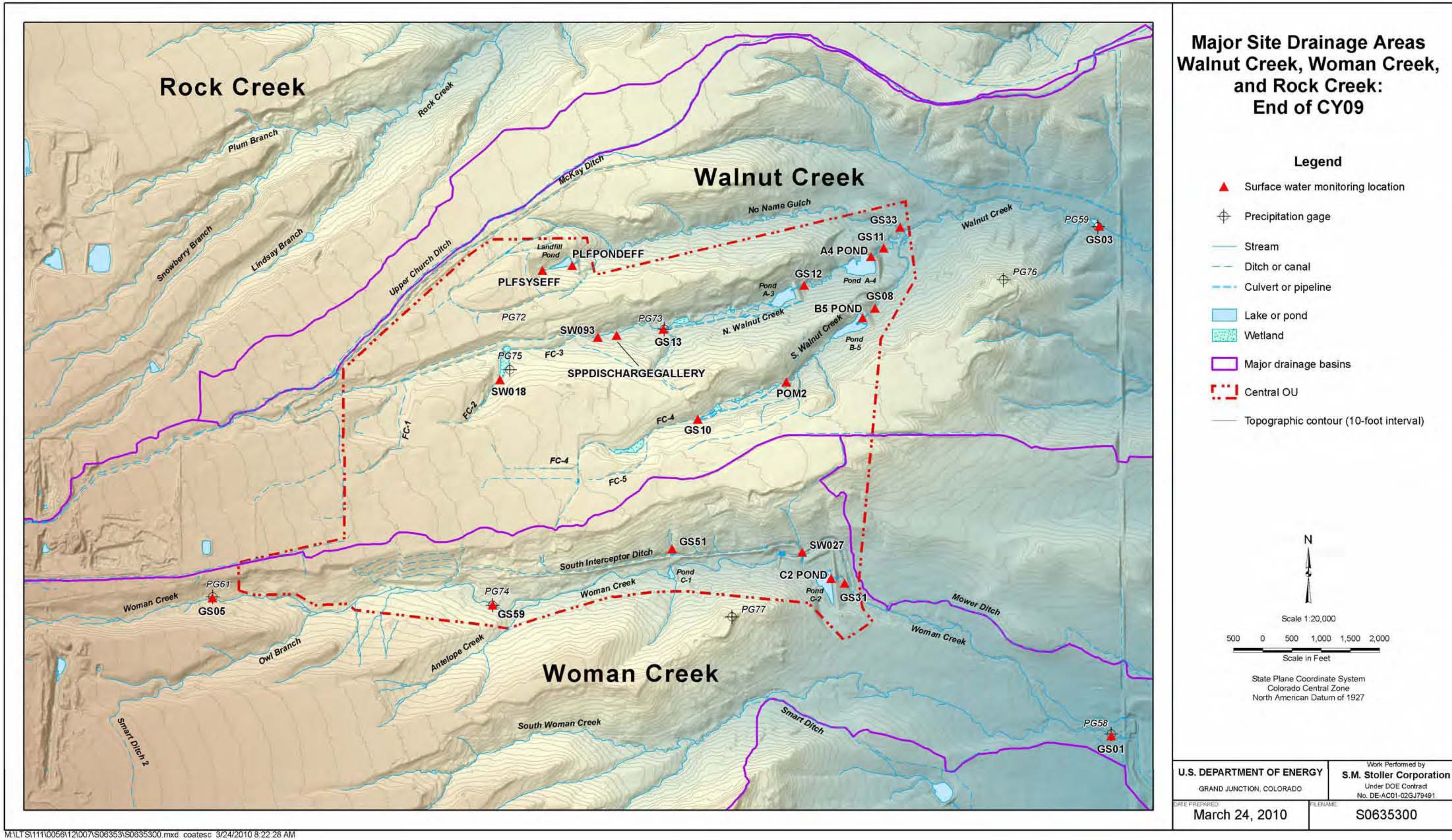

Figure 3–47. Major Site Drainage Areas—Walnut Creek, Woman Creek, and Rock Creek: End of CY 2009

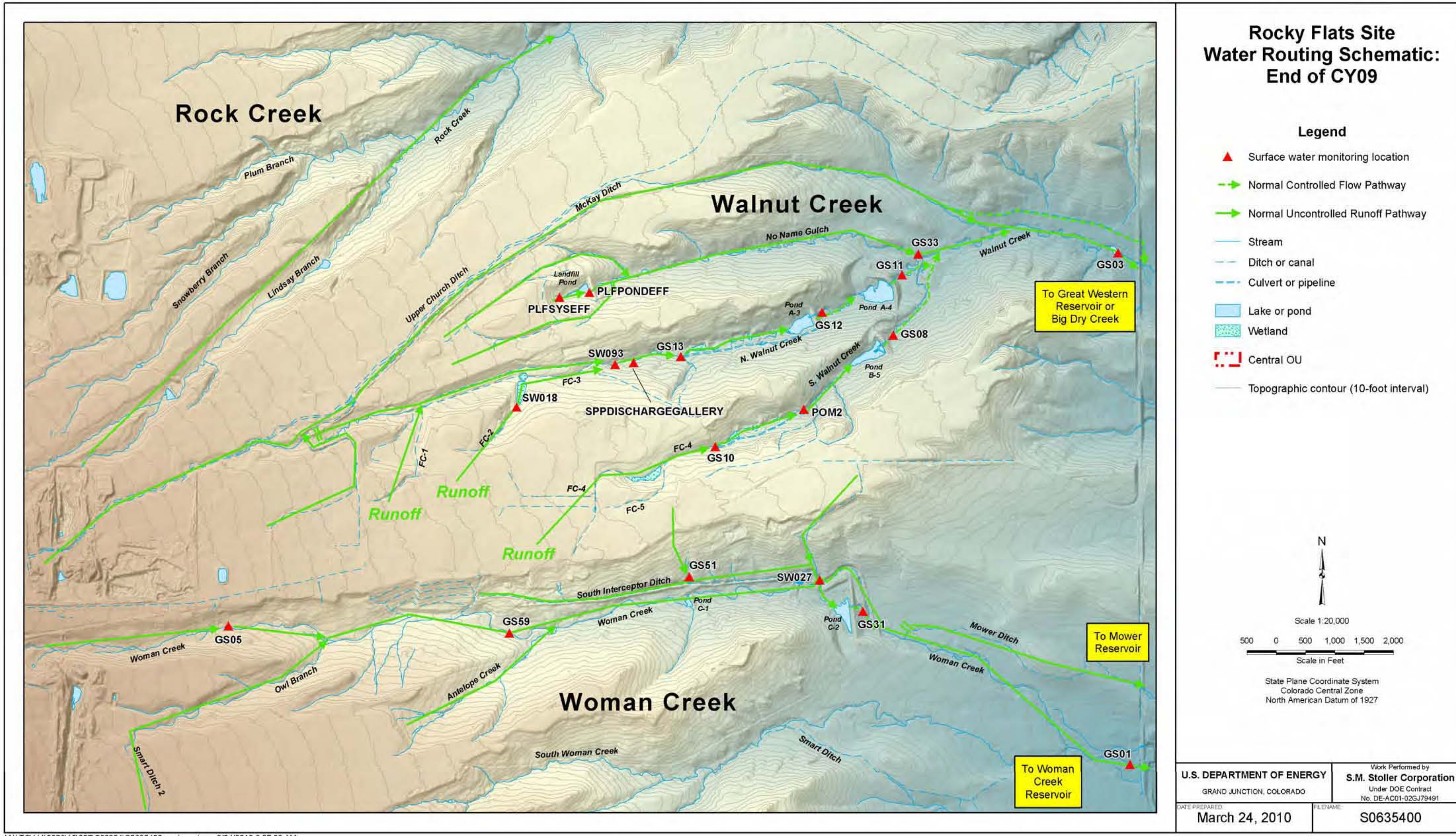

Figure 3–48. Rocky Flats Site Water Routing Schematic: End of CY 2009

the UHSU. For a more thorough description of the hydrogeology at Rocky Flats, refer to 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 diverted in July 1999 into a new pipeline to keep McKay Ditch water from commingling with water in Walnut Creek upstream of Indiana Street. Although no longer a contributor to Walnut Creek, the McKay Ditch drainage is described here to clarify water routing. The new configuration allows the City of Broomfield to direct water from the South Boulder Diversion Canal, across the northern portion of the Refuge and directly into Great Western Reservoir, without entering Walnut Creek. This configuration prevents the commingling of McKay Ditch water with discharged water from the Site ponds. 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 Landfill Pond. 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 and runoff from the area surrounding the Landfill Pond are the sole surface-water sources to the Landfill Pond. The Landfill Pond is normally operated in a flow-through configuration, although the pool level periodically drops below the outlet works.

North Walnut Creek

Runoff from the northern portion of the COU flows into this drainage, which has four ponds (Ponds A-1, A-2, A-3, and A-4). Dams A-1 and A-2 were breached in 2008−2009 (see Section 2.3). The combined capacity of the A-series ponds is approximately 174,000 cubic meters (m^3) (46 million gallons, or 141 acre-feet). In the normal operational configuration, Ponds A-1 and A-2 receive flow for stormwater attenuation and wetland habitat; the stoplog structures control water levels in these ponds, with water subsequently flowing to Pond A-3 for retention. Pond A-3 is discharged in batches to the A-series "terminal pond" Pond A-4. If routine discharge of retained water is warranted, Pond A-4 is isolated, sampled, and water is released if surface water-quality criteria are met. Criteria for emergency discharge, regardless of pre-discharge pond sampling results, are detailed in the *Emergency Response Plan for Rocky Flats Site Dams* (ERP) (DOE 2010e).

South Walnut Creek

Runoff from the central portion of the COU flows into this drainage, which has five ponds (Ponds B-1, B-2, B-3, B-4, and B-5). Dams B-1, B-2, B-3, and B-4 were breached in 2008−2009 (see Section 2.3). The combined capacity of the South Walnut Creek B-series ponds is approximately 93,000 m^3 (25 million gallons or 76 acre-feet). In the normal operational configuration, Ponds B-1, B-2, B-3, and B-4 receive flow for storm water attenuation and wetland habitat; the stoplog structures control water levels in these ponds, with water subsequently flowing to “terminal pond” Pond B-5. If routine discharge of retained water is warranted, Pond B-5 is sampled and water is released if surface water quality criteria are met. Criteria for emergency discharge, regardless of pre-discharge pond sampling results, are detailed in the ERP.

Woman Creek

South of the COU is Woman Creek, which flows through Pond C-1 (breached in 2004) and off site 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 Big Dry Creek by the Woman Creek Reservoir Authority.

South Interceptor Ditch

In the southern portion of the COU, and tributary to Woman Creek, is the SID drainage. Surface-water runoff from the southern portion of the COU is captured by the SID, which flows from west to east into Pond C-2. If routine discharge of retained water is warranted, Pond C-2 is sampled, and water is released to Woman Creek if surface water quality criteria are met. Criteria for emergency discharge, regardless of pre-discharge 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,[16] 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 change 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 or contents. This record loss occurs when recording instruments malfunction or otherwise fail to operate properly, intakes are plugged, the stilling well is frozen, or for various other reasons. For such periods, the daily discharges are estimated from the recorded range in stage, previous or

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

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.

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 CY(s), a table of daily mean discharge values for the CY with summary data, a tabular statistical summary of monthly mean discharge data for the CY, 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.[17]
- 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.

Daily Mean Discharge Values

The daily mean discharge values computed for each gaging station during a CY 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 cfs, during the month; and the lines headed "Maximum" and "Minimum" list the maximum and minimum daily mean discharges for

[17] Drainage area maps show Site configuration at the end of CY 2009.

each month. Total discharge for the month also is expressed in cubic feet ("Cubic Feet"), gallons ("Gallons"), and acre-feet ("Acre-Feet"). The term "Partial Data" denotes a month with incomplete data.

Summary Statistics

A section of the table titled "Annual Summaries for CY09" follows the monthly mean data section. This section provides a statistical summary of annual flow rates and discharge for the labeled CY. 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

Site-Wide Discharge Summary

Discharge summaries for the two major Site drainages receiving flow from the COU (Walnut and Woman Creeks) are given on Figure 3–49 and Figure 3–50.[18] Walnut Creek flows are measured at GS03 and Woman Creek flows are measured at GS01. Figure 3–51 shows the relative total CY 1997−2009 discharge volumes from the major Site drainages as measured at Site POEs and POCs. 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.

[18] The pre-closure period is for the dates 1/1/97−10/1/05; the post-closure period is for the dates 10/1/05−12/31/09.

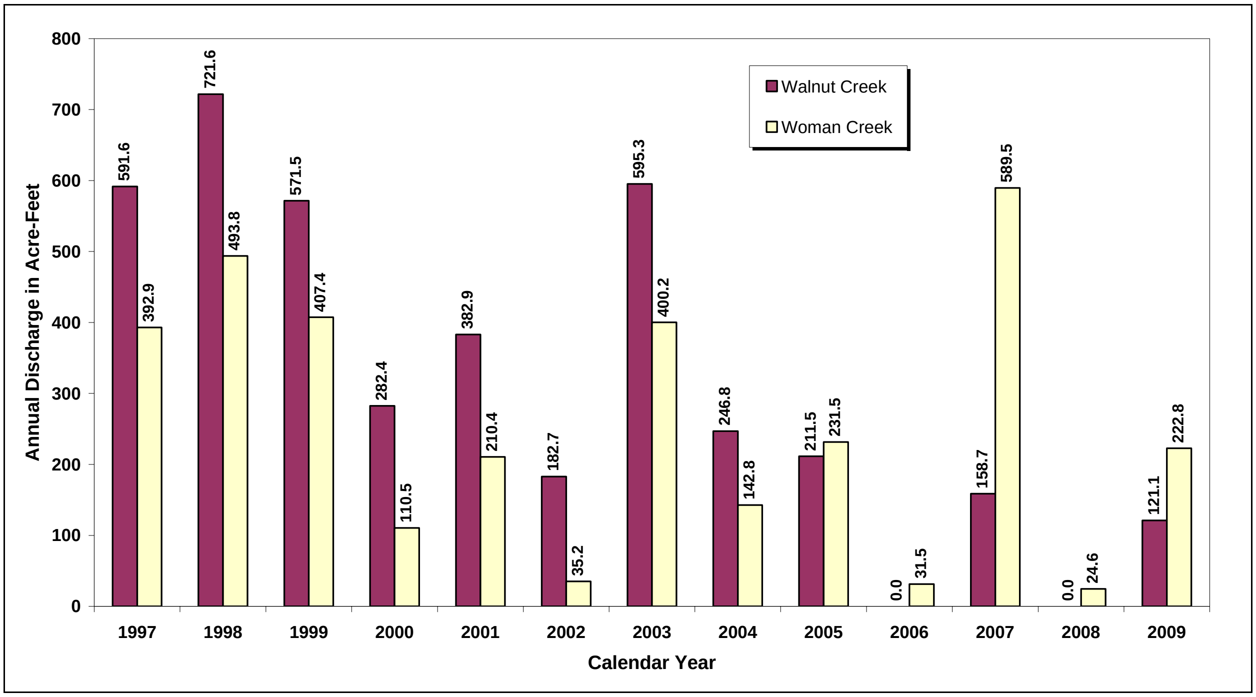


Figure 3–49. Annual Discharge Summary from Major Site Drainages: CY 1997−2009

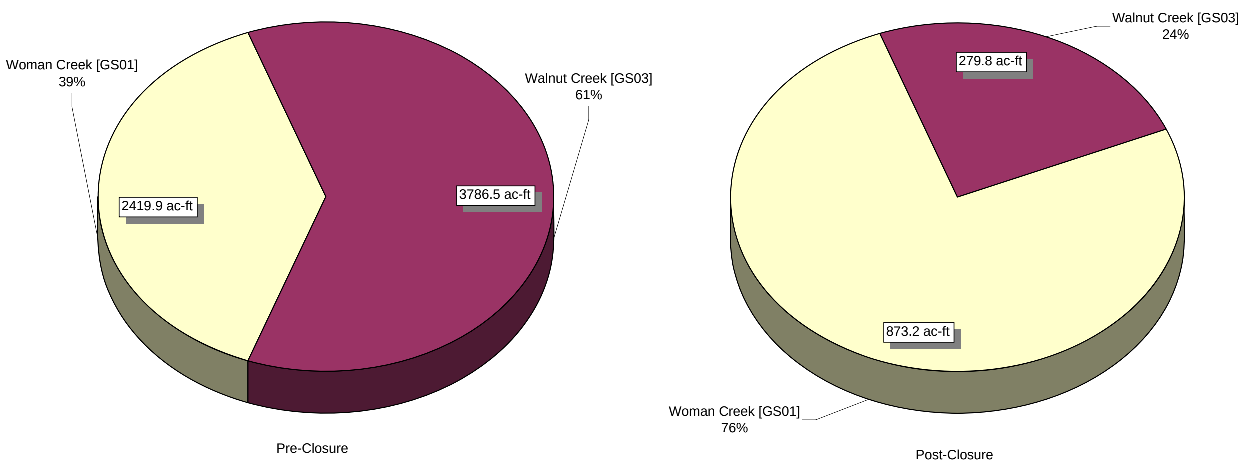


Figure 3–50. Relative Total Discharge Summary from Major Site Drainages: Pre- and Post-Closure Periods

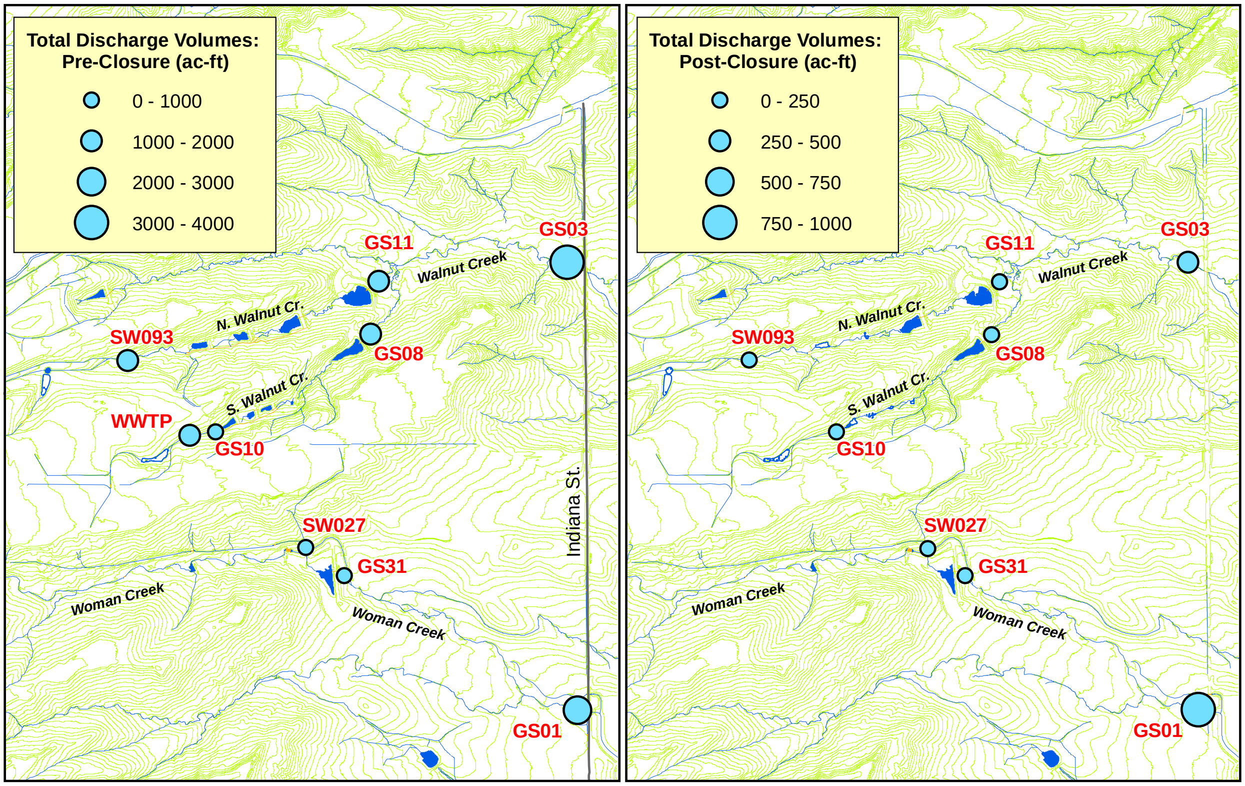


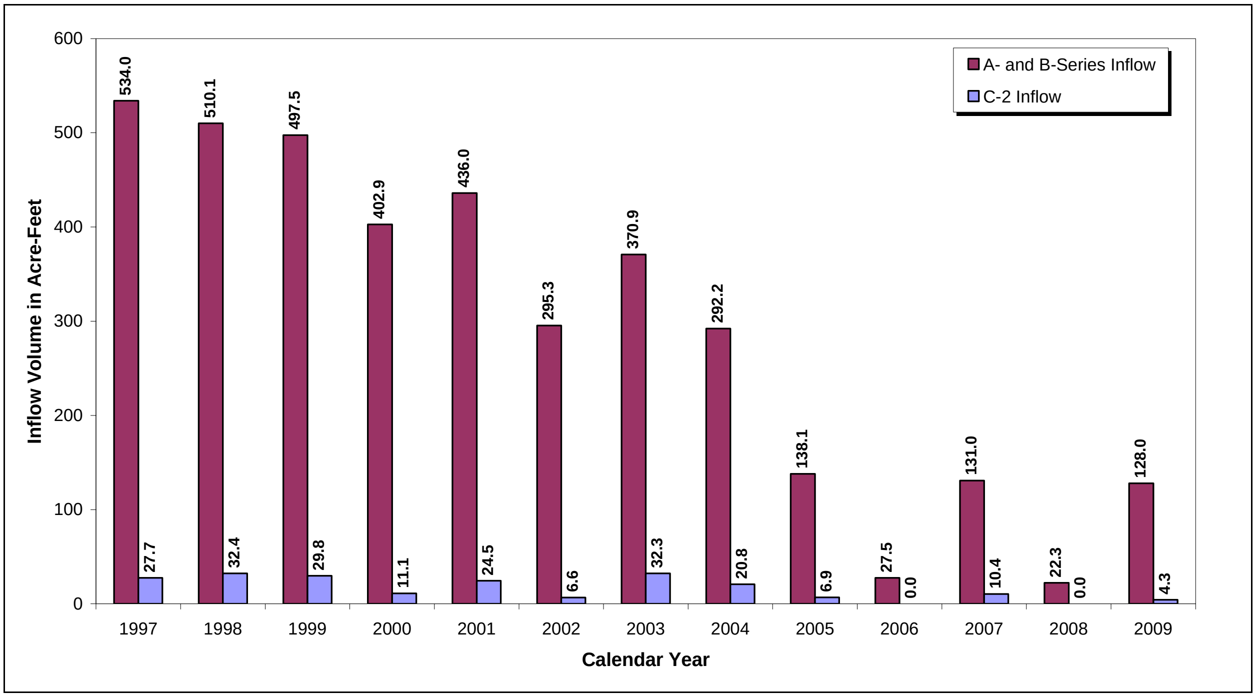
Figure 3–51. Map Showing Relative CY 1997−2009 Discharge Volumes for POEs and POCs: Pre- and Post-Closure Periods

Pond Discharge Summary

Figure 3–52 and Figure 3–53 show the annual ponds inflows and outflows, respectively. Due to the intermittent pump transfers of Pond B-5 water to Pond A-4, the 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 3–54 and Figure 3–55 show the relative total CY 1997−2009 discharge volumes from the ponds (as measured at GS08, GS11, and GS31) and from the major drainages tributary to the ponds (as measured at GS10, SW027, SW091, SW093, and the former Waste Water Treatment Plant [WWTP] [995POE]).[19, 20] 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.

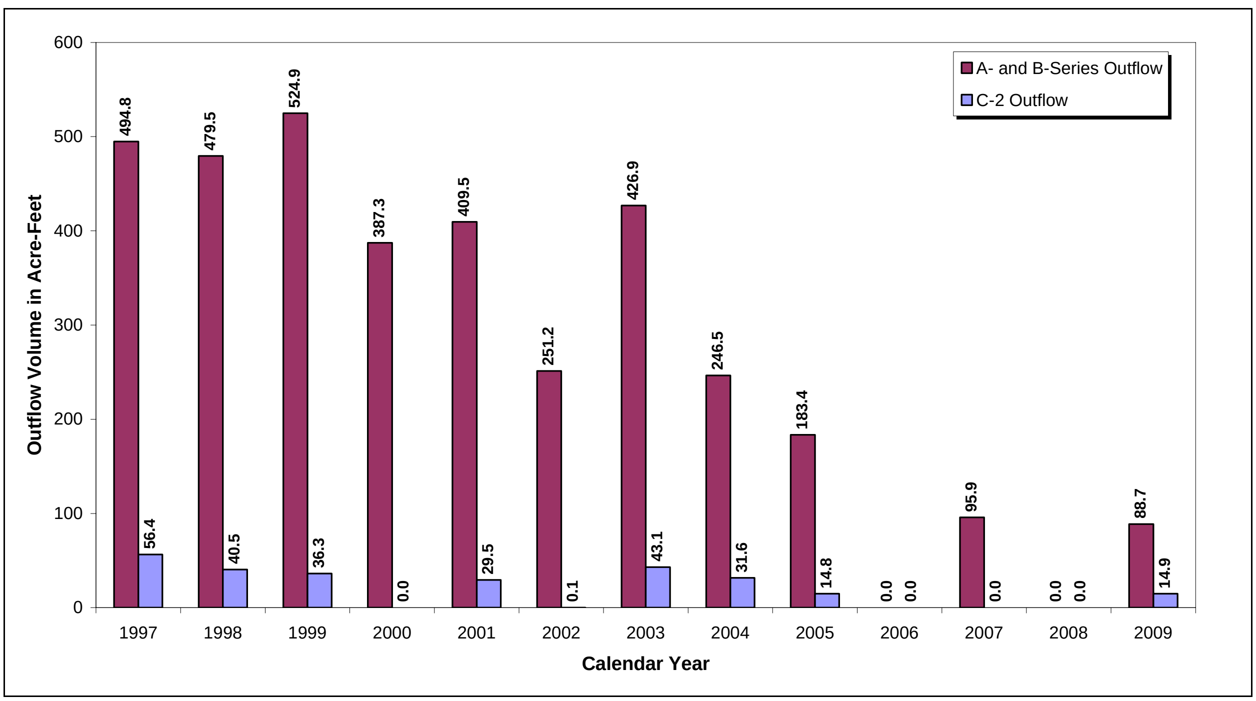
[19] The WWTP was removed from service on November 4, 2004.

[20] The pre-closure period is for the dates 1/1/97−10/1/05; the post-closure period is for the dates 10/1/05−12/31/09.



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 3–52. Pond Inflows: CY 1997−2009



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

Figure 3–53. Pond Outflows: CY 1997−2009

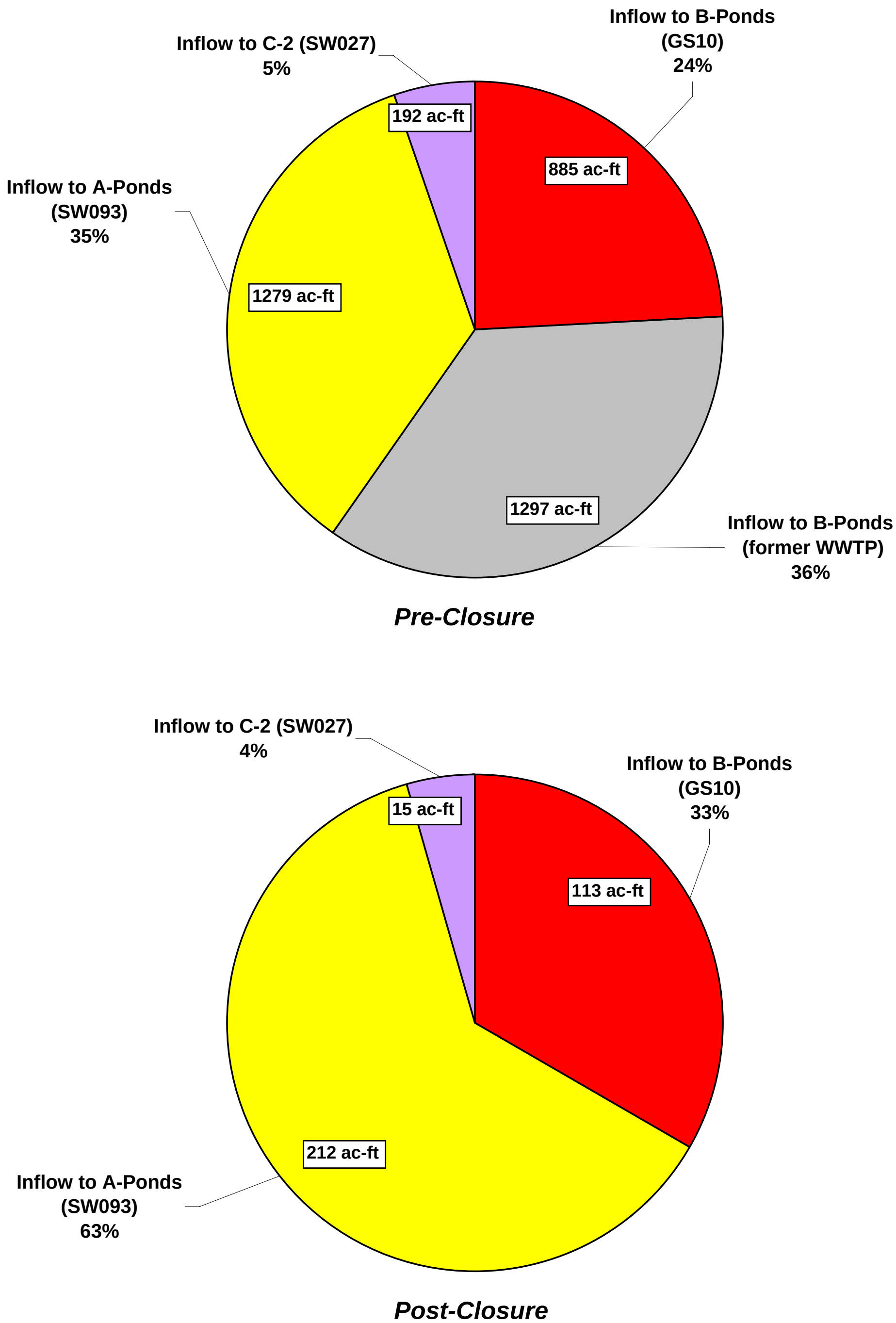


Figure 3–54. Relative Total Inflow Volumes for Site Ponds: Pre- and Post-Closure Periods

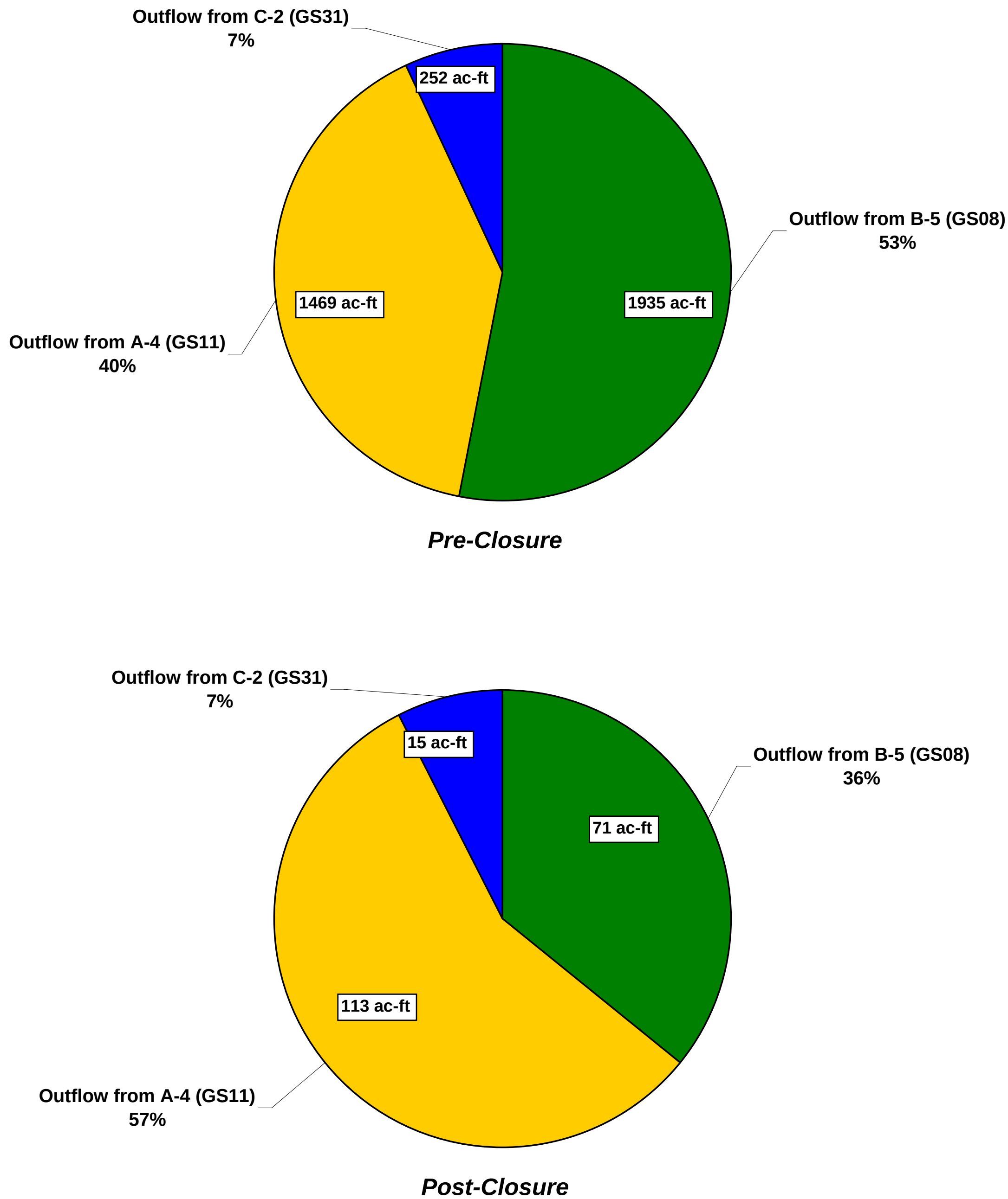


Figure 3–55. Relative Total Outflow Volumes for Site Ponds: Pre- and Post-Closure Periods

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 on-site sampling location using a 9-inch Parshall flume.

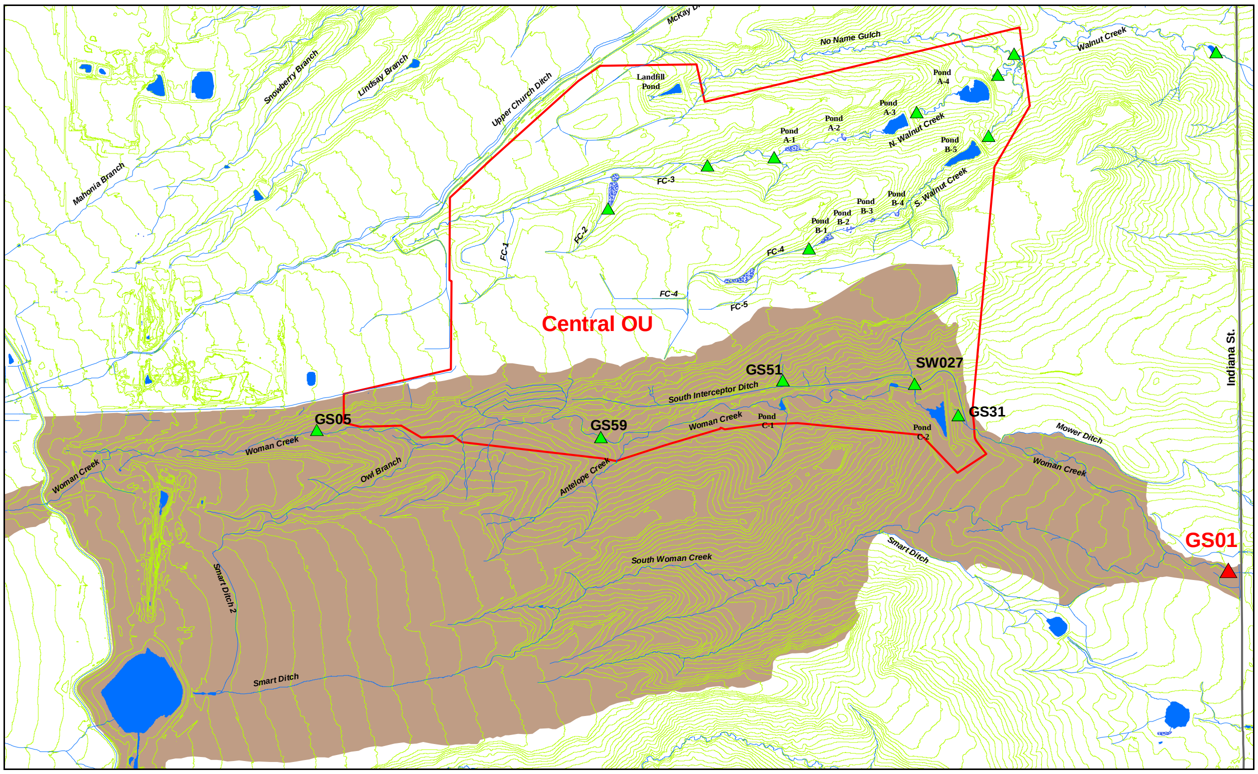


Figure 3–56. GS01 Drainage Area

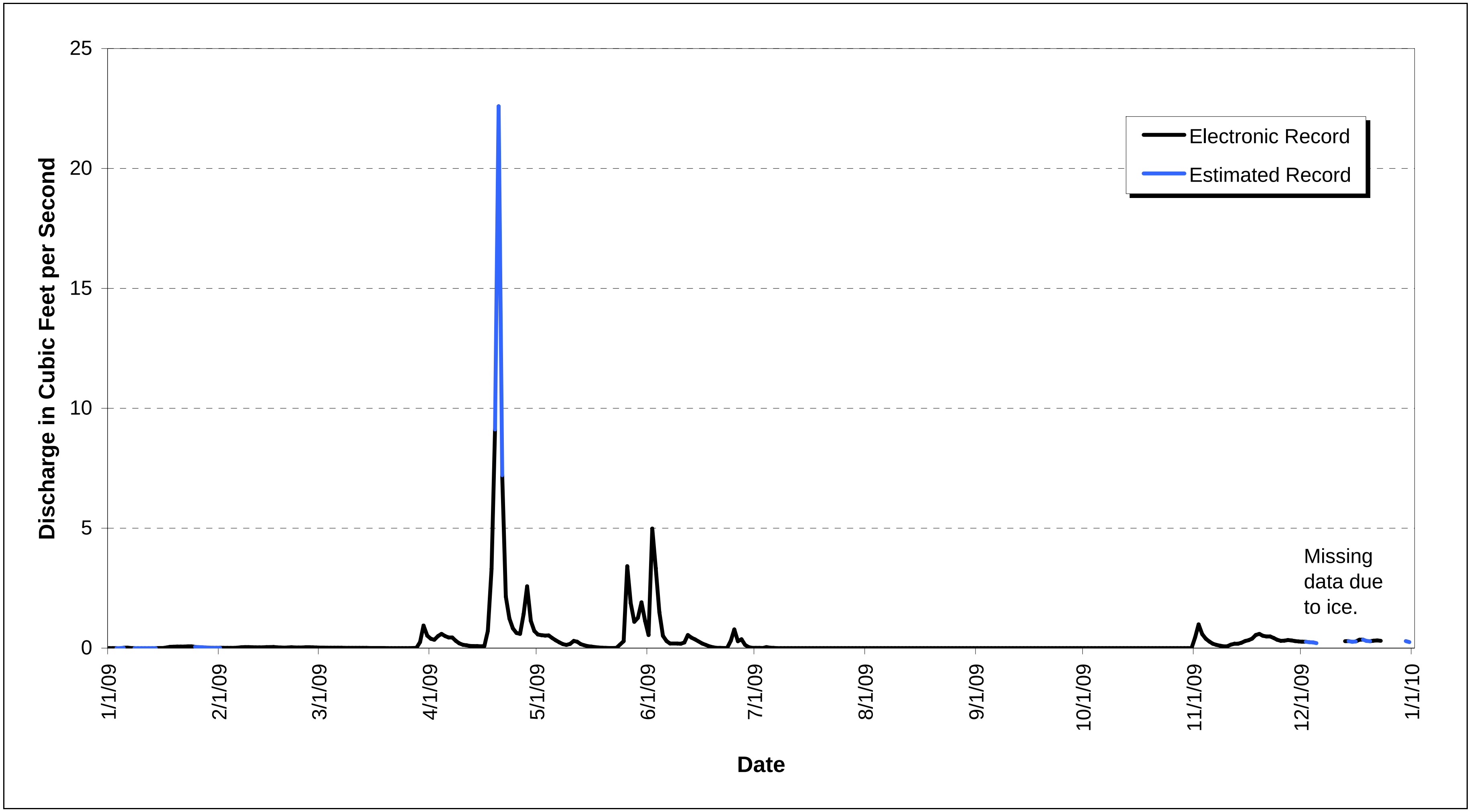


Figure 3–57. CY 2009 Mean Daily Hydrograph at GS01: Woman Creek at Indiana Street

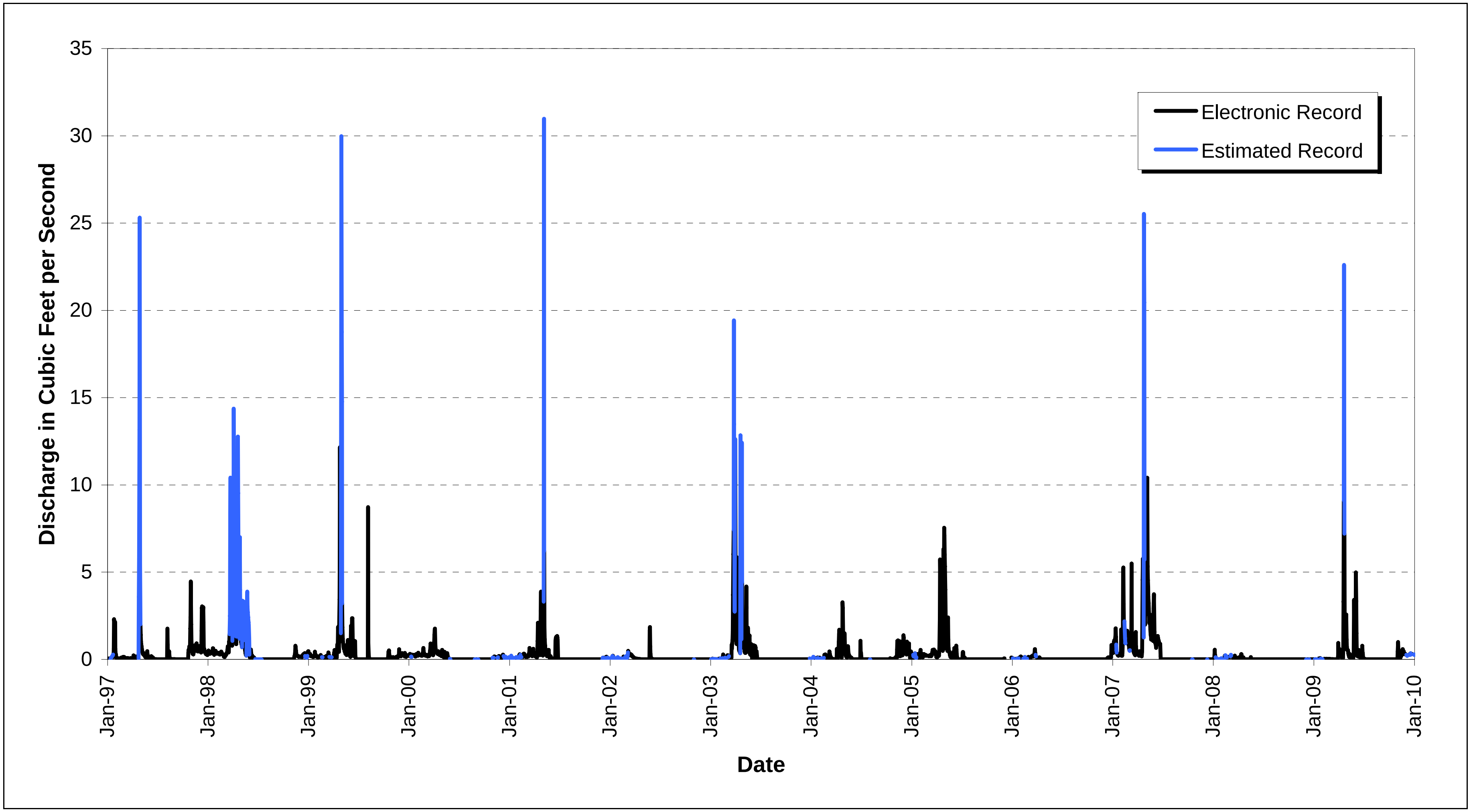


Figure 3–58. CY 1997−2009 Mean Daily Hydrograph at GS01: Woman Creek at Indiana Street

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.

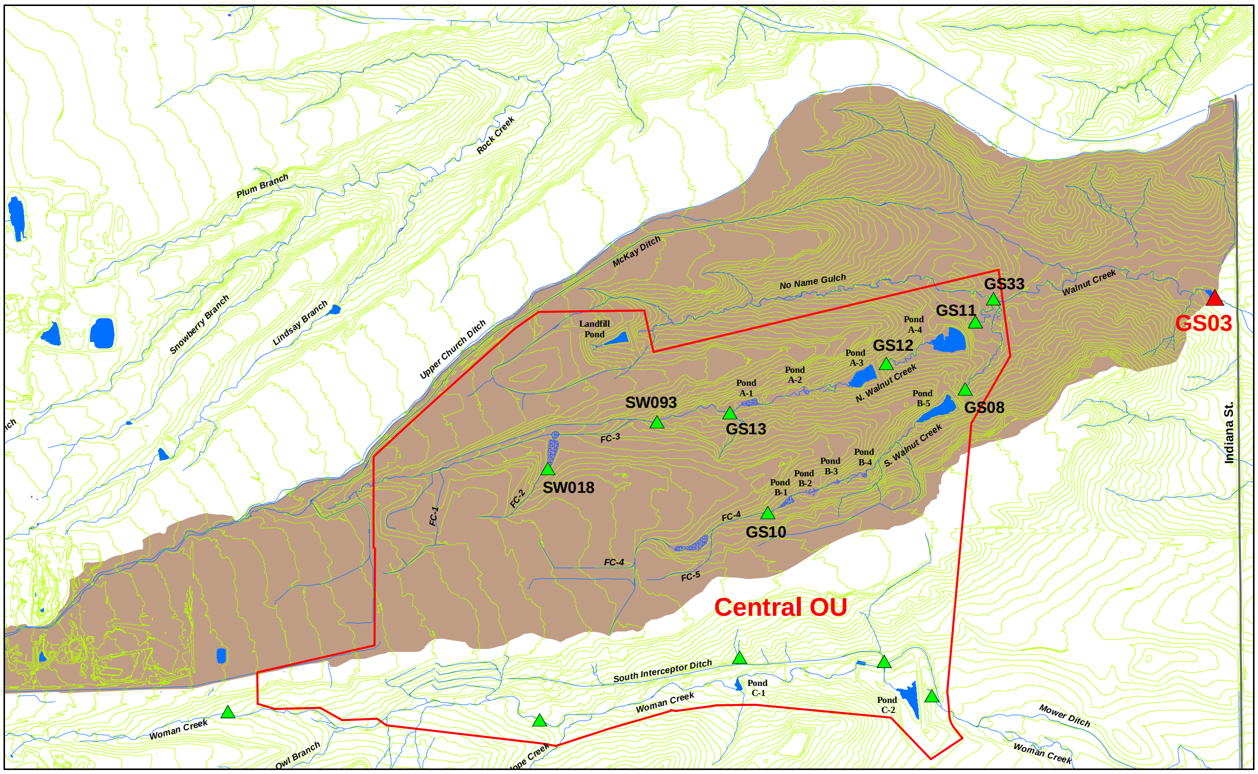


Figure 3–59. GS03 Drainage Area

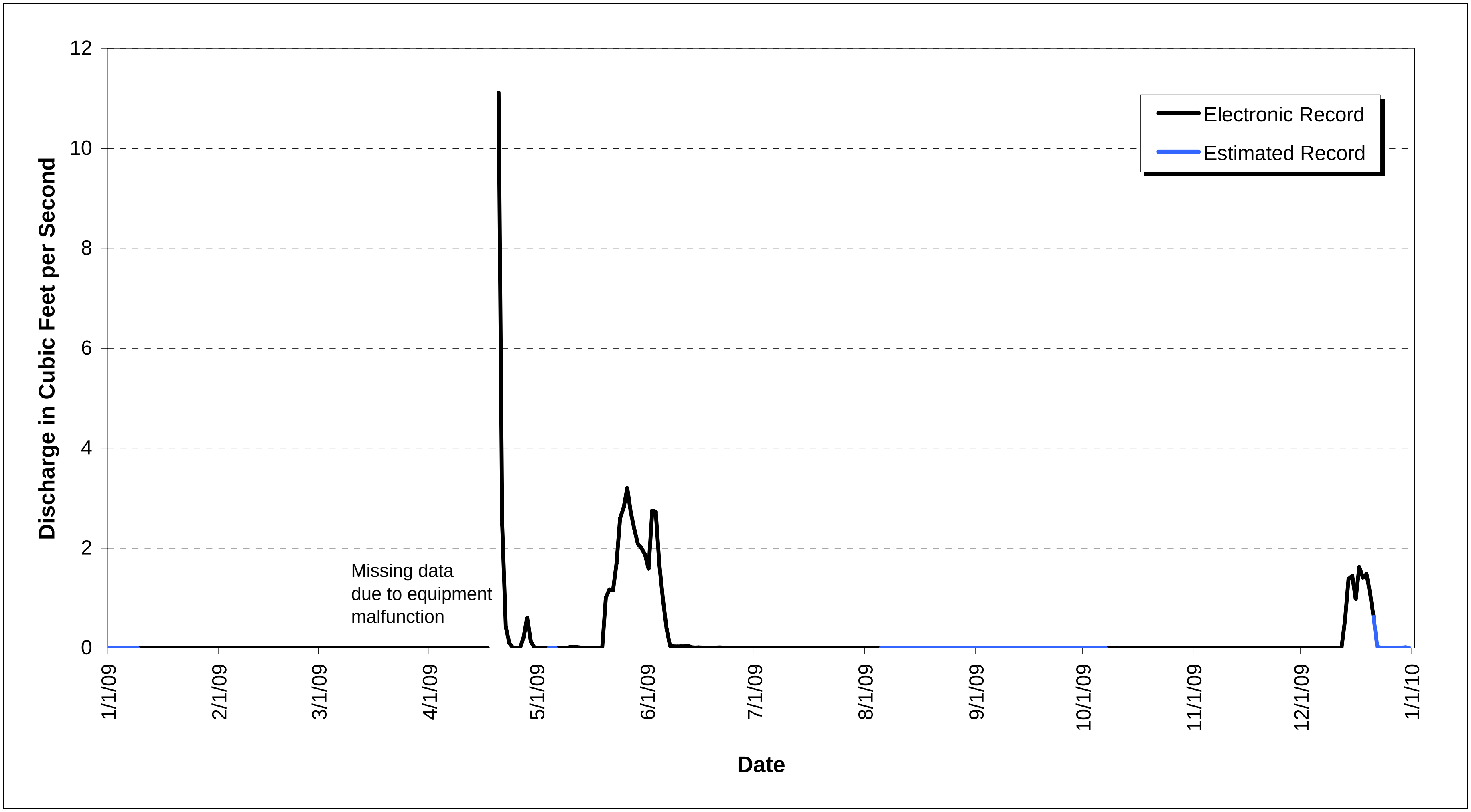


Figure 3–60. CY 2009 Mean Daily Hydrograph at GS03: Walnut Creek at Indiana Street

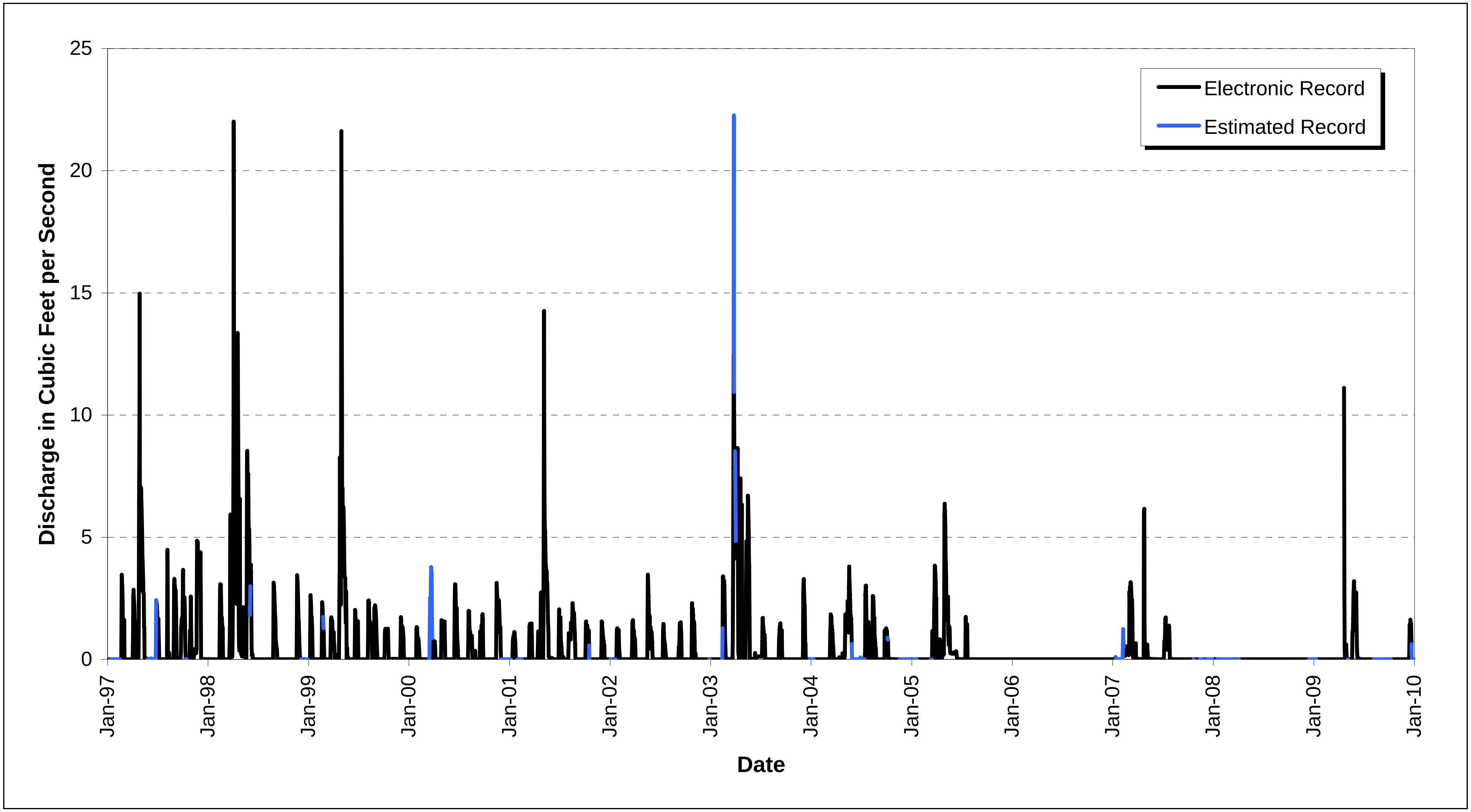


Figure 3–61. CY 1997−2009 Mean Daily Hydrograph at GS03: Walnut Creek at Indiana Street

GS05: North Woman Creek at West Fenceline

Location—Woman Creek east of western Site 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.

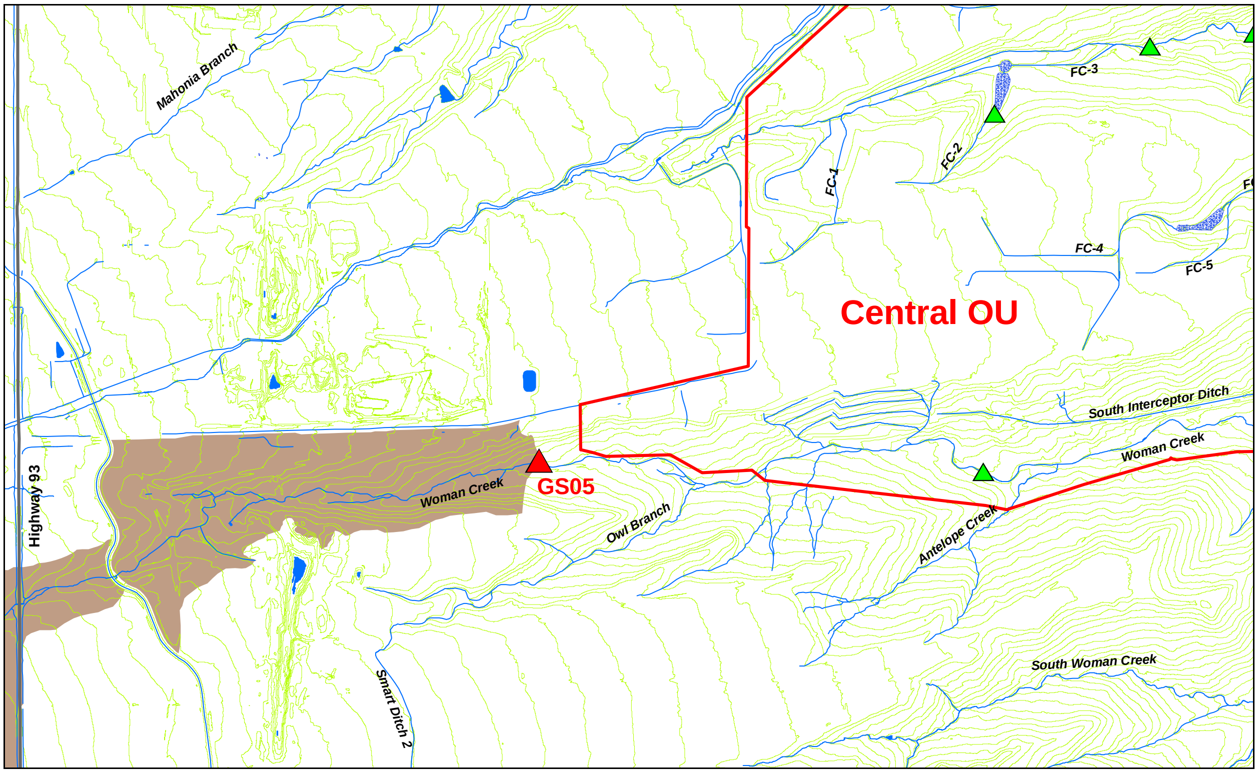


Figure 3–62. GS05 Drainage Area

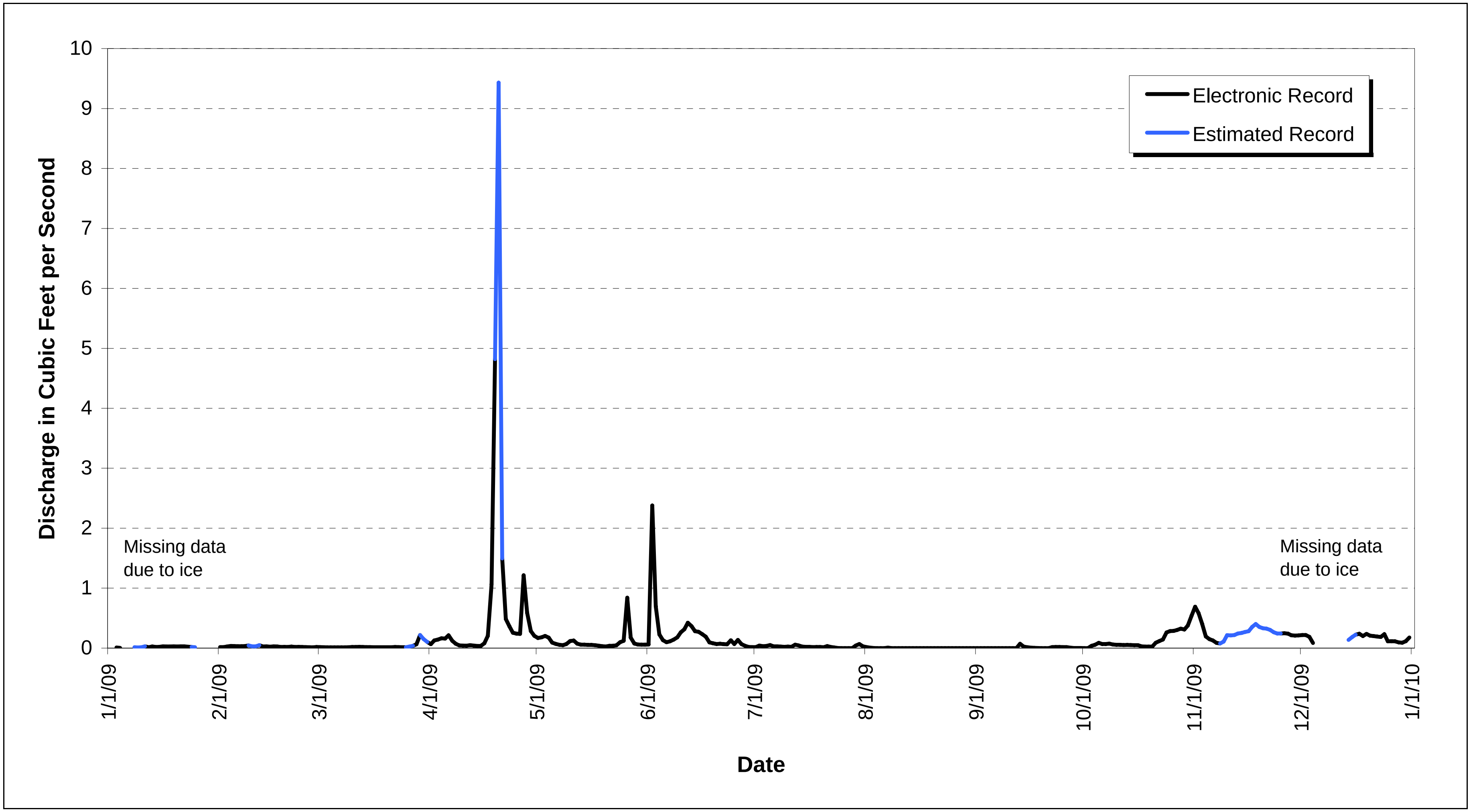


Figure 3–63. CY 2009 Mean Daily Hydrograph at GS05: North Woman Creek at West Fenceline

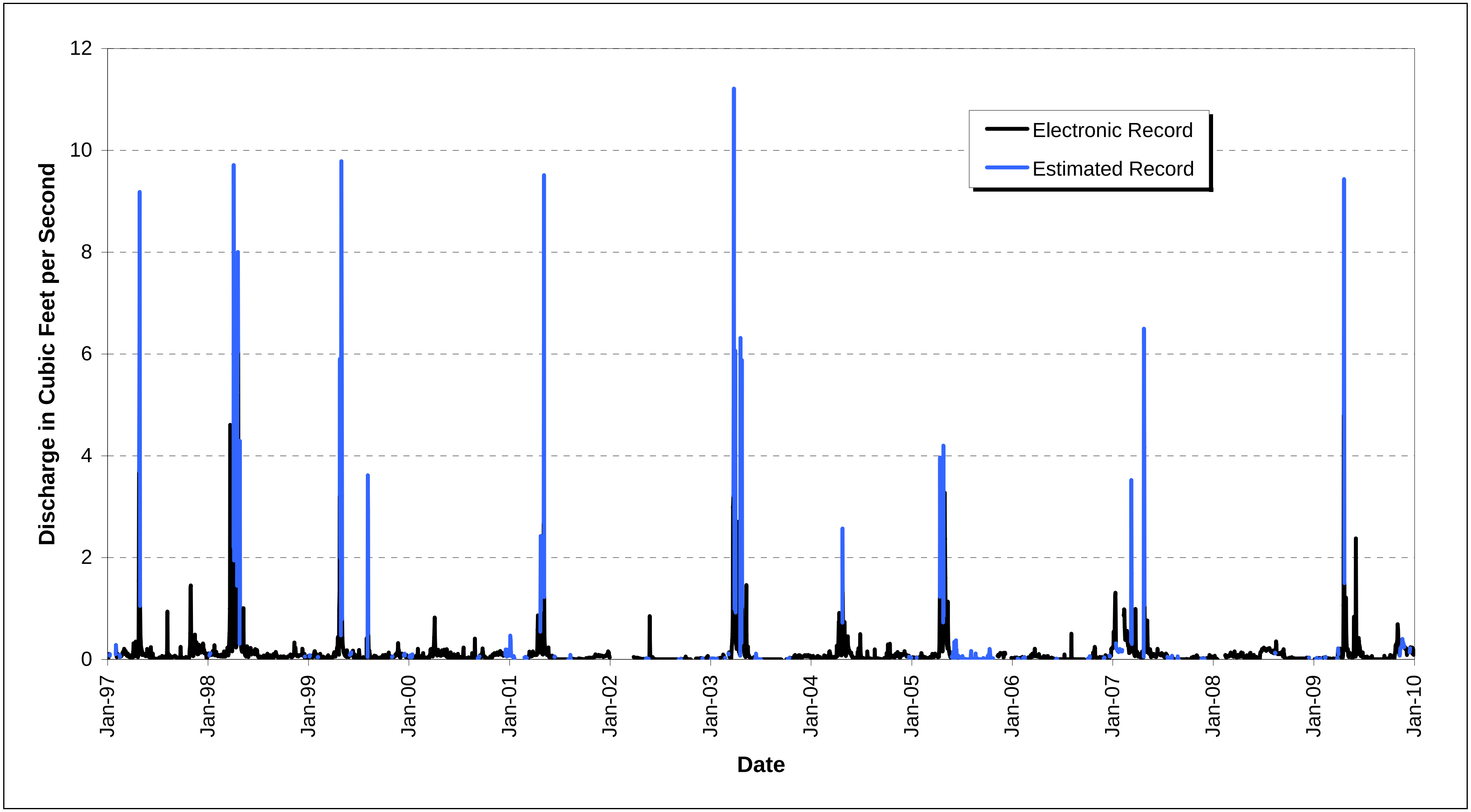


Figure 3–64. CY 1997−2009 Mean Daily Hydrograph at GS05: North Woman Creek at West Fenceline

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.

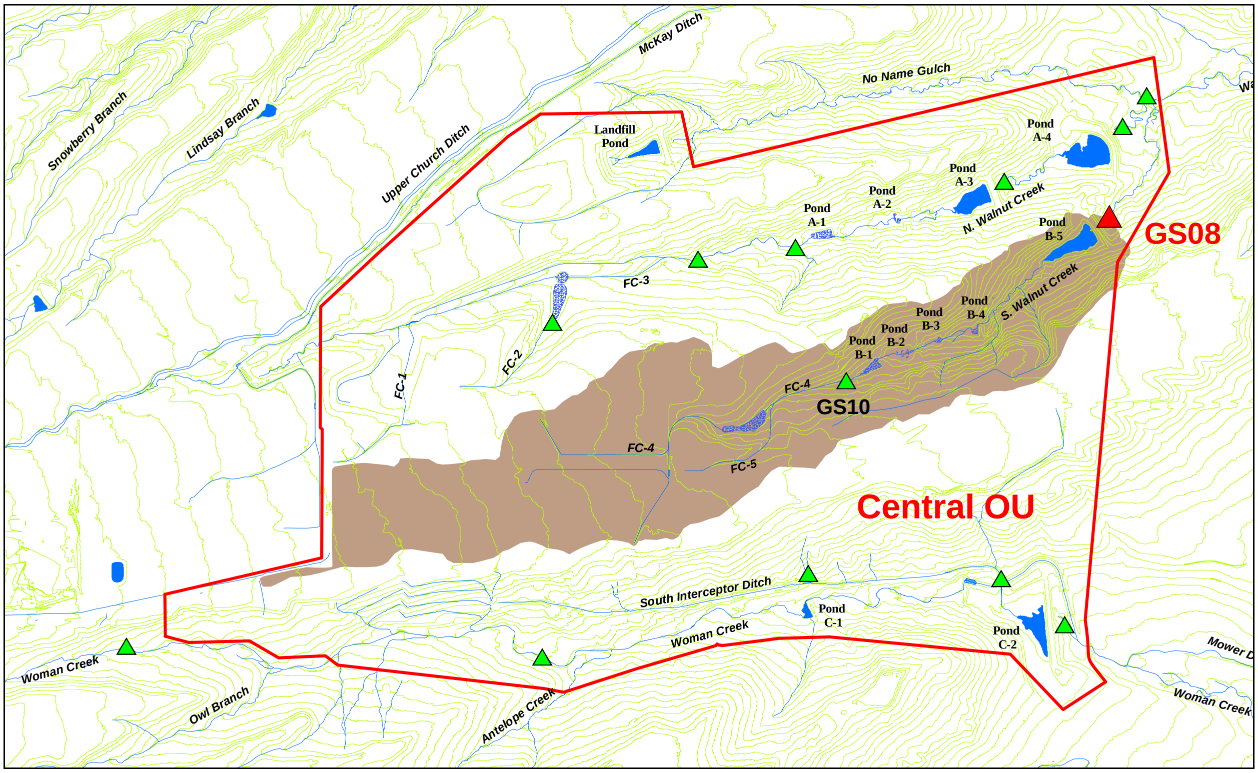


Figure 3–65. GS08 Drainage Area

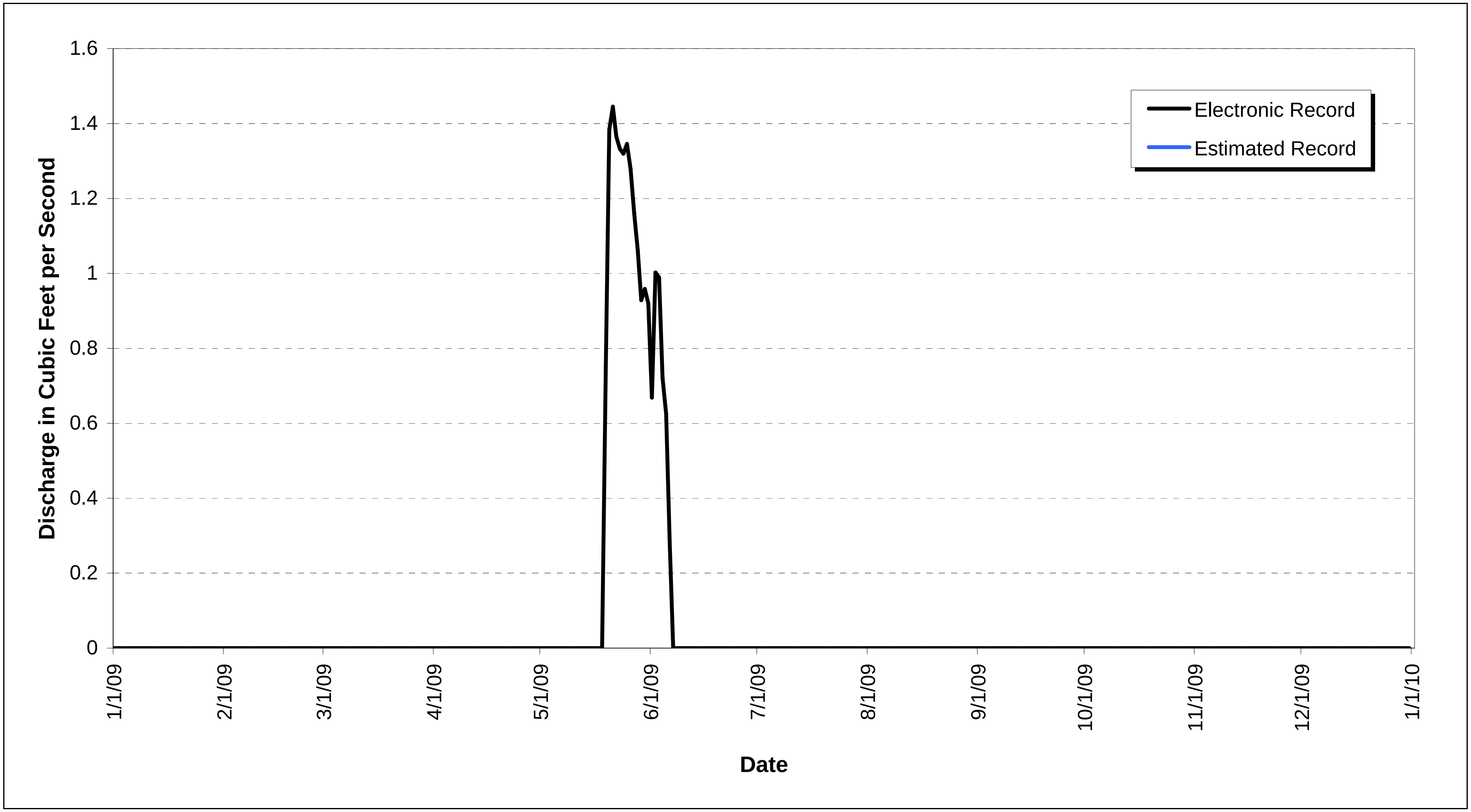


Figure 3–66. CY 2009 Mean Daily Hydrograph at GS08: South Walnut Creek at Pond B-5 Outlet

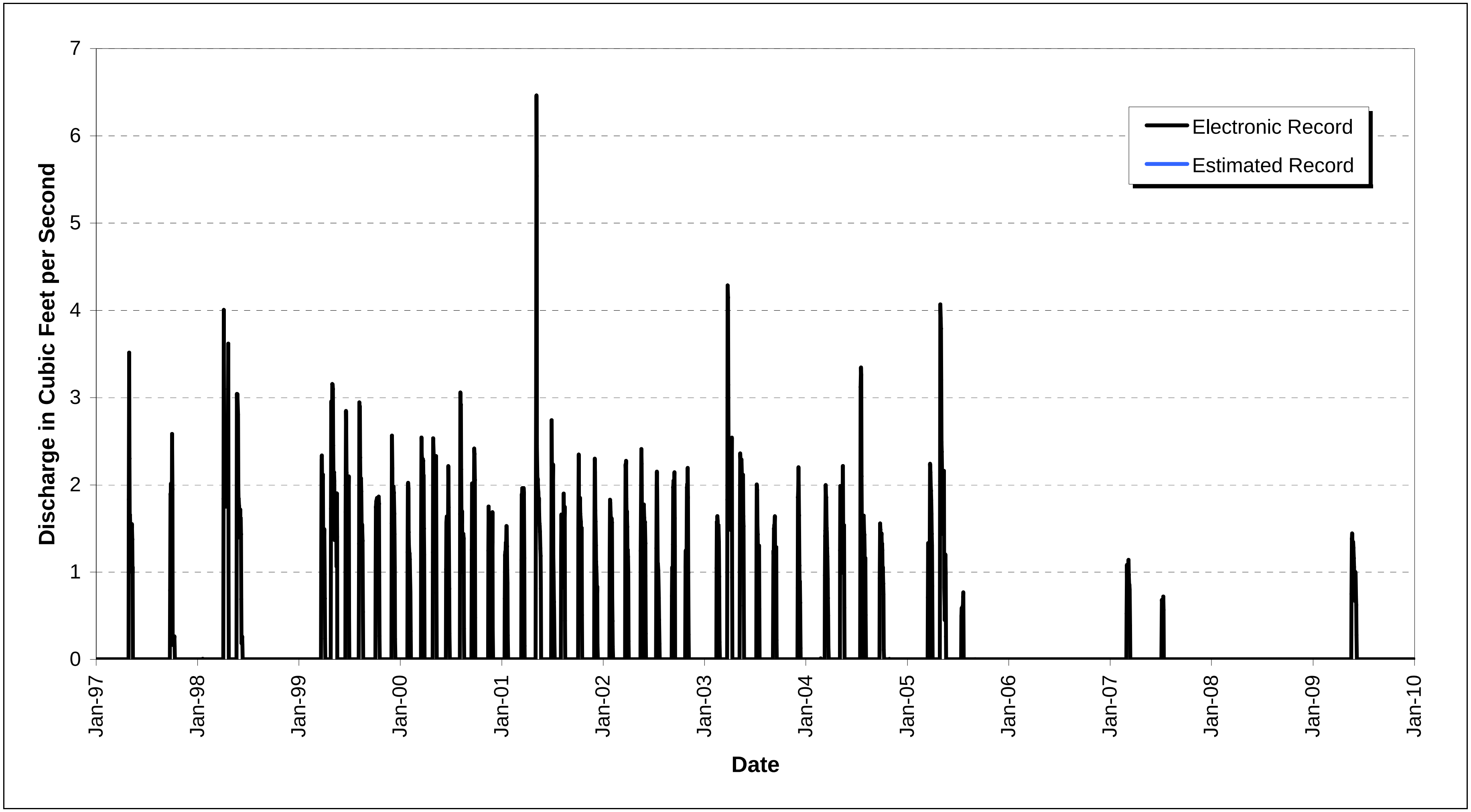


Figure 3–67. CY 1997−2009 Mean Daily Hydrograph at GS08: South Walnut Creek at Pond B-5 Outlet

GS10: South Walnut Creek at Pond B-1

Location—South Walnut Creek above 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.

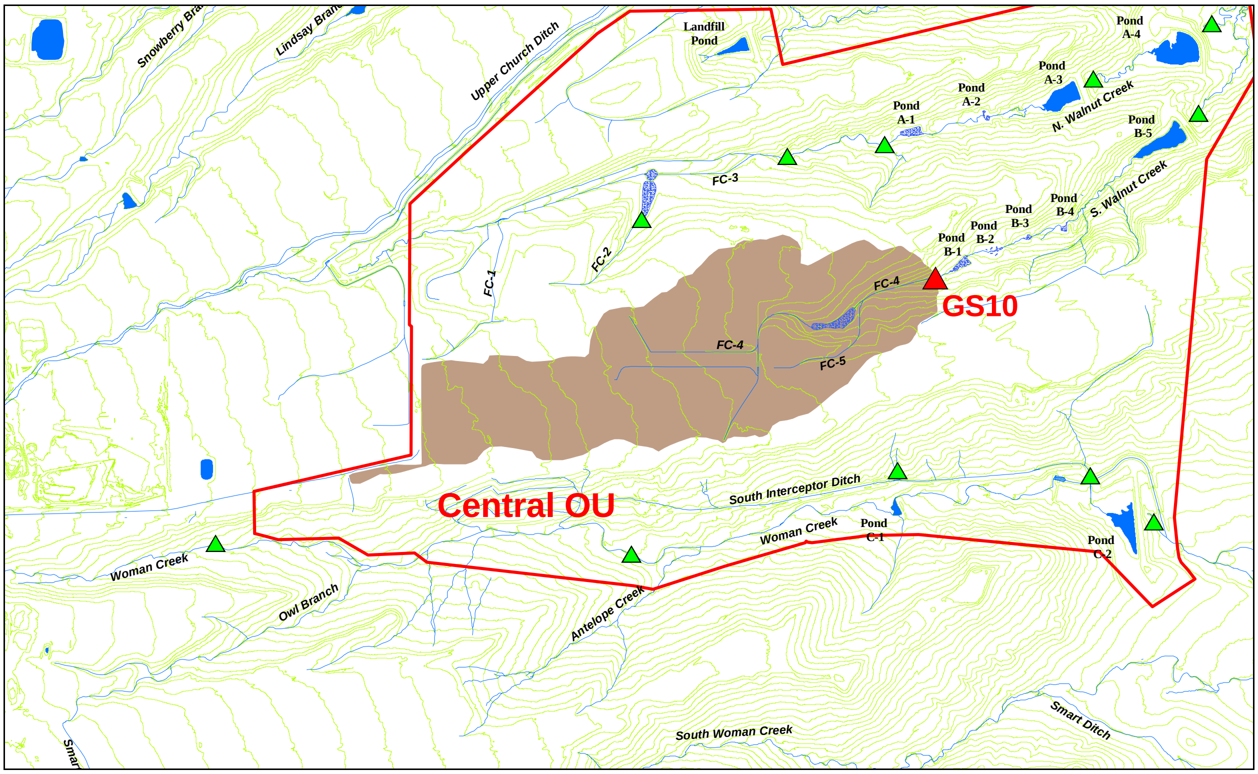


Figure 3–68. GS10 Drainage Area

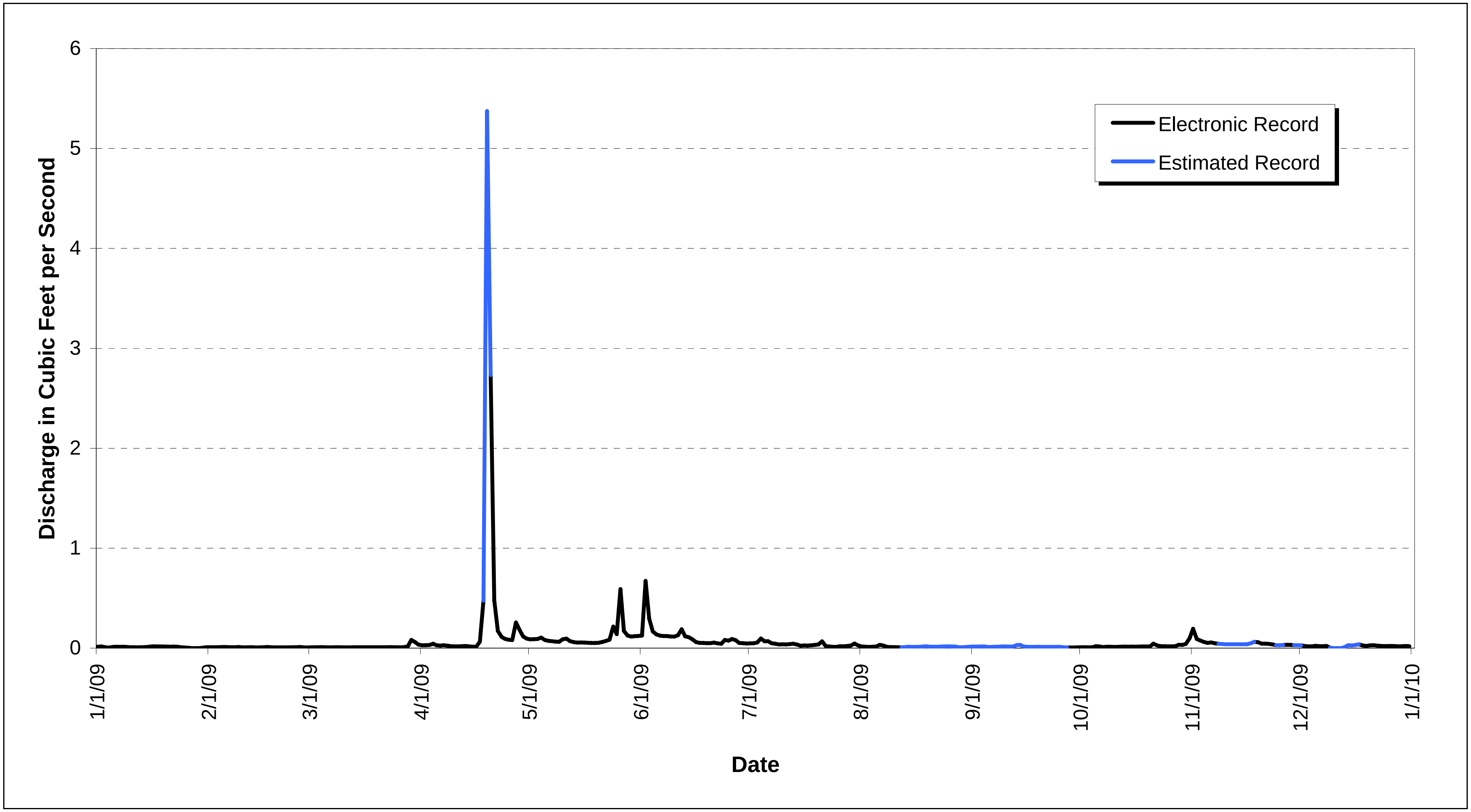


Figure 3–69. CY 2009 Mean Daily Hydrograph at GS10: South Walnut Creek at Pond B-1

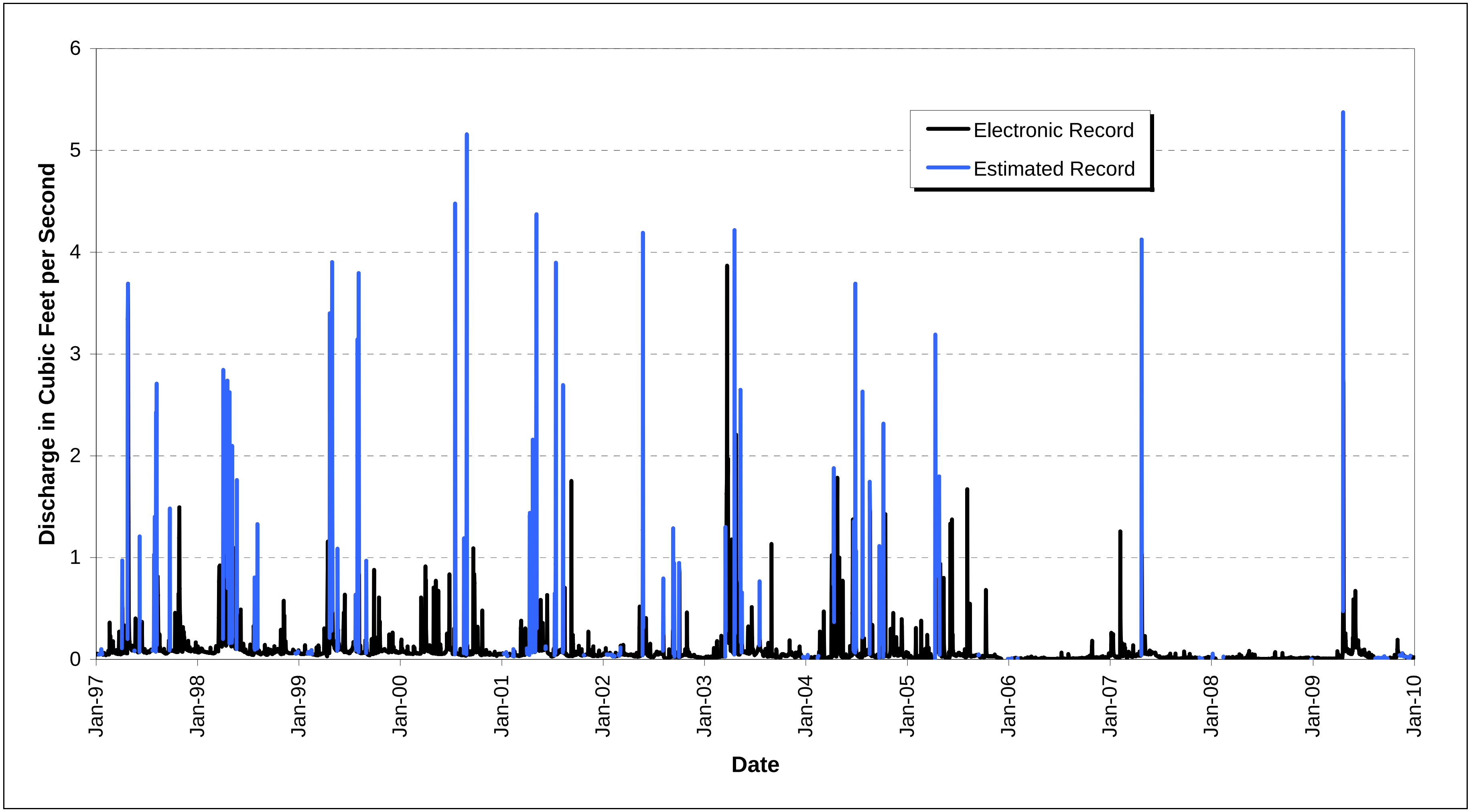


Figure 3–70. CY 1997–2009 Mean Daily Hydrograph at GS10: South Walnut Creek at Pond B-1

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.

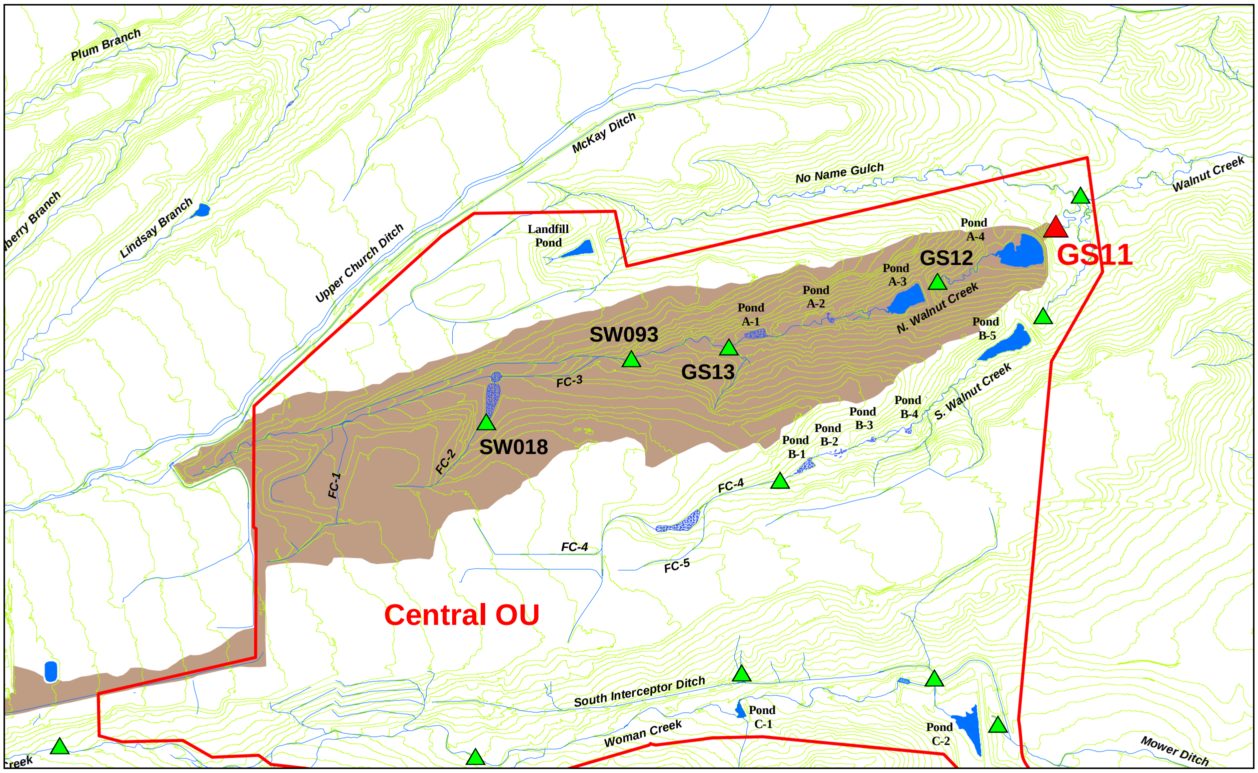


Figure 3–71. GS11 Drainage Area

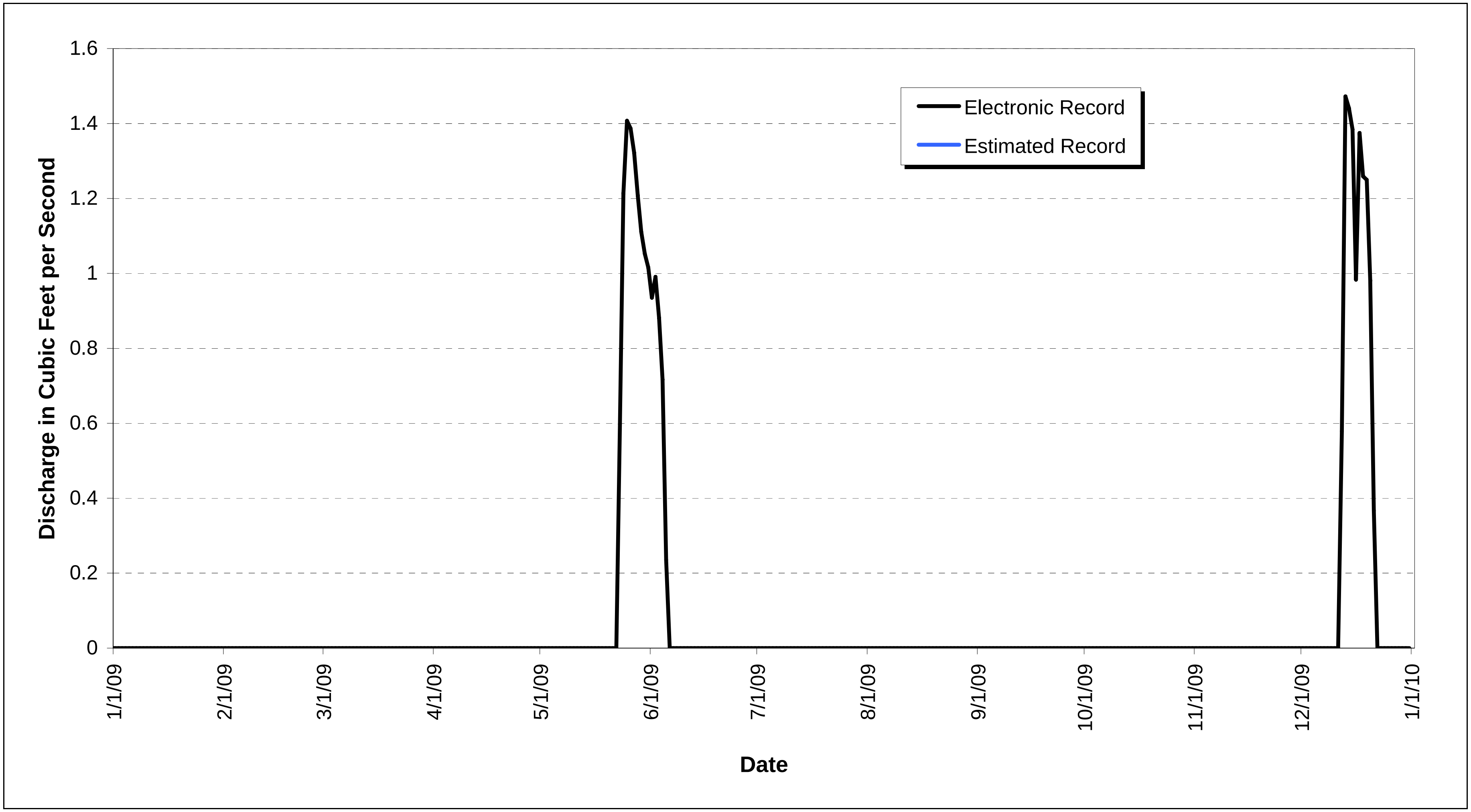


Figure 3–72. CY 2009 Mean Daily Hydrograph at GS11: North Walnut Creek at Pond A-4 Outlet

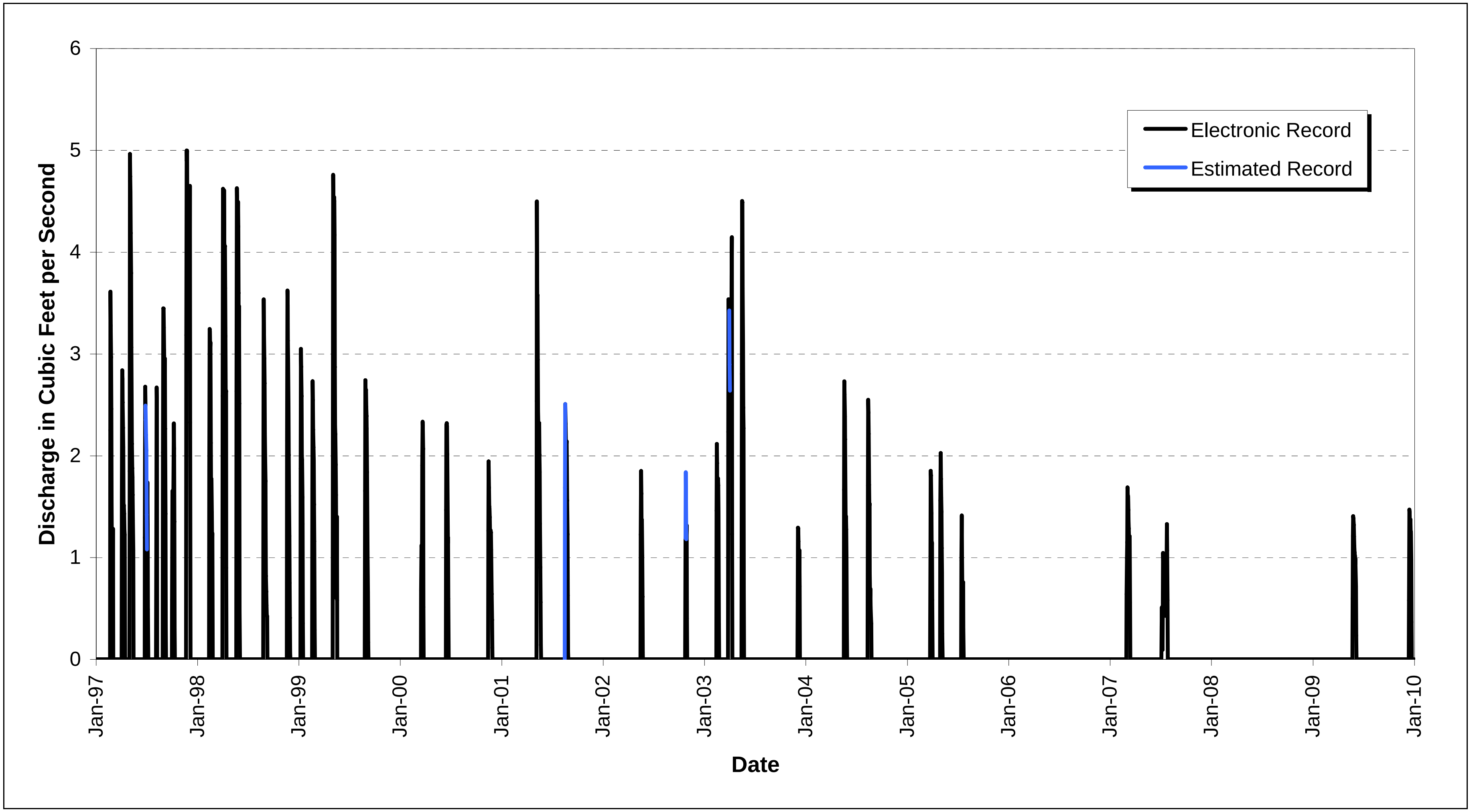


Figure 3–73. CY 1997−2009 Mean Daily Hydrograph at GS11: North Walnut Creek at Pond A-4 Outlet

GS12: North Walnut Creek at Pond A-3 Outlet

Location—North Walnut Creek at 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.

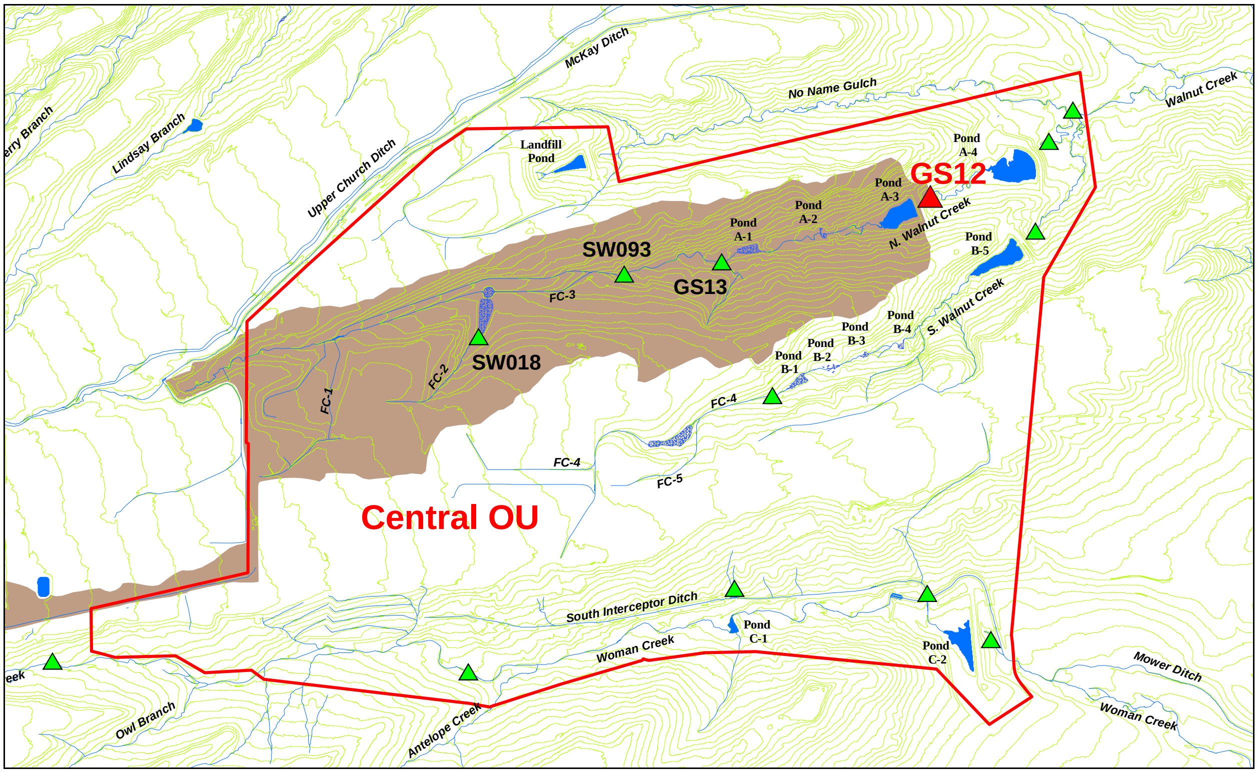


Figure 3–74. GS12 Drainage Area

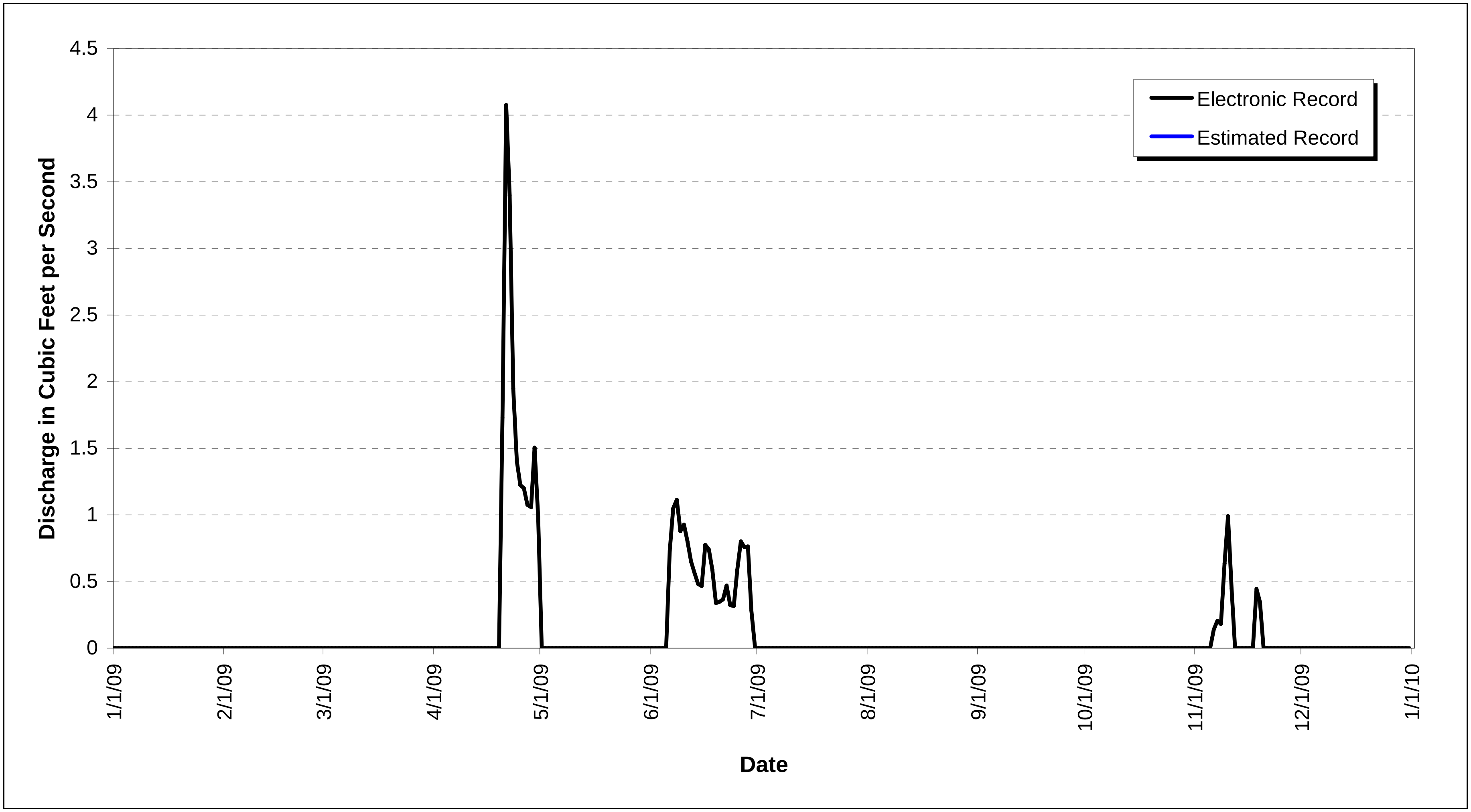


Figure 3–75. CY 2009 Mean Daily Hydrograph at GS12: North Walnut Creek at Pond A-3 Outlet

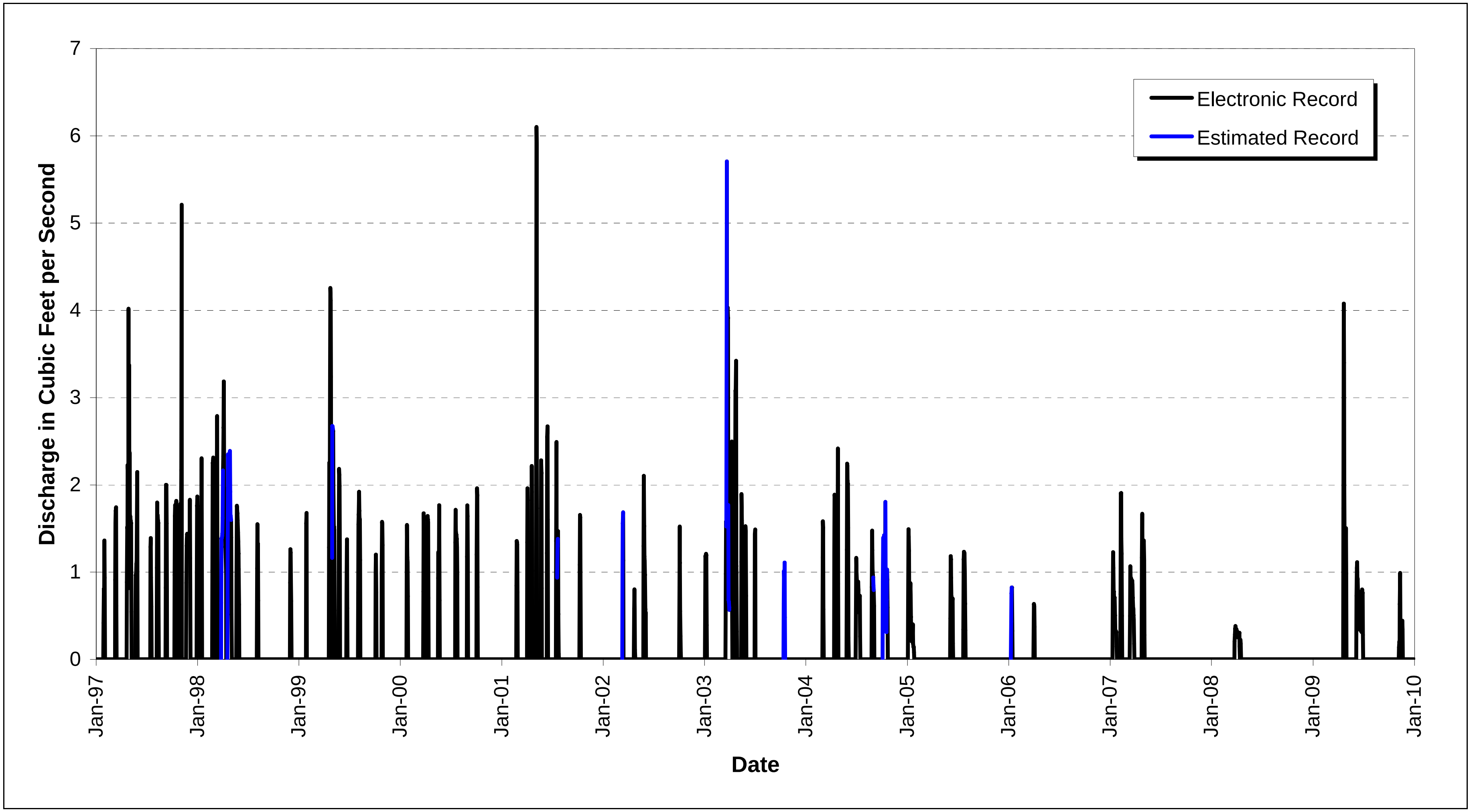


Figure 3–76. CY 1997−2009 Mean Daily Hydrograph at GS12: North Walnut Creek at Pond A-3 Outlet

GS13: North Walnut Creek at Pond A-1

Location—North Walnut Creek at 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.

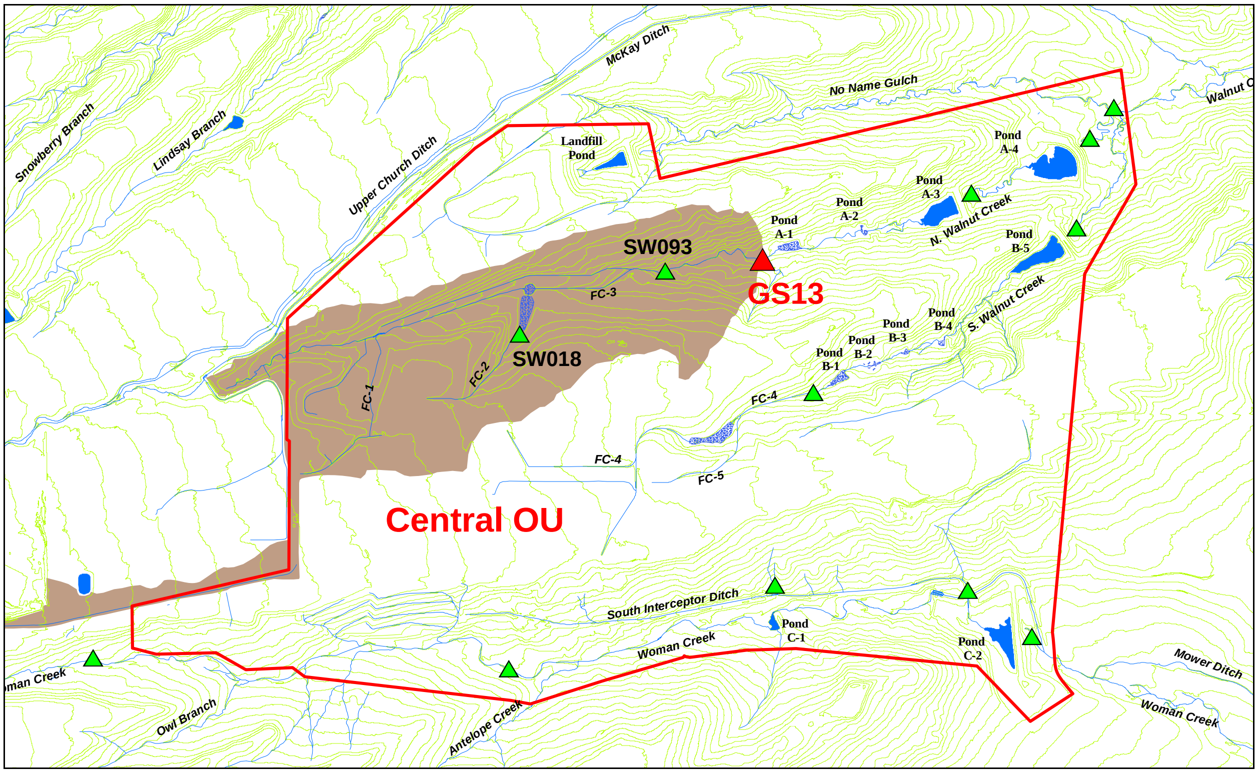


Figure 3–77. GS13 Drainage Area

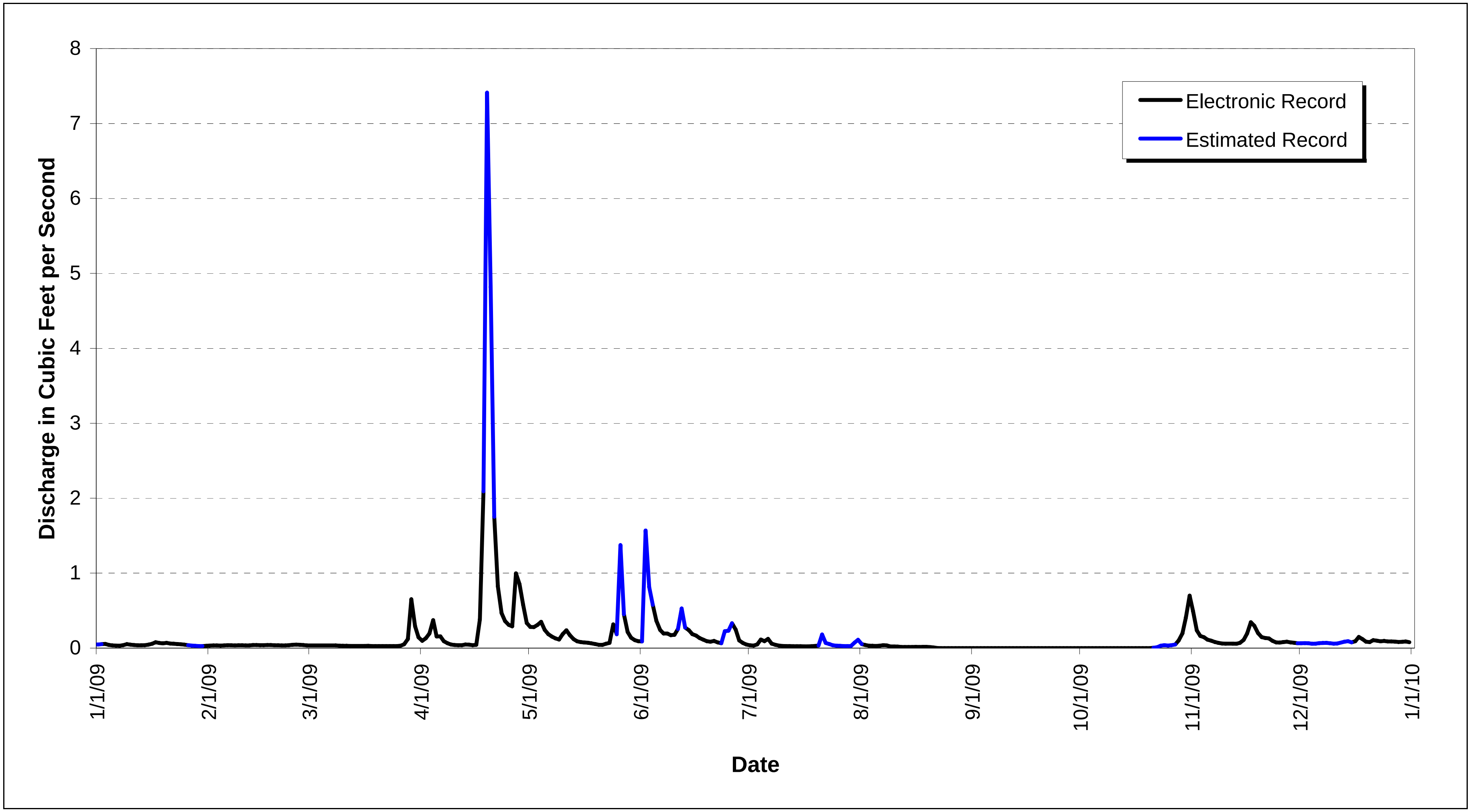


Figure 3–78. CY 2009 Mean Daily Hydrograph at GS13: North Walnut Creek at Pond A-1 Bypass

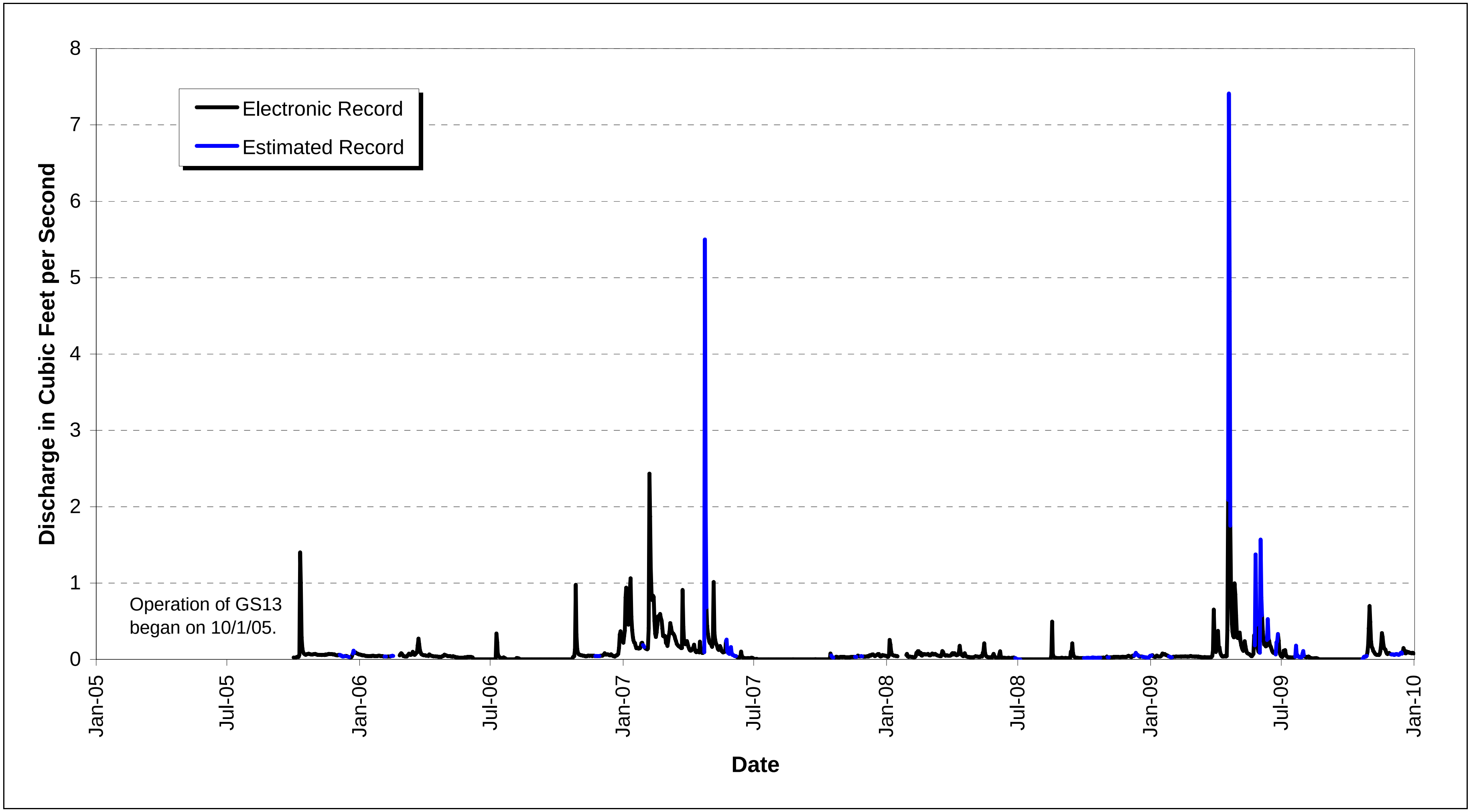


Figure 3–79. CY 2005−2009 Mean Daily Hydrograph at GS13: North Walnut Creek at Pond A-1 Bypass

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.

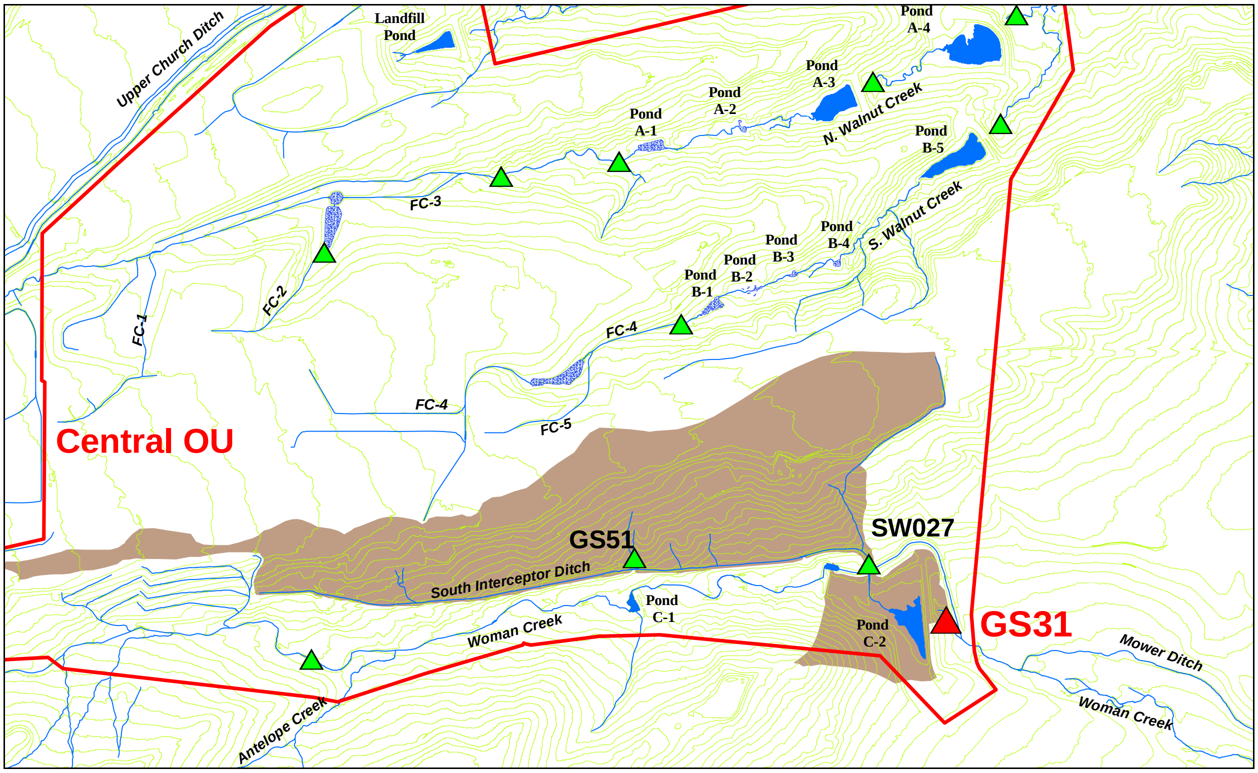


Figure 3–80. GS31 Drainage Area

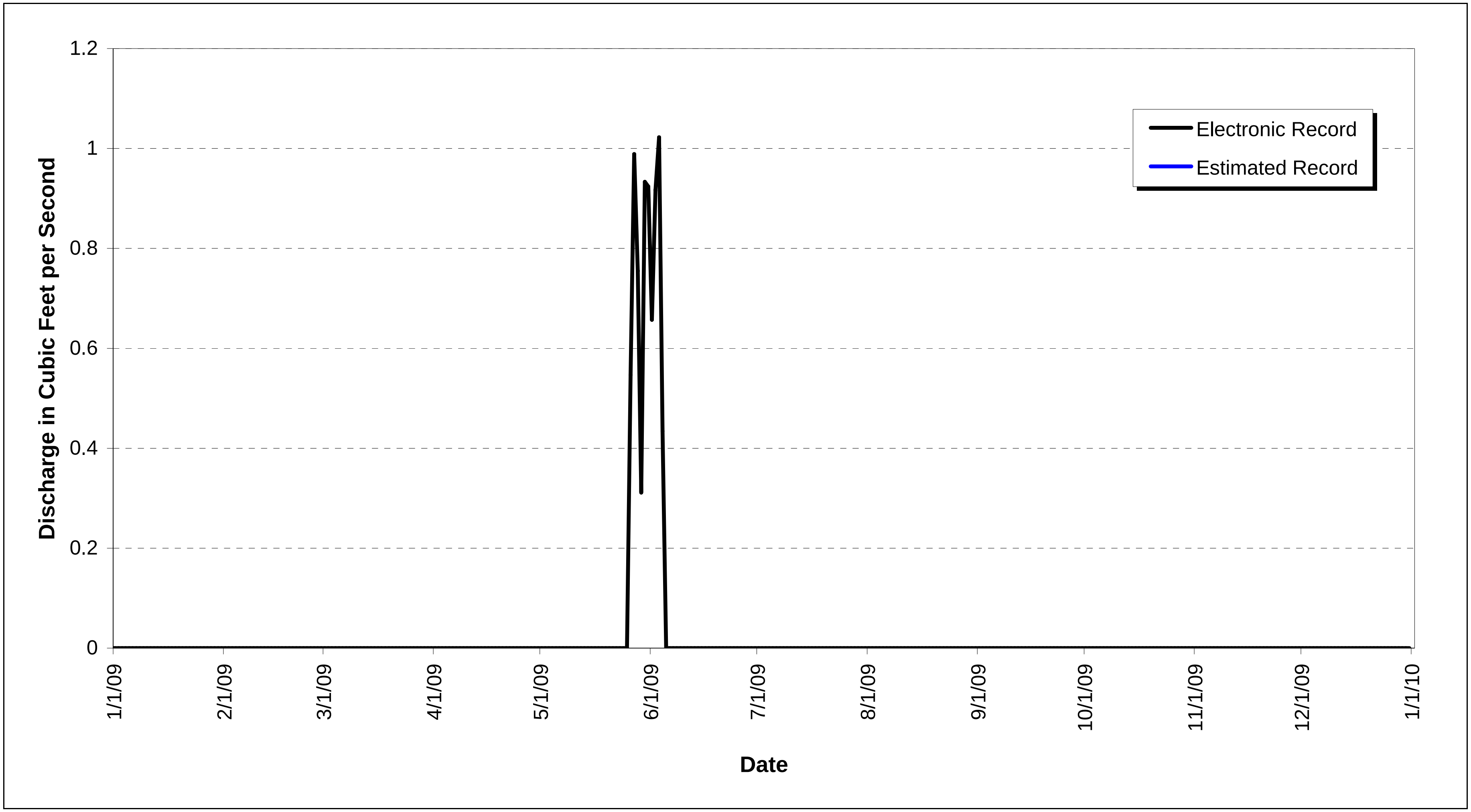


Figure 3–81. CY 2009 Mean Daily Hydrograph at GS31: Woman Creek at Pond C-2 Outlet

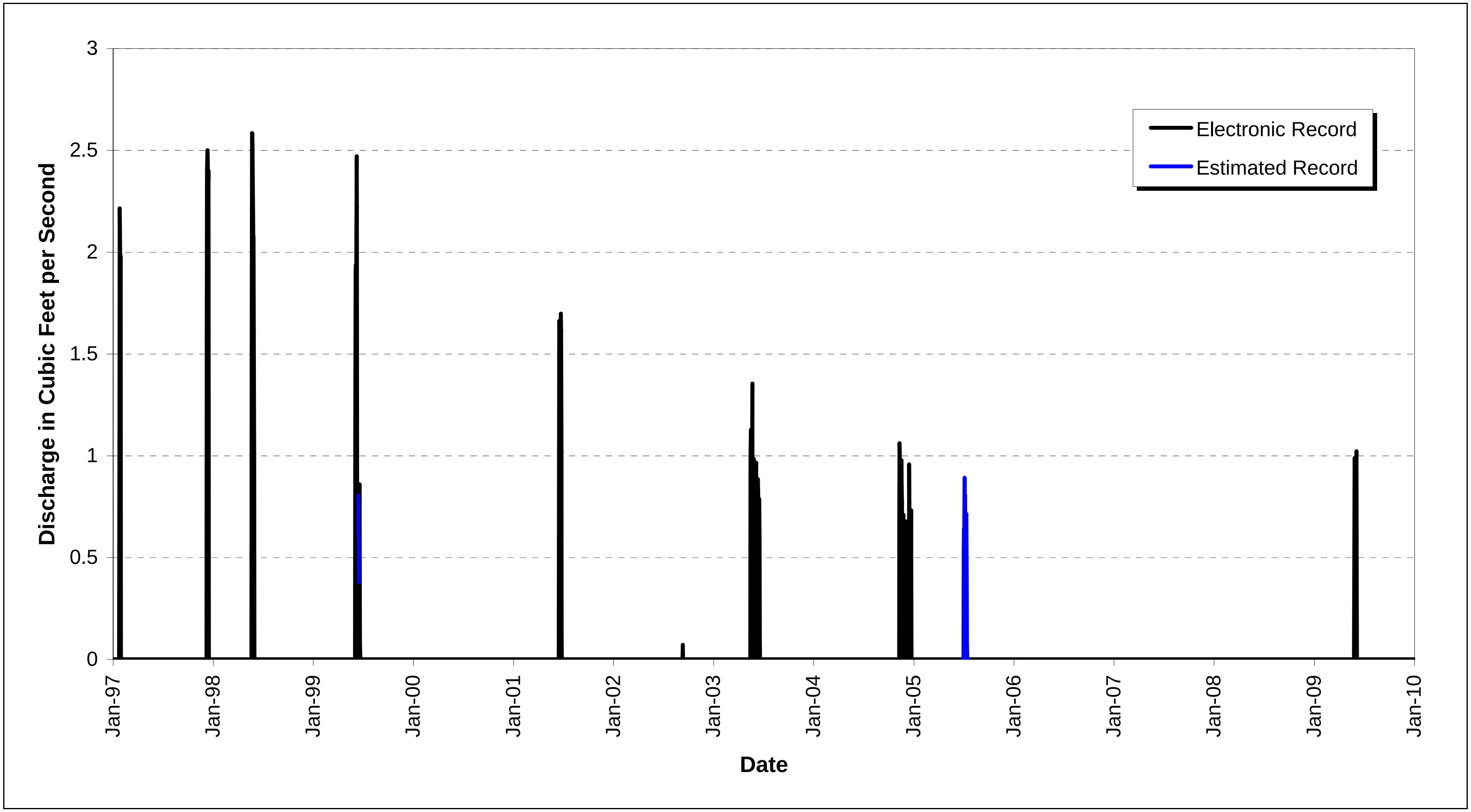


Figure 3–82. CY 1997−2009 Mean Daily Hydrograph at GS31: Woman Creek at Pond C-2 Outlet

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.

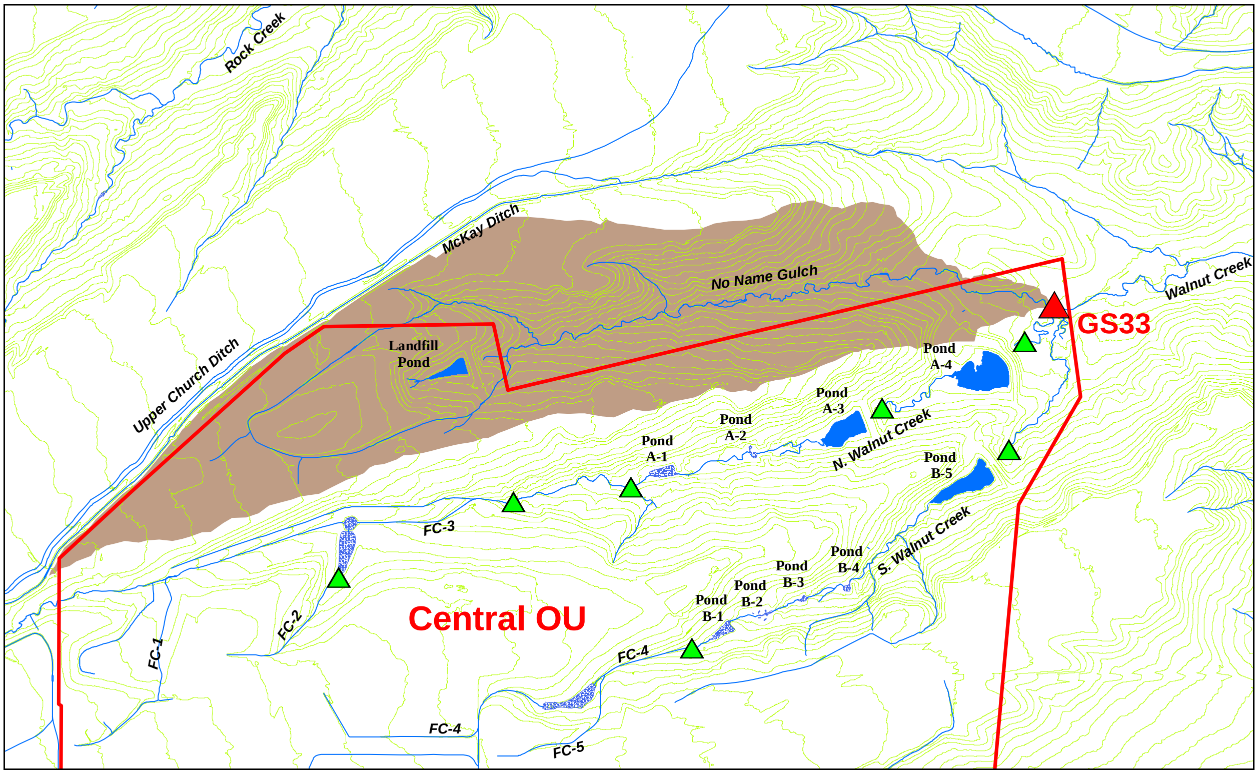


Figure 3–83. GS33 Drainage Area

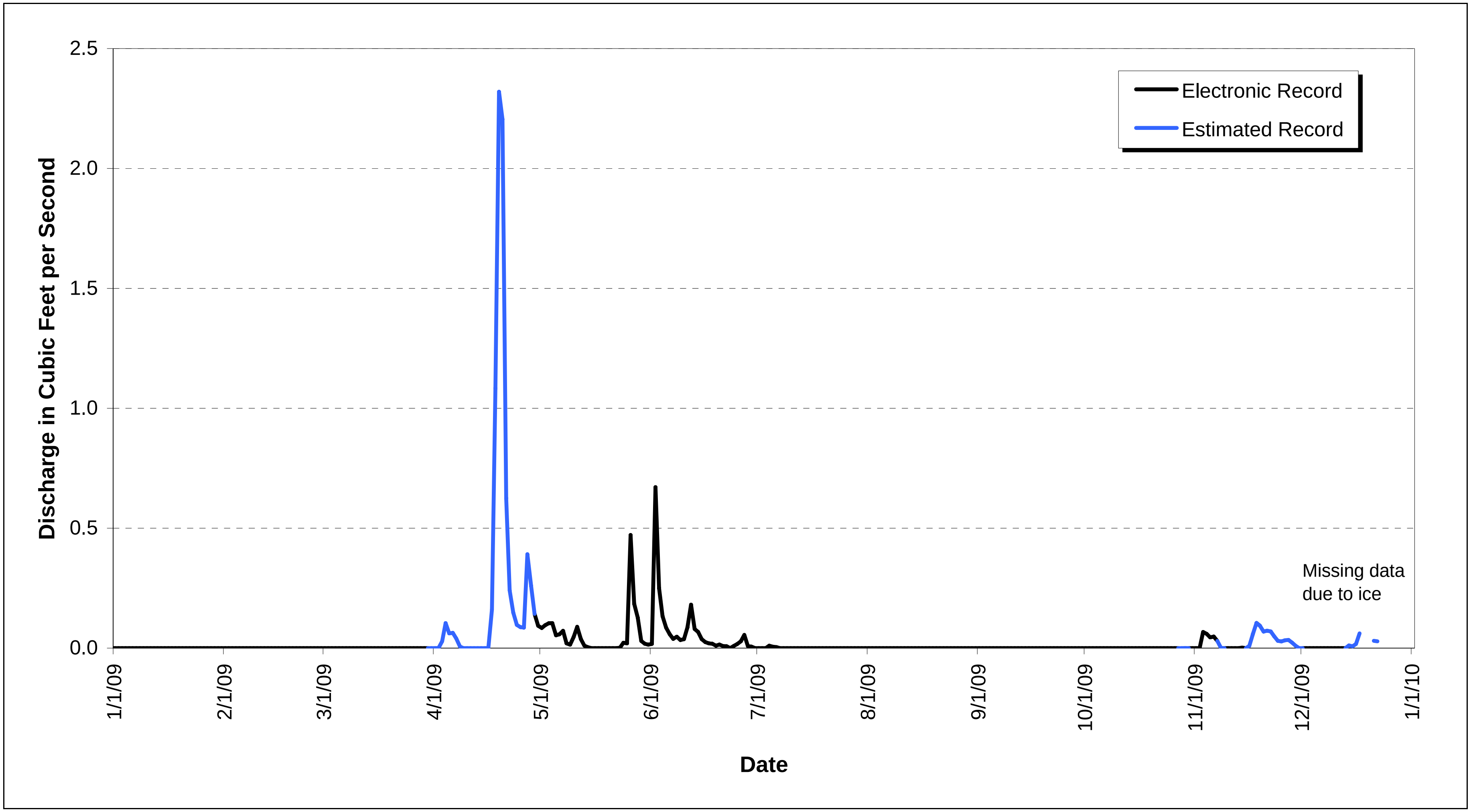


Figure 3–84. CY 2009 Mean Daily Hydrograph at GS33: No Name Gulch at Walnut Creek

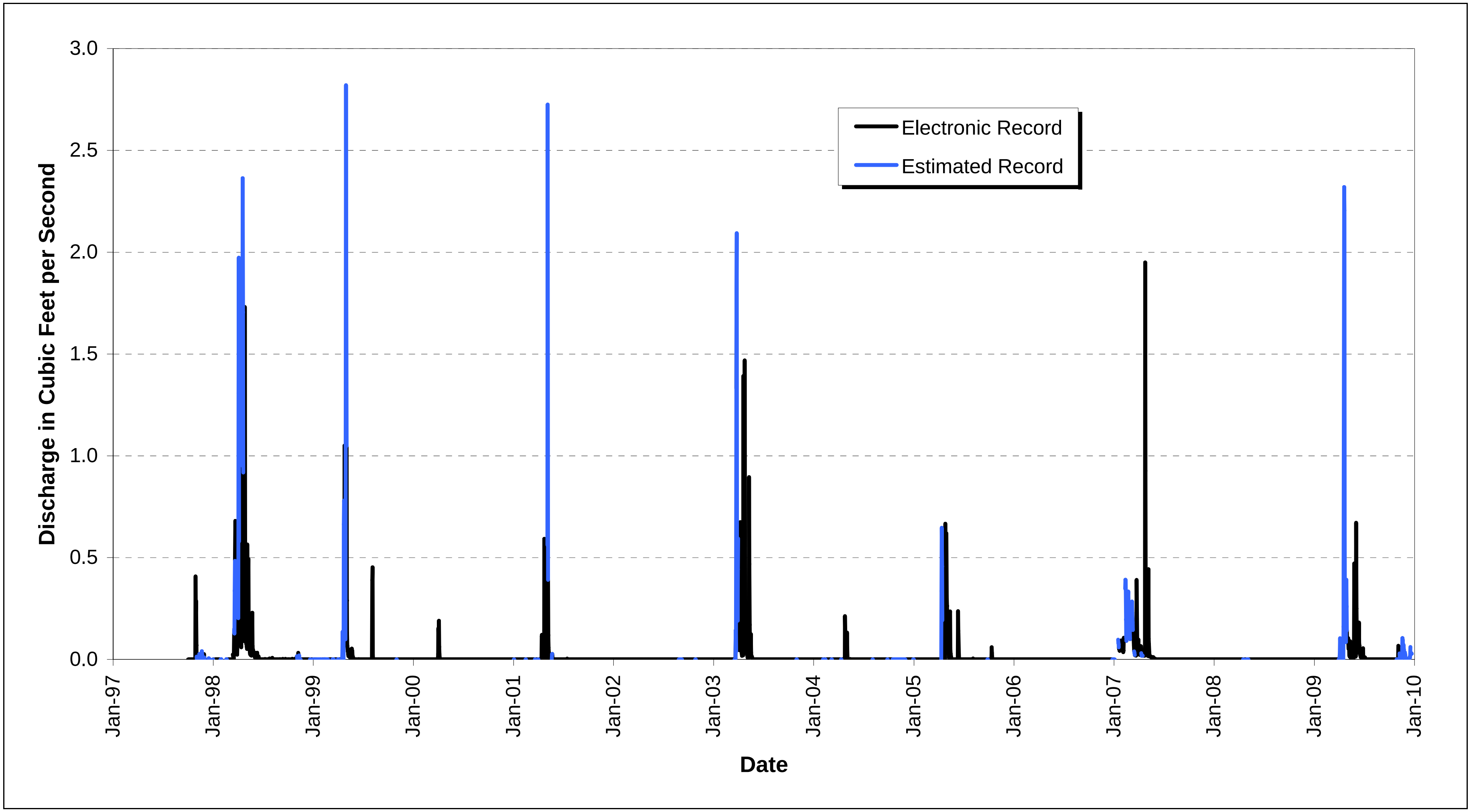


Figure 3–85. CY 1997−2009 Mean Daily Hydrograph at GS33: No Name Gulch at Walnut Creek

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.

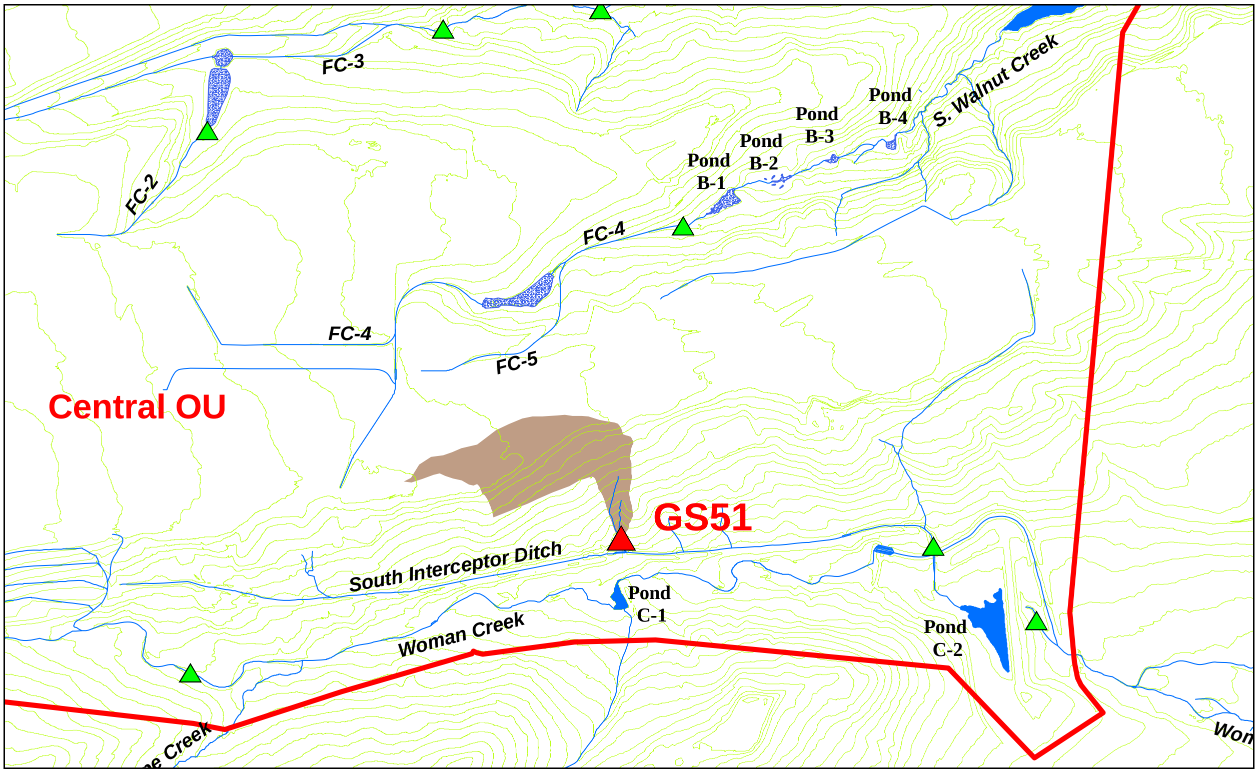


Figure 3–86. GS51 Drainage Area

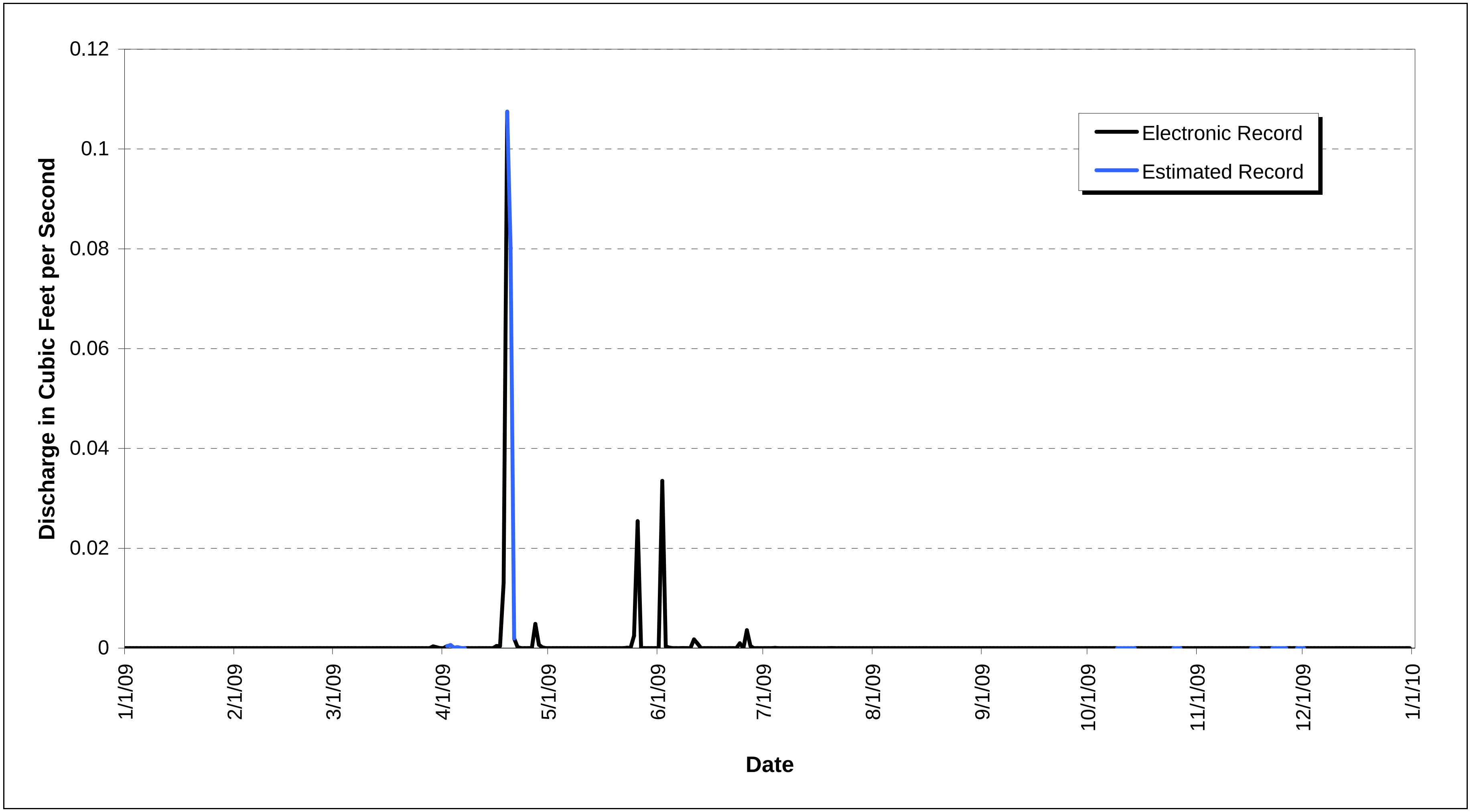


Figure 3–87. CY 2009 Mean Daily Hydrograph at GS51: Ditch South of 903 Pad

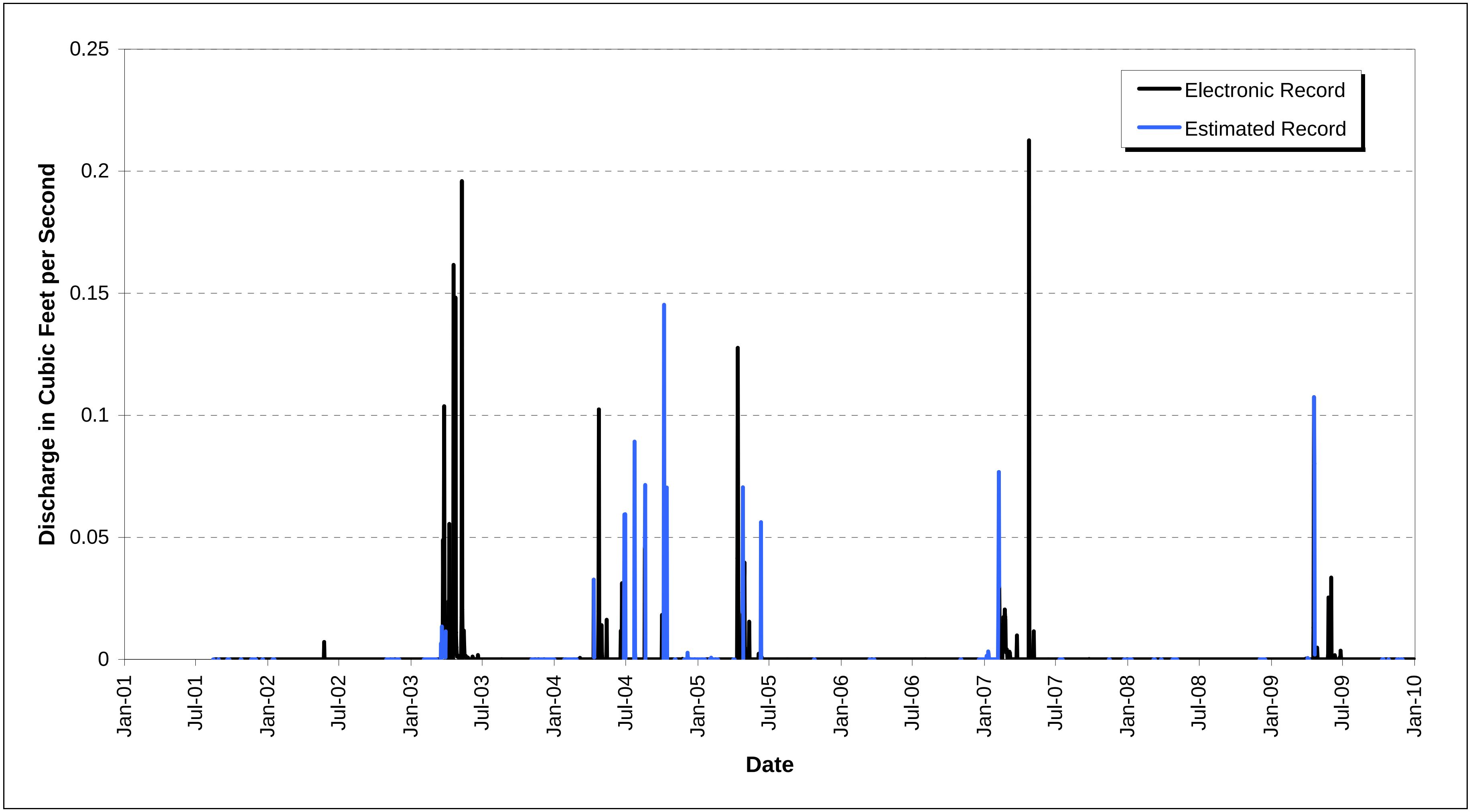


Figure 3–88. CY 2001−2009 Mean Daily Hydrograph at GS51: Ditch South of 903 Pad

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.

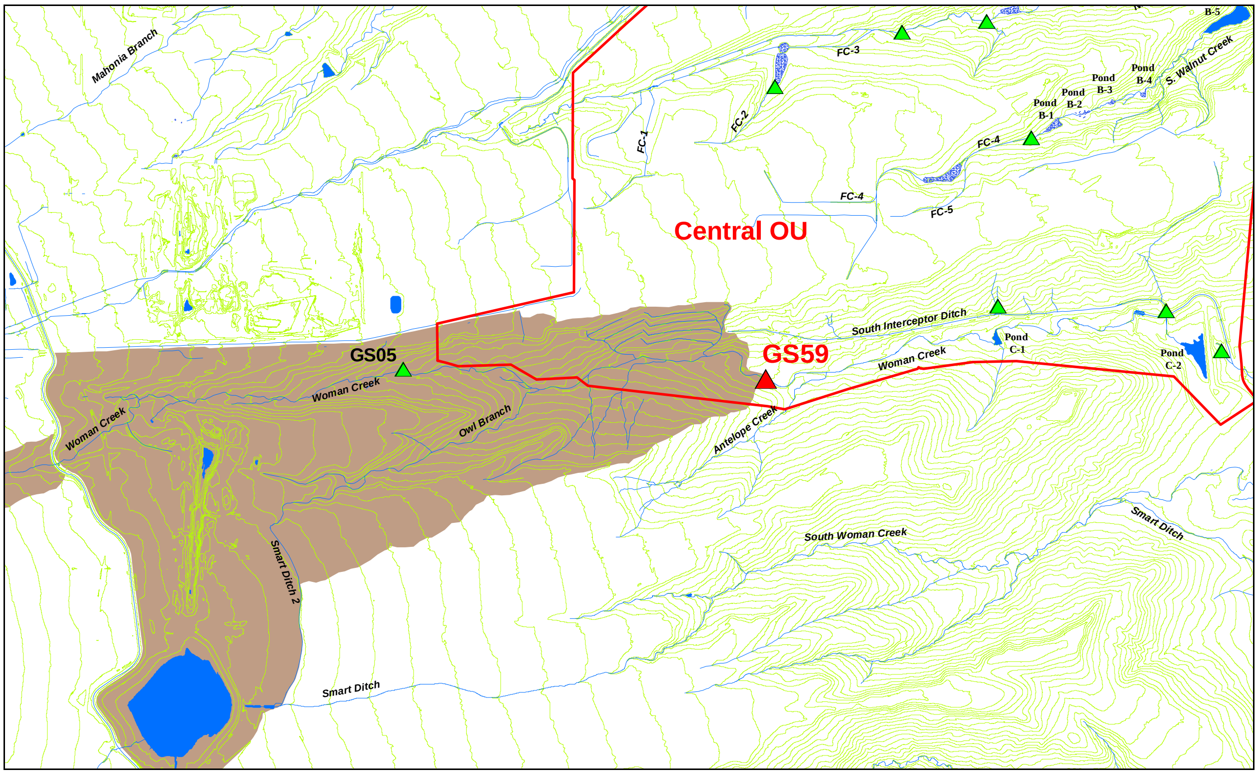


Figure 3–89. GS59 Drainage Area

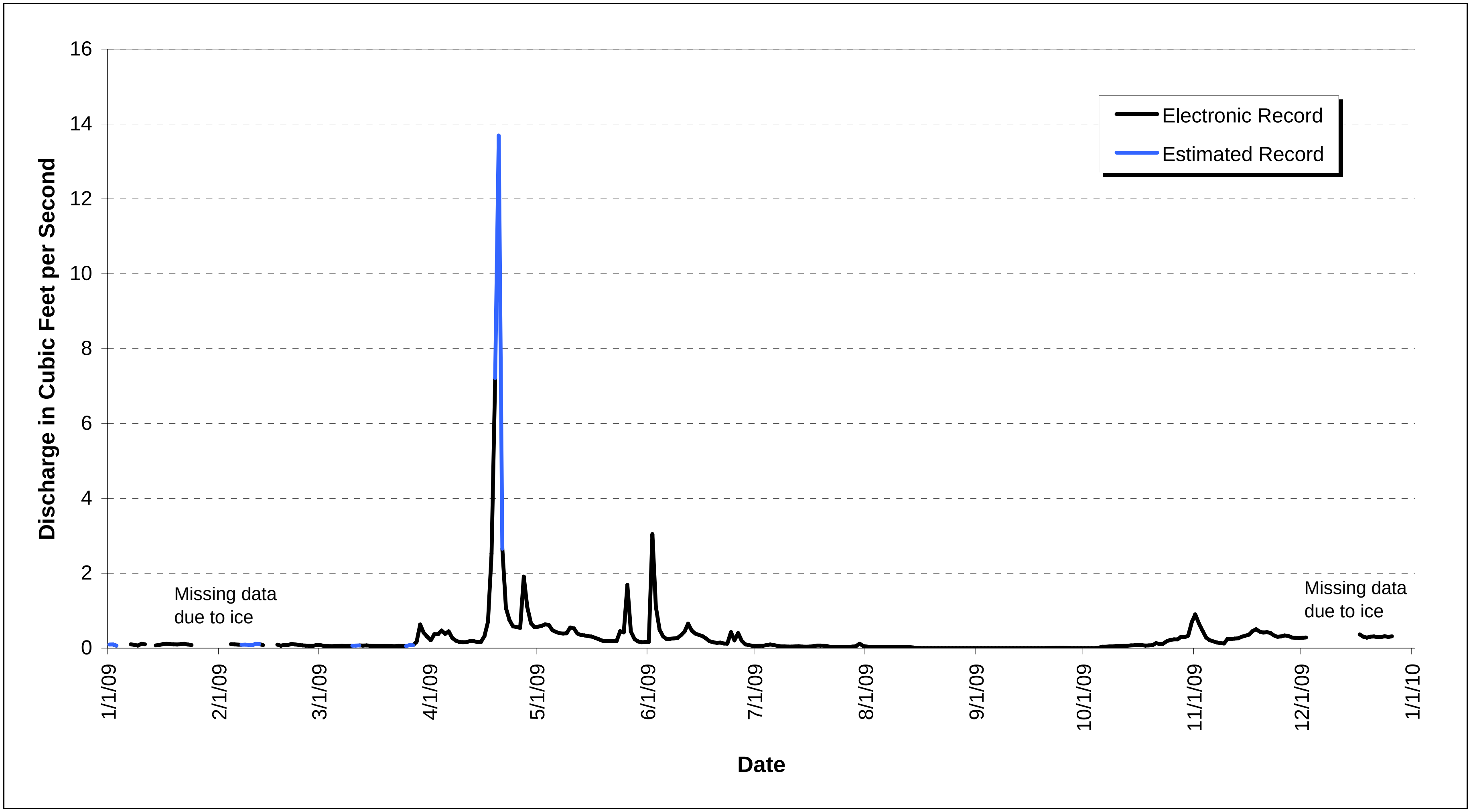


Figure 3–90. CY 2009 Mean Daily Hydrograph at GS59: Woman Creek Upstream of Antelope Springs Confluence

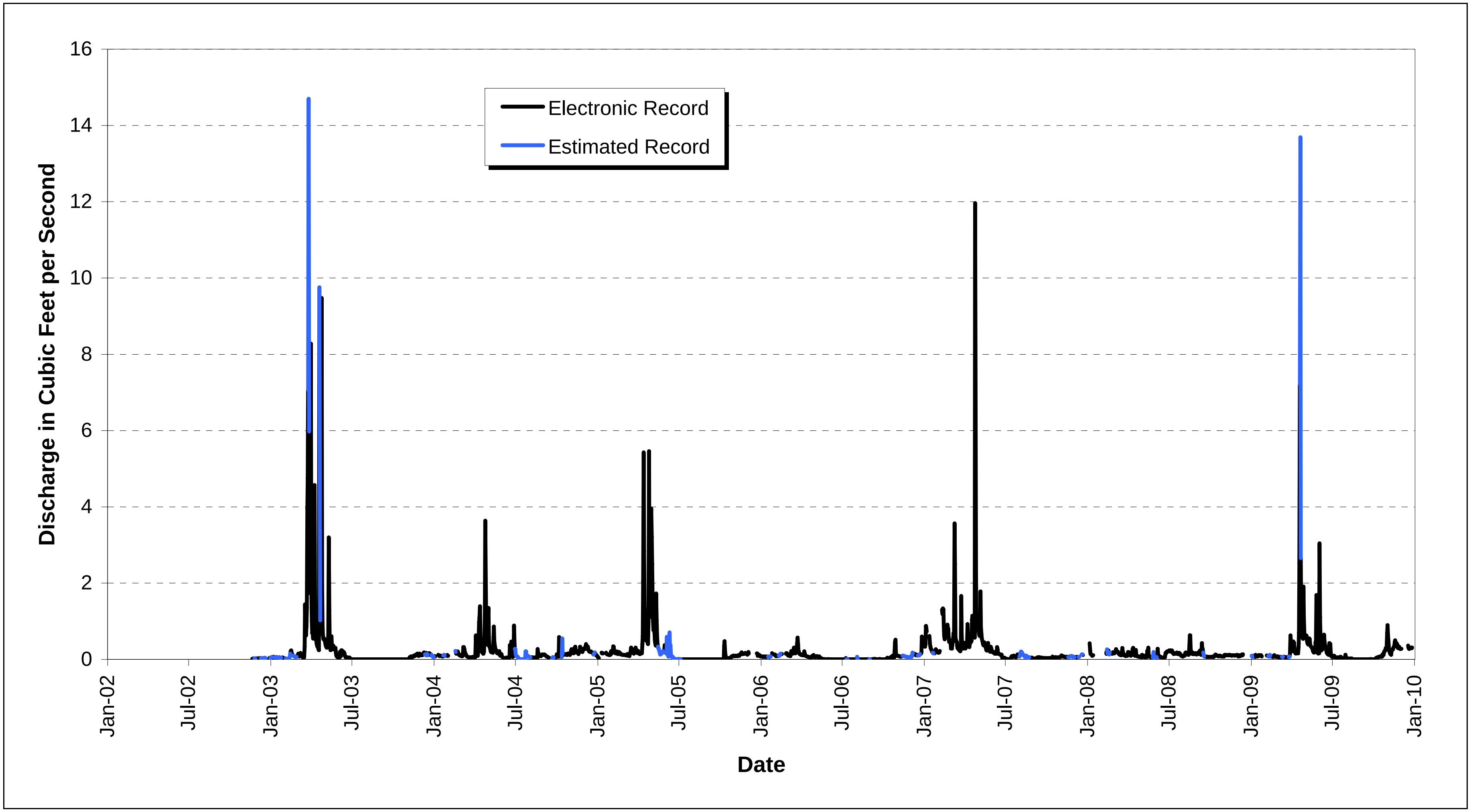


Figure 3–91. CY 2002−2009 Mean Daily Hydrograph at GS59: Woman Creek Upstream of Antelope Springs Confluence

SW018: FC-2 at FC-2 Wetland

Location—FC-2 drainage just upstream of FC-2 wetland; State Plane: E2083351, N751006.

Drainage Area—The basin includes FC-2 areas tributary to North Walnut Creek (total of 42.4 acres).

Period of Record—October 10, 2003, to current year.

Gage—Water-stage recorder and 1-foot Parshall flume through September 12, 2006. One-foot H flume installed on September 13, 2006.

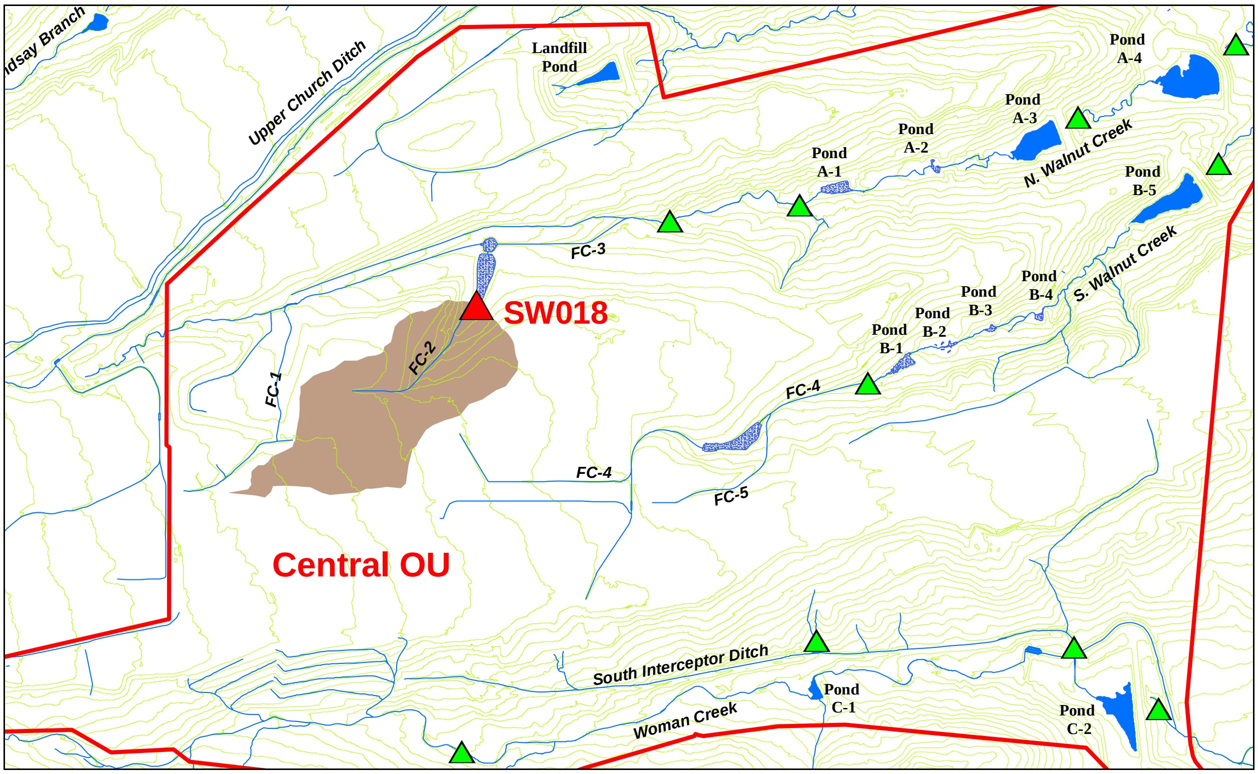


Figure 3–92. SW018 Drainage Area

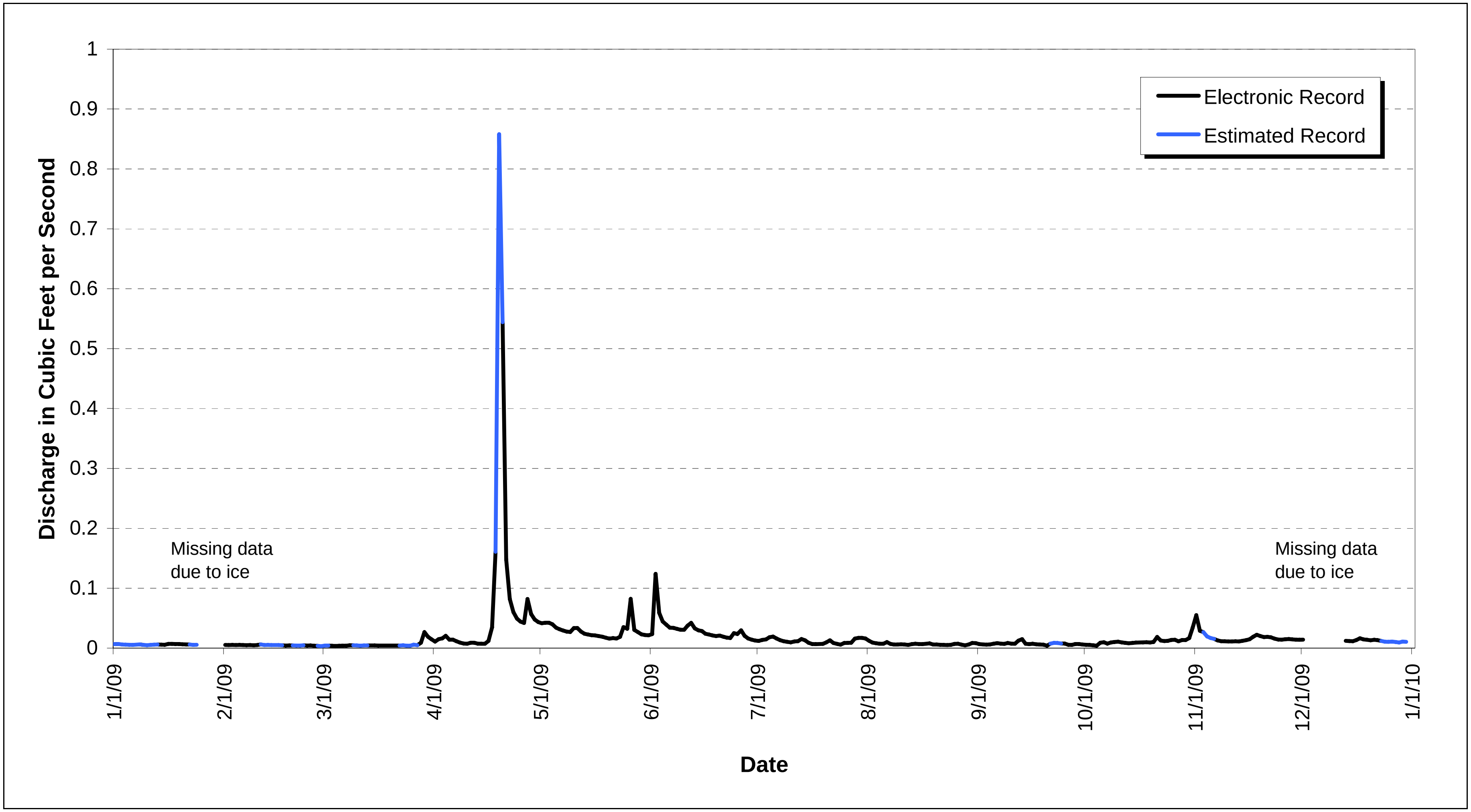


Figure 3–93. CY 2009 Mean Daily Hydrograph at SW018: FC-2 at FC-2 Wetland

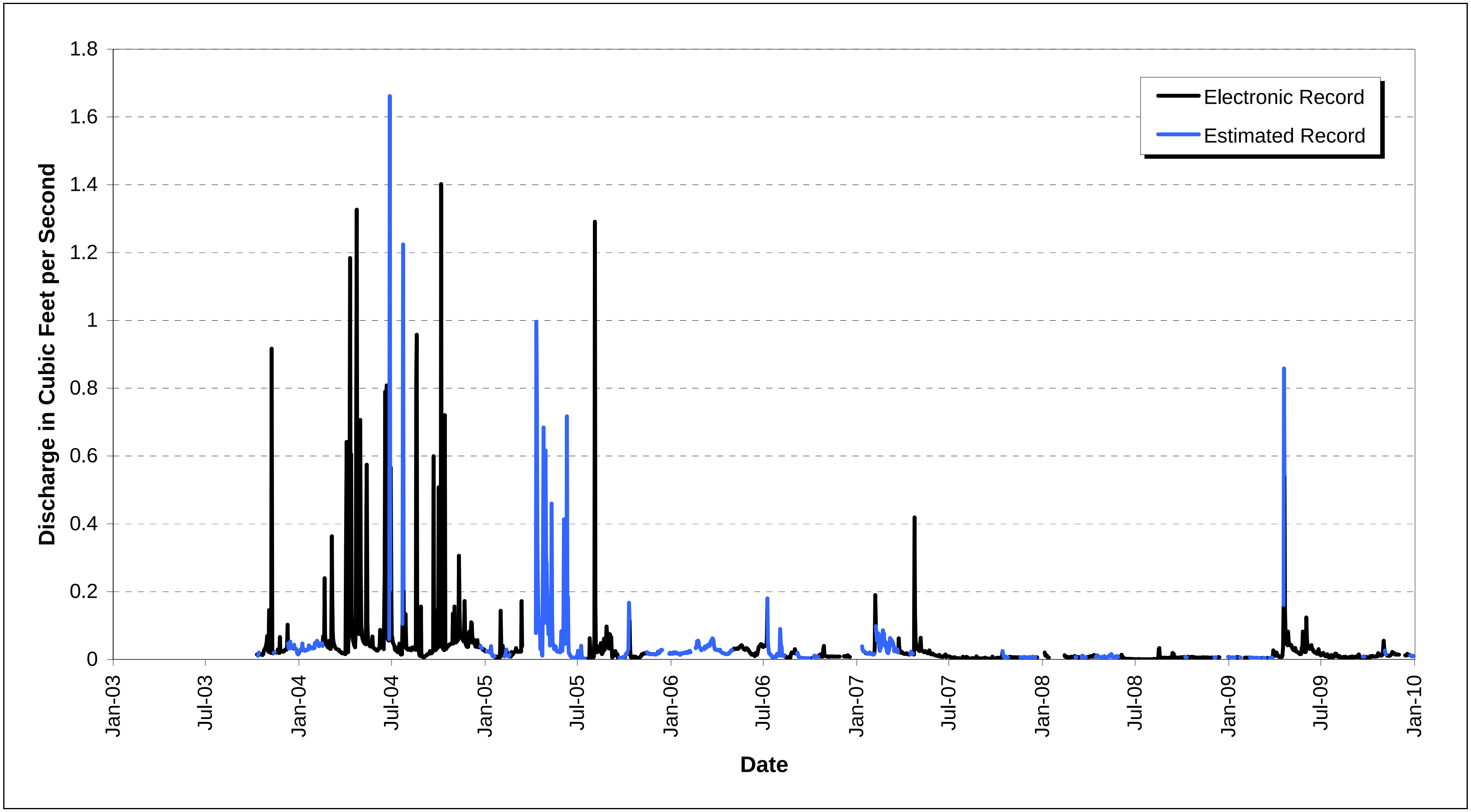


Figure 3–94. CY 2003−2009 Mean Daily Hydrograph at SW018: FC-2 at FC-2 Wetland

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.

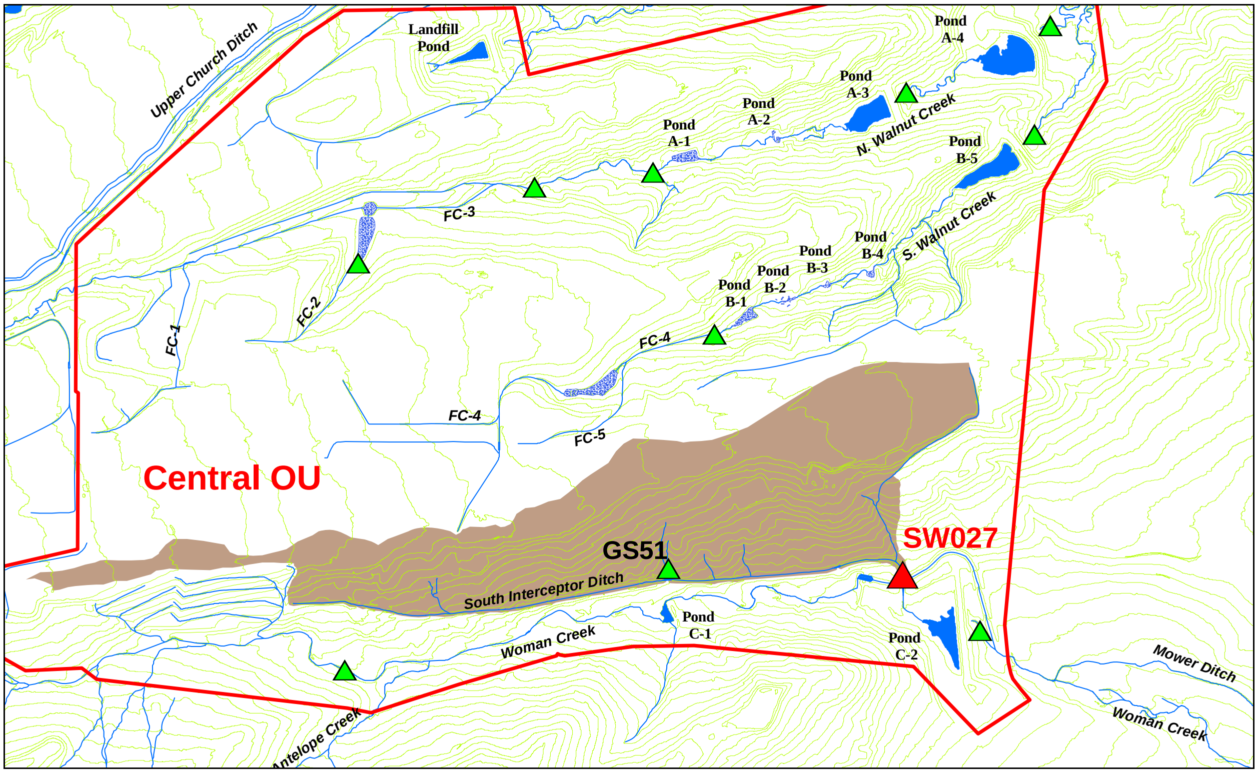


Figure 3–95. SW027 Drainage Area

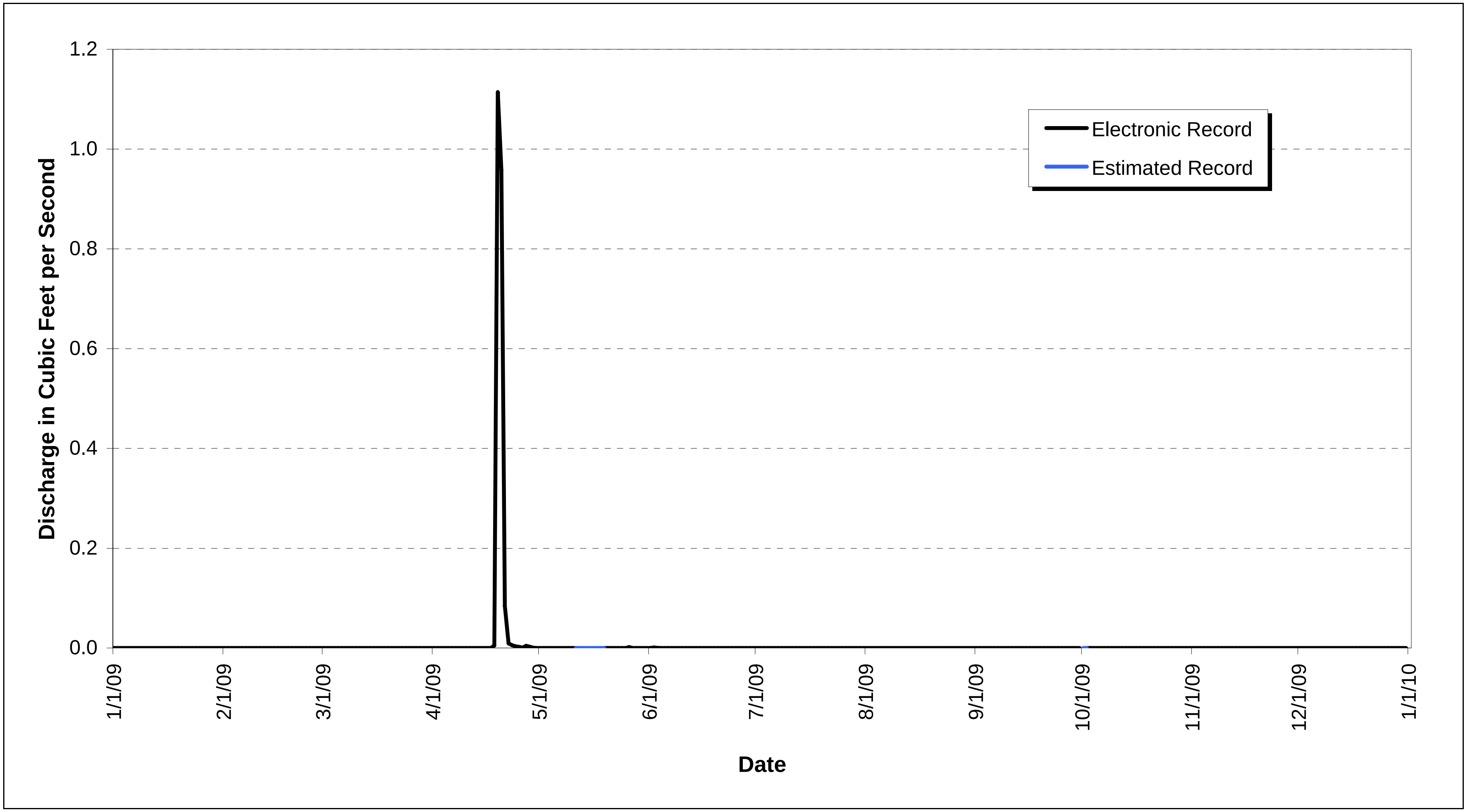


Figure 3–96. CY 2009 Mean Daily Hydrograph at SW027: SID at Pond C-2

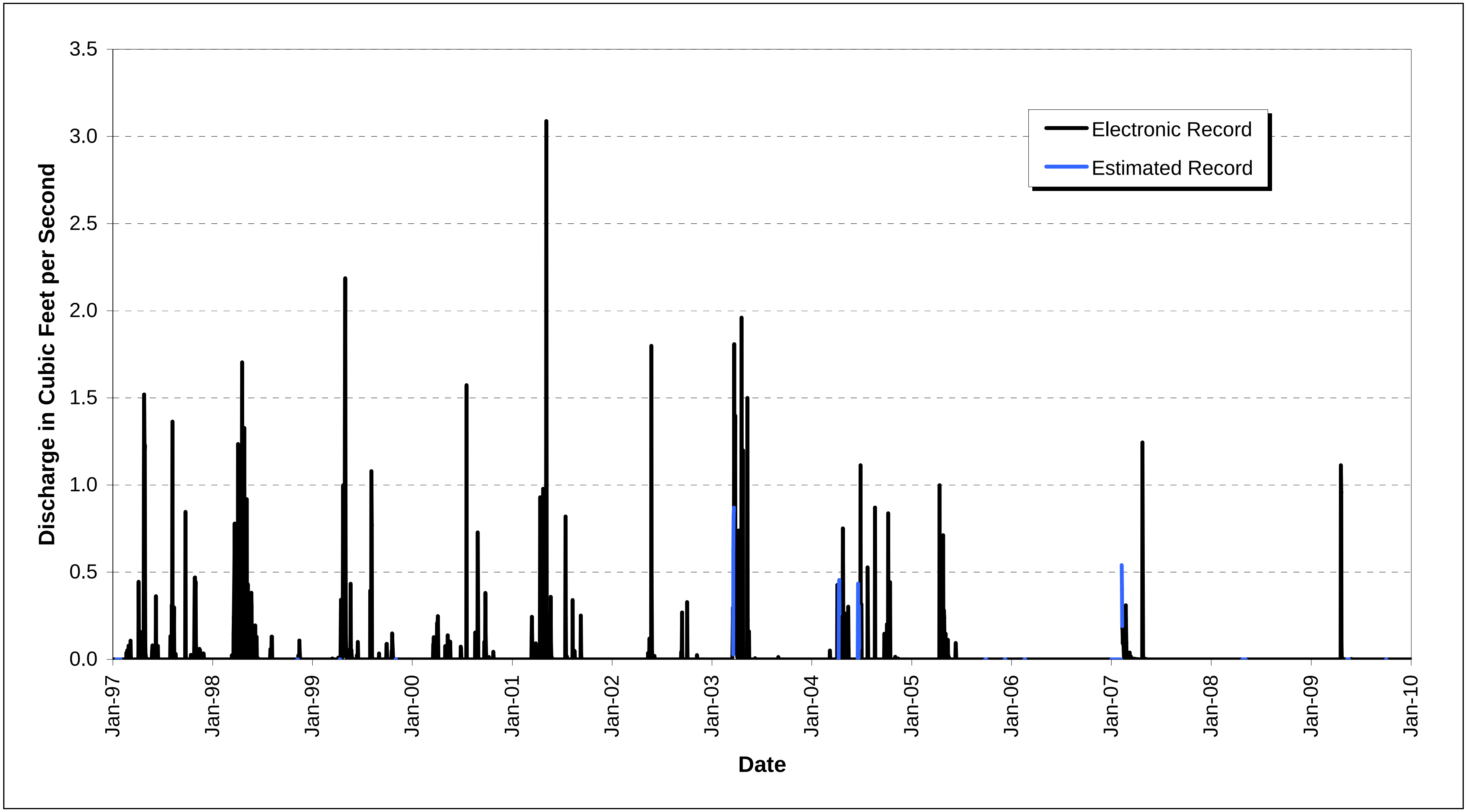


Figure 3–97. CY 1997−2009 Mean Daily Hydrograph at SW027: SID at Pond C-2

SW093: North Walnut Creek Upstream of Pond A-1

Location—North Walnut Creek 1,300 feet above 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.

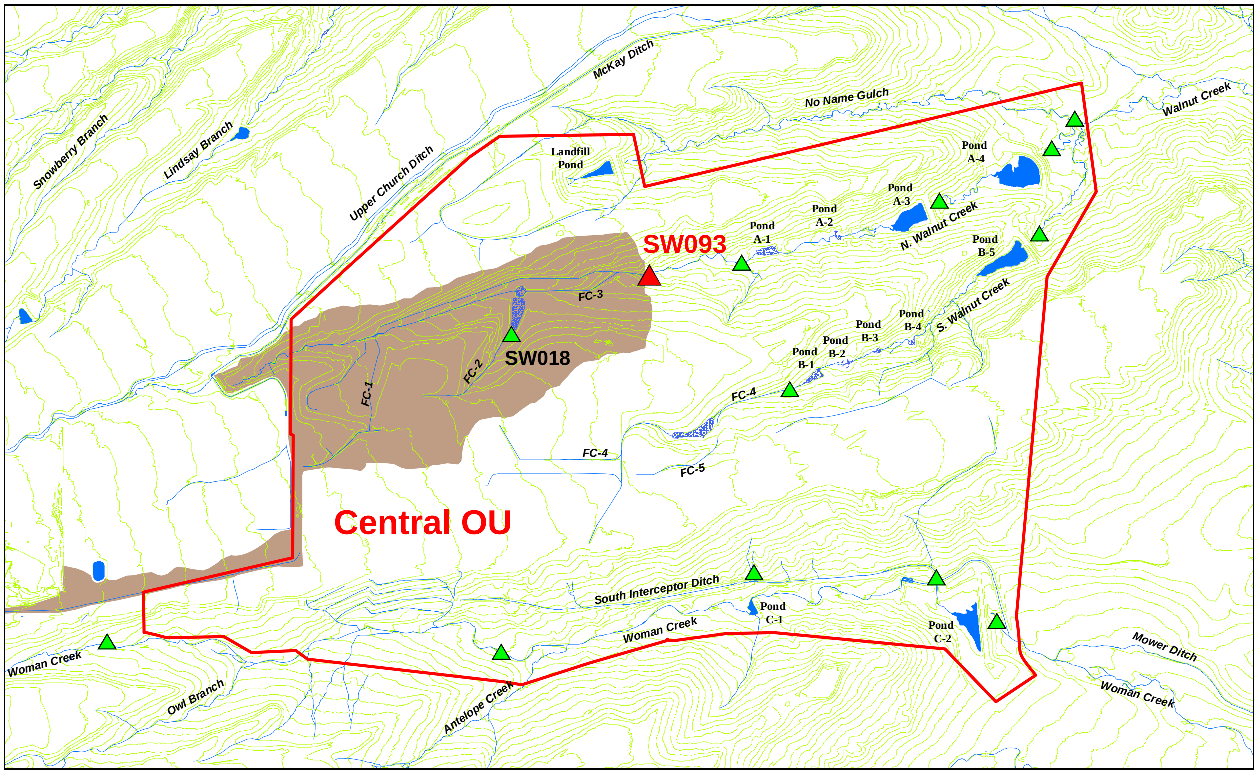


Figure 3–98. SW093 Drainage Area

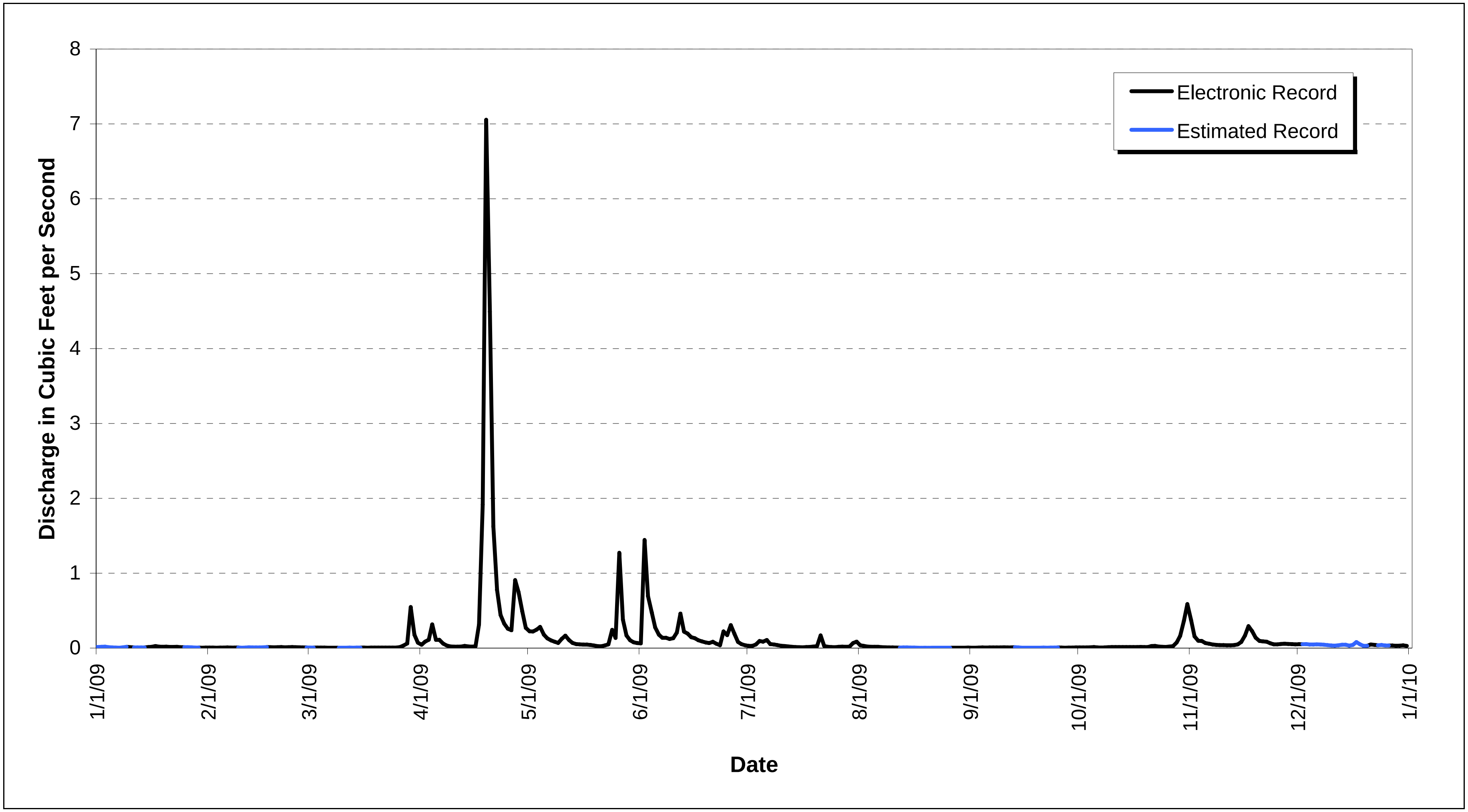


Figure 3–99. CY 2009 Mean Daily Hydrograph at SW093: North Walnut Creek Upstream of Pond A-1 Bypass

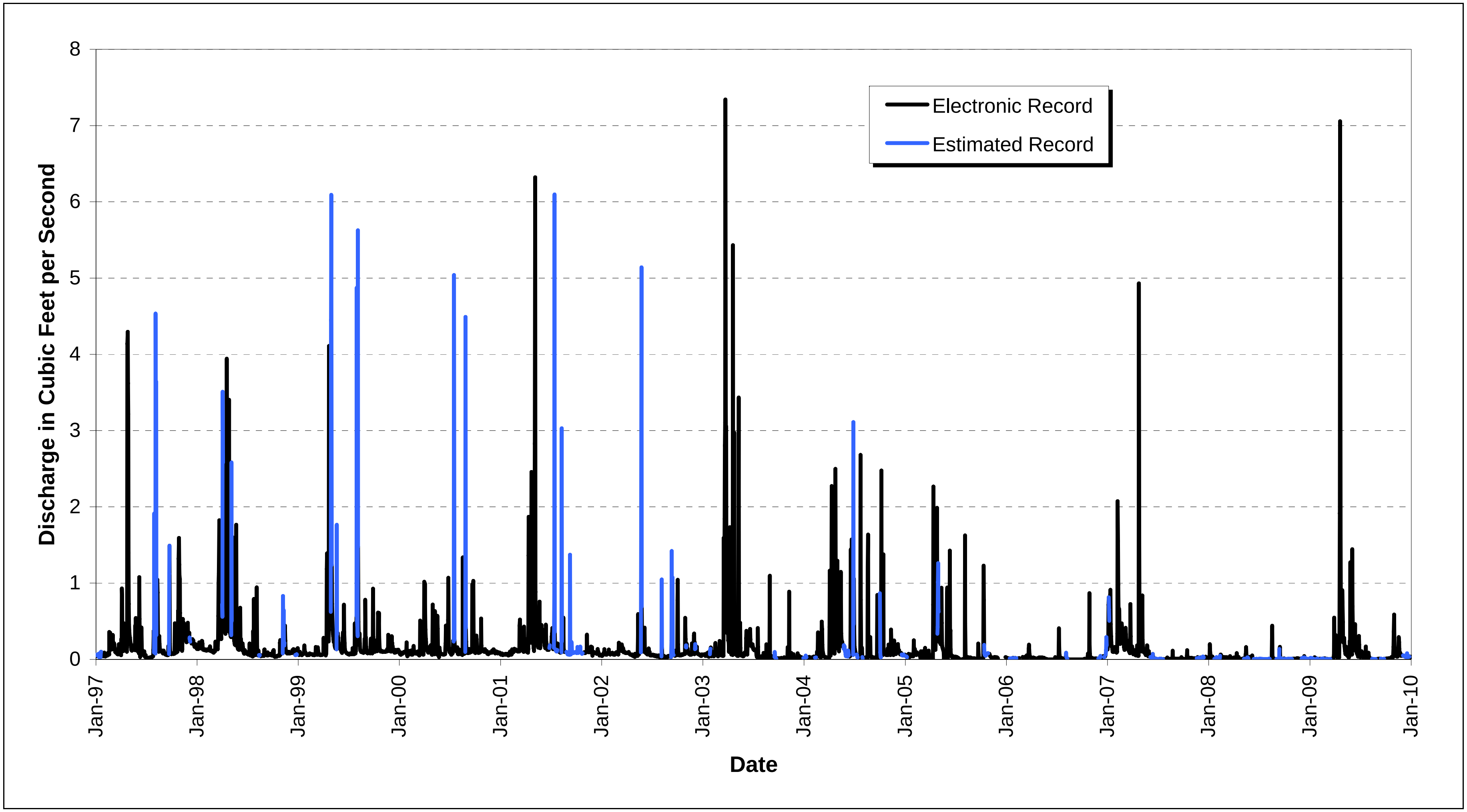


Figure 3–100. CY 1997−2009 Mean Daily Hydrograph at SW093: North Walnut Creek Upstream of Pond A-1 Bypass

3.1.3.4 Precipitation Data

During CY 2009, eight precipitation gages were operated as part of the automated surface-water monitoring network (Table 3–38 and Figure 3–101). The locations employ tipping-bucket rain gages generally mounted at ground level. Precipitation totals are logged on 5-minute intervals, 15-minute intervals, or both. The gages are not heated and will not accurately record equivalent precipitation for all snowfall events. The following sections present several figures (Figure 3–102, Figure 3–103, Figure 3–104, Figure 3–105, Figure 3–106, and Figure 3–107) summarizing the precipitation data collected for CY 1997−2009.

Table 3–38. 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	10/11/96−current year
PG59 [GS03]	2093598.99	753629.51	4/1/96−current year
PG61 [GS05]	2078432.10	747285.45	4/1/96−current year
PG73 [GS13]	2086169.70	751862.47	9/27/05−current year
PG74 [GS59]	2083245.00	747172.00	9/5/06−current year
PG75 [SW018]	2083522.00	751181.00	3/27/08–current year
PG76 [NA]	2091963.00	752705.00	3/28/07−current year
PG77 [NA]	2087329.00	746937.00	8/23/07−current year

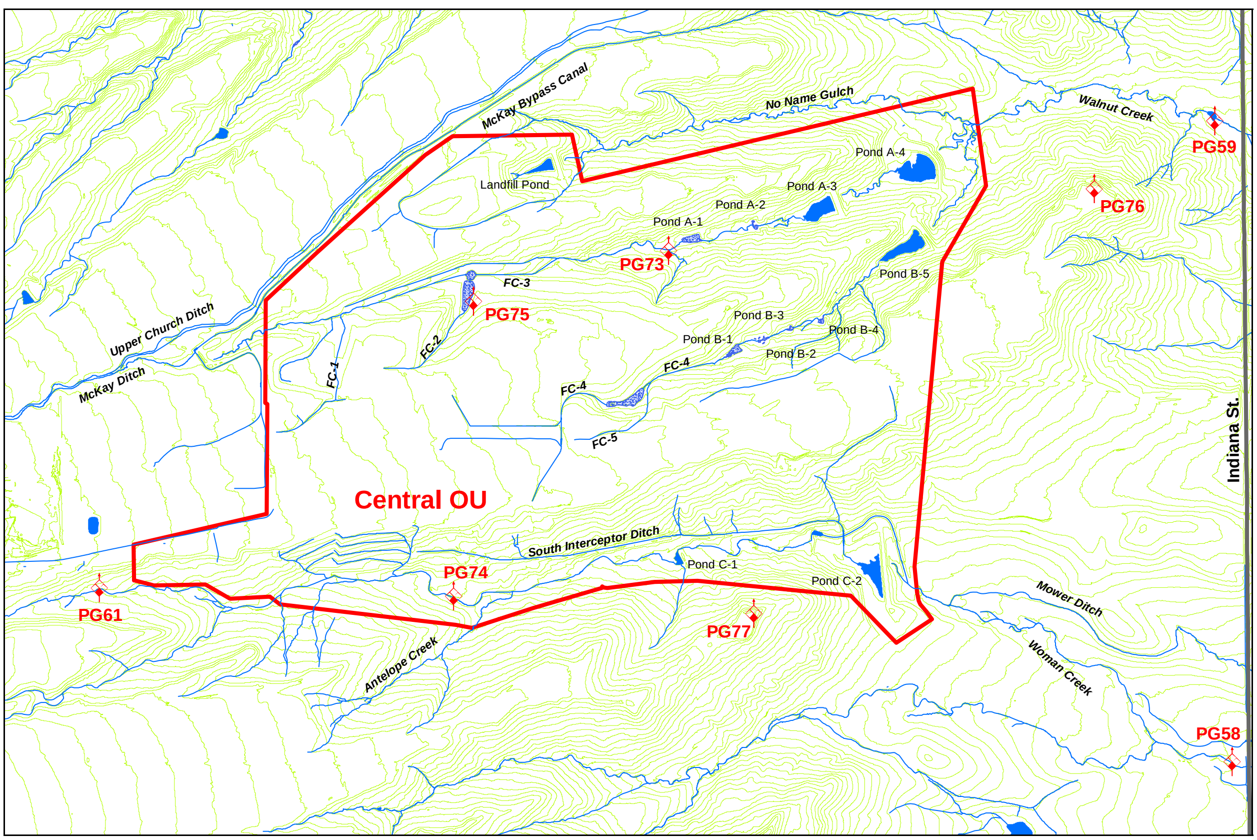
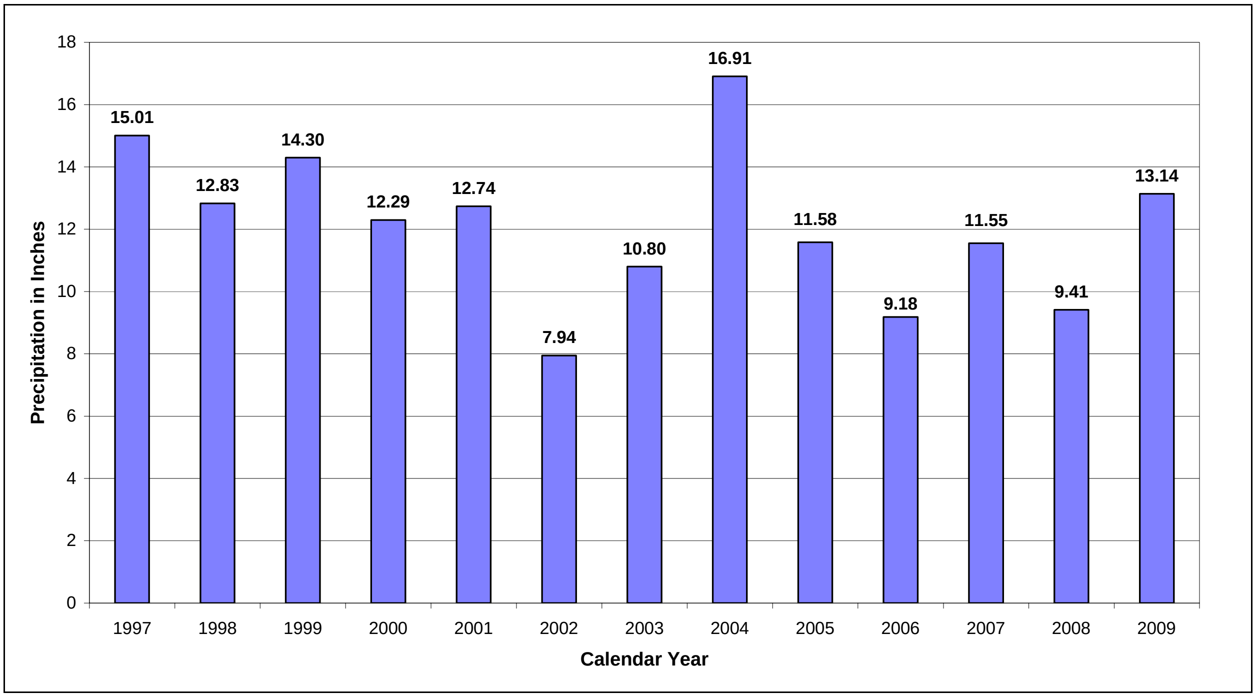


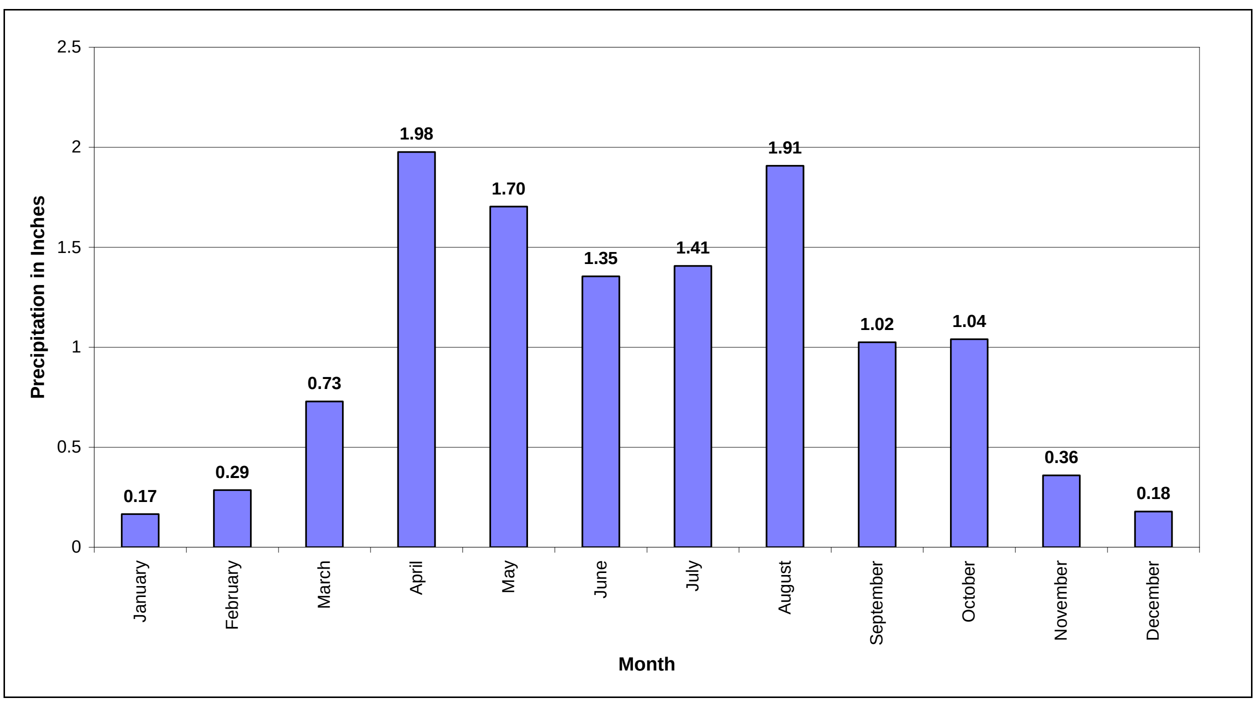
Figure 3–101. Site Precipitation Gages: CY 2009

CY 1997–2009 Summary



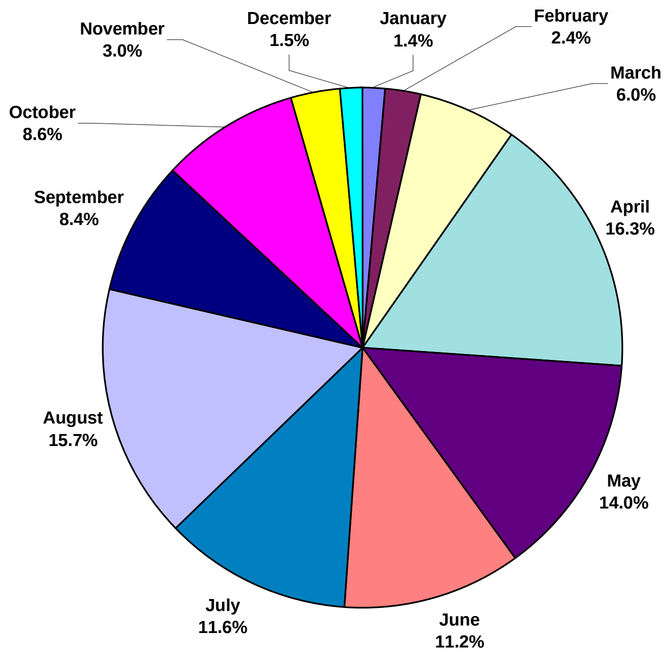
Note: Arithmetic average of gages in operation.

Figure 3–102. Annual Total Precipitation for CY 1997–2009



Note: Arithmetic average of gages in operation.

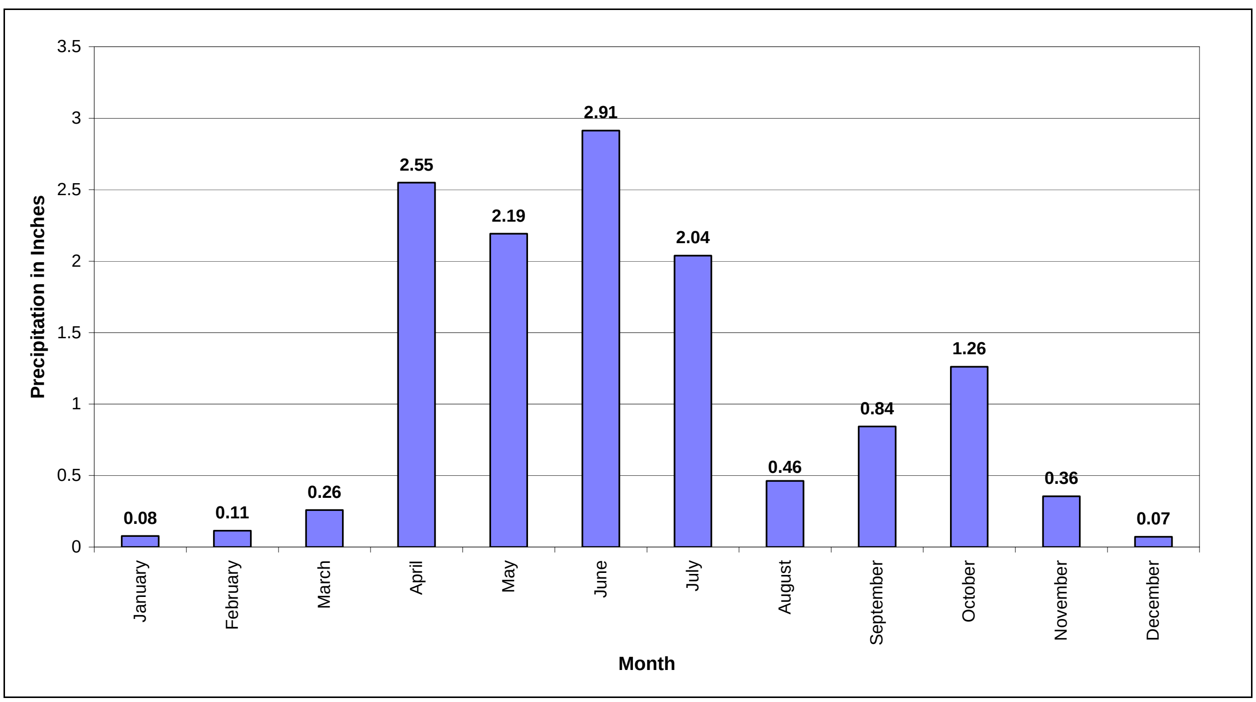
Figure 3–103. Average Monthly Precipitation for CY 1997–2009



Note: Arithmetic average of gages in operation.

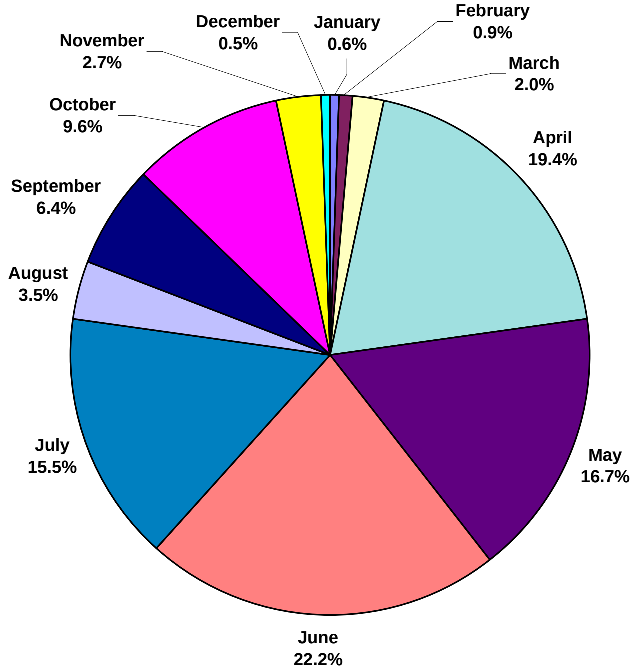
Figure 3–104. Relative Monthly Precipitation Totals for CY 1997–2009

CY 2009 Summary



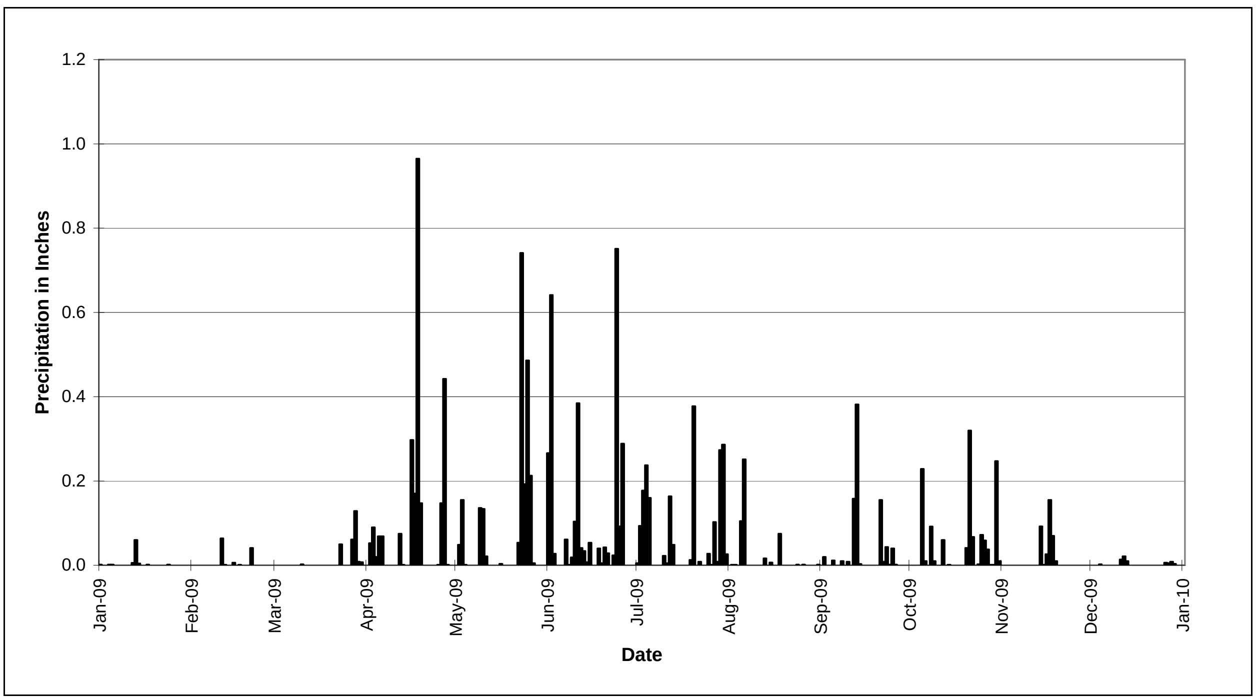
Note: Arithmetic average of gages in operation.

Figure 3–105. Monthly Precipitation for CY 2009



Note: Arithmetic average of gages in operation.

Figure 3–106. Relative Monthly Precipitation Volumes for CY 2009



Note: Arithmetic average of gages in operation.

Figure 3–107. Daily Precipitation Totals for CY 2009

3.1.3.5 Groundwater Flow

This section summarizes groundwater elevations and flow characteristics. Groundwater elevation data are discussed through the construction and interpretation of potentiometric surface maps and hydrographs. Groundwater flow characteristics are then assessed, including flow velocities.

Groundwater Elevations

Groundwater elevation data were manually collected at the start of the second and fourth quarters in 2009; these data are included in Appendix A. Groundwater elevations are also monitored at selected wells using dedicated instrumentation. Appendix A contains a discussion of the automated water-level collection.

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 2009 is included as Figure 3–108, and the map for the fourth quarter of CY 2009 is included as Figure 3–109. These maps are derived from manual water level measurements.

All 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.

Seeps posted on both potentiometric surface maps are from the 1995 Hydrogeologic Characterization Report (EG&G 1995a). Although this depiction of seeps is the best available map of the seeps for the Site, it is no longer accurate, having been most strongly affected by the removal of all artificial water sources, as well as land surface reconfiguration (e.g., excavations and placement of fill) in some areas.

Potentiometric surface maps for 2009 are based on many fewer locations than 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 from the unimpacted former Buffer Zone provide no meaningful value.

Several locations on the potentiometric maps are labeled as dry. Wells are labeled as dry if they are measured to be dry, 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), the reduction in contributions from artificial sources (e.g., removal of water lines, foundation drains, and dust suppression water), 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). However, many 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 associated well.

Groundwater flow paths in 2009 are consistent with conditions in 2008, as estimated from the potentiometric surface maps (Figure 3–108 and Figure 3–109). In addition, unsaturated areas in 2009 are similar to several of those depicted in 2008. Well 95299, located adjacent to and downgradient of the ETPTS groundwater intercept trench, was dry. This area is typically dry due to the dewatering effects of that trench. Well 90299 was also dry during 2009; again, this is the typical condition for this well. Conversely, well 45608 remained artesian, as indicated on the potentiometric surface maps and corresponding hydrograph. A discussion of the hydrographs is presented below and provides more detail on various wells.

Water levels in 2009 appeared to have stabilized following Site closure activities. Prior to closure, other influences—most particularly, the addition of imported water to the hydrologic system (from leaks in the water distribution infrastructure, normal Site operations, and closure-related application of dust suppression waters), the limitation of direct recharge by impermeable surfaces, and the diversion of groundwater by engineered building foundation drains—were also major factors in some areas, but these influences no longer appear to have a meaningful effect on groundwater levels. Water levels in 2009 were influenced by seasonal variations and were more dependent on precipitation than has been generally observed in prior years. Although there are exceptions, overall, the monitoring network indicates that water levels in 2009 were slightly higher in the fourth quarter than the second quarter. This is opposite the usual pattern and is attributed to the fairly wet period beginning in mid-April (just as collection of the second-quarter water level data was being wrapped up) through July; the Site received a total of 9.69 inches during this period. August and September also reported significant precipitation.

Precipitation in 2009 was recorded at eight locations across the Site. The "total" precipitation (i.e., as measured by unheated rain gages, which do not accurately reflect precipitation totals related to snowfall) recorded at the Site in CY 2009 was 13.14 inches. This value is about 6 percent more than the historical (1993−2008) average estimated total annual precipitation, which is 12.36 inches. Figure 3–102 summarizes precipitation totals for recent CYs, and displays the total precipitation for 2009. (Note that the amount shown for 2003 incorporates 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.) See Section 3.1.3.4 for additional discussion of precipitation.

Hydrographs

Water level measurements provide additional information on the hydrogeologic conditions surrounding the wells, including well recharge patterns. Hydrographs were prepared 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.

Groundwater levels at selected wells across the Site are monitored using dedicated downhole instrumentation. The automated as well as manually collected water level data were used to generate hydrographs. Therefore, wells equipped with the automated instrumentation are represented by two hydrographs. Appendix A includes the automated water level hydrographs superimposed over the curves created using manually-collected water level data.

As in the previous annual reports (DOE 2007f, 2008d, 2009g) and similar to the treatment of analytical data as discussed above, water level data for original and replacement wells are combined into a single hydrograph under the assumption that the corresponding data are continuous. As additional data are collected, this assumption may prove to be false at some locations, in which case the corresponding data will no longer be pooled. Water level data used for these hydrographs includes routine, pre-sampling, and any requested nonroutine measurements.

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, as calculated from the total depth of well casing recorded during its installation. The same water level is posted 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.

Groundwater recharge is typically controlled by several factors, including soils, vegetation, topographic relief, drainage density, geology (permeable or impermeable formation), and climate. The hydrographs more clearly illustrate the effects of the primary seasonal factors, precipitation and evapotranspiration, than in the past; an artificial component, sample collection, is also apparent. Other artificial controls on groundwater that were obvious in prior years, the impacts of Site facilities and closure activities, are no longer readily apparent in current data. As a result, in this report water level hydrographs are grouped based on three observed patterns: seasonal, relatively uniform, and water levels that appear to reflect a more complicated mix of influences.

Wells that display seasonal peaks in water level appear to be directly influenced by precipitation. These seasonal variations in water level are most apparent during the post-closure years (2006−2009), following the removal or termination of such conditions or activities as impermeable surfaces, water importation, and closure-related work. For example, seasonal correlations to groundwater levels are clearly represented by the wells monitoring the buried drainage that hosts the VC Plume upgradient of FC-2 (i.e., wells 33604, 33703, 33502, and 33905; refer also to Section 3.1.5.3 for a discussion of this plume). These hydrographs exhibit water levels that correlate directly to precipitation events (typically, rising limbs during spring and recession limbs during fall), a behavior that was limited prior to closure by the presence of the overlying impermeable surfaces.

Hydrographs that exhibit strong seasonal effects also display rising limbs in 2009 that appear to be more sudden than historically observed. Sharply rising limbs beginning in the spring of 2009 are attributed to a series of precipitation events. As noted above, the Site received a total of 9.69 inches during the period of April through July (see Table 3–39). The majority of hydrographs in 2009 exhibit a peak in the spring or summer, though the hydrograph for well 80105, which monitors downgradient (south) of the OLF, displays seasonal peaks each fall rather than in the spring.

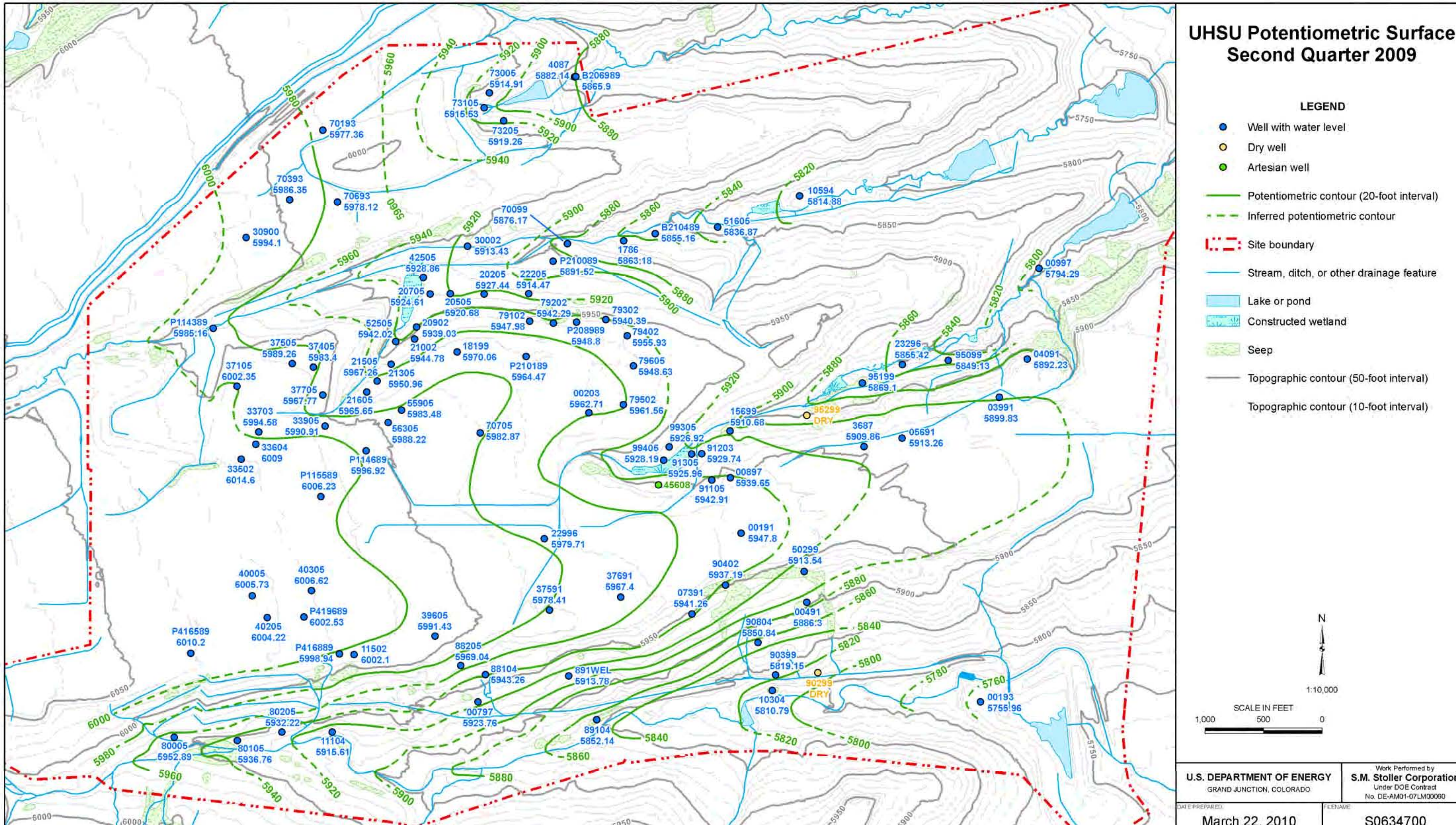


Figure 3–108. UHSU Potentiometric Contours: Second Quarter CY 2009

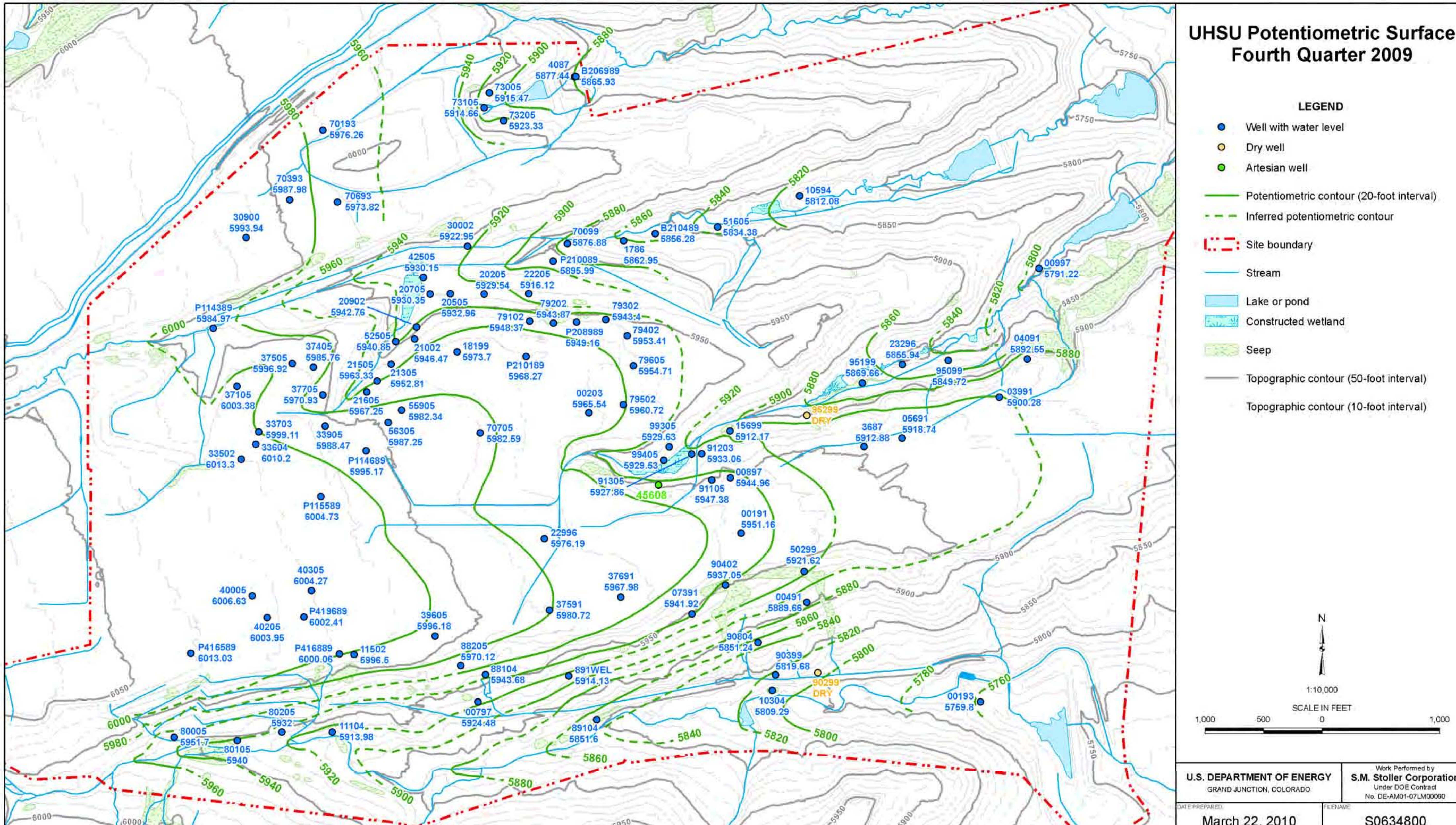


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Figure 3–109. UHSU Potentiometric Contours: Fourth Quarter CY 2009

Table 3–39. Total Monthly Precipitation Data for 2009

Month	Precipitation (inches)
January	0.08
February	0.11
March	0.26
April	2.55
May	2.19
June	2.91
July	2.04
August	0.46
September	0.84
October	1.26
November	0.36
December	0.07
Total Annual	**13.14**

NOTE: Values are averaged from eight precipitation gauges across the Site.

While most wells in the Rocky Flats monitoring network are represented by hydrographs that show seasonal recharge patterns, a number of hydrographs appear to be less strongly influenced by seasonal precipitation. For example, well 95099, located adjacent to the ETPTS, is represented by a hydrograph with a water level curve that does not appear to reflect seasonal or sampling-affected influences. This group of hydrographs also includes a few wells represented by water level data that display more than one peak in 2009. Well 40305, located near the former IA, is one such example. The hydrograph for this well exhibits a water level peak in May and a second peak in November, 2009. Sample collection can exert a real or perceived effect on water levels shown on the hydrographs, either through water removal and slow recharge (a real hydrologic effect), or via the inclusion of additional water level data that suggest different responses than are indicated by other wells in the area (a perceived effect). The hydrograph for well 40305 represents an example of the latter. Other wells in the former 400 Area—most notably 40005, 40205, and P419689, all of which are Evaluation wells and were therefore not scheduled for routine sampling in 2009—show fairly similar hydrographs. Sentinel well 40305, however, was sampled twice in 2009, and therefore the hydrograph for this well includes the additional water level data that were collected as a part of the sampling process. These additional data in the hydrograph for 40305 could lead to an inference that this well displays a distinctly different hydrologic response compared to its neighbors, a conclusion that does not appear justified.

Several hydrographs appear to have no observed peak in water levels throughout 2009. An example of such a hydrograph is that for well 90804, which is located south of the former 903 Pad. The hydrograph for this well historically presents very little change in water levels. This well is screened across (from shallower to deeper) reworked claystone, the detachment surface of a slump, and weathered bedrock claystone. Groundwater in this well is attributed to a high-permeability detachment surface, along which groundwater readily drains from upgradient to downgradient. Other hydrographs that show little variation are those for wells monitoring dry or artesian conditions. Well locations that are historically observed to be dry are 90299 and 95299. Wells 04091, 37591, and 37691 were dry in 2008, but recharged in the summer of 2009.

Well location 45608 has been observed to present artesian flow since its installation in March 2008. The slump that developed on the hillside south of former B991, in which this well is installed, was regraded in late 2007 (DOE 2009g). Although only 9 feet east of 45608, original well 45605 was never observed to have artesian flow. However, as illustrated on the hydrograph for this well, the top of the replacement well is some 14 feet lower in elevation than that of the original well. Although this does not entirely explain the change in behavior—the elevation of the water level in well 45608 is higher than was ever observed in 45605—it is a factor in the presence of artesian flow at the replacement well. This artesian flow is interpreted as evidence that this well acts as an outlet for the water collected by the remnants of the French drain underlying this constructed hillside. Additional discussion of this well is presented in Section 3.1.5.3.

Well 23296, located downgradient of the groundwater intercept trench feeding the ETPTS and adjacent to South Walnut Creek, also exhibited water levels in 2009 that were above historical levels. Rising water levels were first observed in October 2008; this coincides with the Dam Breach project that started in September of that year. The rising water level in this well continued through most of 2009, with a slight dip in the summer months that is likely due to the effects of evapotranspiration. The pattern of rising water levels is attributed to surface water being routed through the South Walnut Creek drainage since the B-Pond dams were breached, rather than bypassing the ponds via the bypass pipeline, as had been the practice in prior years.

Groundwater Flow Velocities

Groundwater flow directions and velocities in 2009 are generally consistent with those reported in 2008. 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. Using 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).

Well pairs selected for use in this report are generally the same as those selected in 2008, with one exception. Well 21605 was used instead of 56305 as the downgradient pairing to well P114689, in order to better reflect the flow direction indicated by the potentiometric surface maps.

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

$$v = \left(K/n\right)\left(dh/dl\right)$$

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 gradient was calculated from groundwater elevation data collected in the second and fourth quarters of 2009. Results of this calculation typically differ slightly when using data from one quarter versus that from another, but the differences are typically not large, with two exceptions. The hydraulic gradients calculated for well pair 40305-39605 for second and fourth quarters are 0.013 and 0.007, respectively. The steeper gradient seen in second quarter than fourth quarter is the result of the relative timing of high water level conditions in the two wells. The hydrographs for these wells illustrate this difference: Upgradient well 40305 has higher water levels during the second and third quarters of 2009, while downgradient well 39605 has higher water levels in the third and fourth quarters of the year. Similarly, the gradients calculated for well pair P419689-11502 are 0.001 and 0.011 for second and fourth quarters, respectively; the same explanation applies, but in this case water levels in the downgradient well are higher in the second quarter, and those in the upgradient well are higher in the fourth quarter.

Calculated seepage velocities are only useful as estimates. These velocities are most often used to estimate the travel time of conservative (nonreactive) constituents. Reactive constituents will tend to migrate more slowly than the calculated velocity. These calculated velocities do not take into account properties such as sorption and chemical reactions (e.g., precipitation, biodegradation, and volatilization) that can strongly influence the transport of groundwater contaminants.

For each well pair, the value of K selected for this calculation was based on the predominant lithologic unit comprising the flow path between the two wells. 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 between the wells and, from the hydrographs, appears to comprise a meaningful fraction of the saturated interval, an average K was calculated from the lithologies. K values used for these calculations are from 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 for Rocky Flats Alluvium is used because the source of the fill was typically deposits of Rocky Flats Alluvium. However, it is unlikely that the backfilled alluvium has the internal structure or is as compacted as the original deposits, resulting in a higher effective porosity and K 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 will be higher still. For this report, well pairs crossing areas of sufficiently thick backfill deposits may use the K 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.

An example well pair may serve to illustrate some of the related difficulties. Well 18199 is located between former B776 and B771. It screens Rocky Flats Alluvium and sandstone of the Arapahoe Formation (the "No. 1 Sandstone"; EG&G 1995a). Groundwater in this area previously flowed toward the west as a result of the B771 foundation drain system. Following disruption of this drain, groundwater flow is anticipated to be more northerly, potentially through the rubble- and alluvium-backfilled subsurface remnants of B771. Well 20505 was selected as the downgradient well in this well pair. This well screens artificial fill, clays, claystone, and silty claystone. The transect from 18199 to 20505 is mostly occupied by the artificial fill of the B771 closure, and that fill is essentially reworked alluvium. During the fourth quarter of 2009, the water level in well 18199 was within the bedrock, while that in well 20505 was within the artificial fill. Therefore, an average hydraulic conductivity of the Arapahoe Formation No. 1 Sandstone (well 18199) and Rocky Flats Alluvium and claystone (well 20505) was used to calculate the fourth quarter seepage velocity between this well pair. During the second quarter of 2009, the water level in both wells was within bedrock, and the average hydraulic conductivity of the sandstone (well 18199) and claystone (well 20505) was used to calculate the corresponding seepage velocity.

As noted above, these calculated velocities are based in part on data displayed on the hydrographs: where water is shown above the bedrock contact, hydraulic conductivities for the unconsolidated surficial material (e.g., Rocky Flats Alluvium or colluvium), as well as bedrock to account for water flowing through this unit, are included for this calculation. 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 extreme variability of bedrock lithologies (e.g., from claystone to silty claystone to clayey siltstone to siltstone) is often reflected in cores from the screened interval of a given well, but a single K value is selected to represent the well.

Table 3–40 presents the results of the calculation of seepage velocities. Refer to Figure 3–108 and Figure 3–109 for the locations of the wells. Estimated seepage velocities in 2009 range from a low of 2.51 feet per year (ft/yr) within the bedrock from well P419689 to well 11502 in the southern IA, to a high of 432 ft/yr within the artificial fill and bedrock from well 88205 to well 00797 in the 881 Hillside area. The corresponding travel time between each well in a well pair ranges from approximately 9 months (from well 88205 to well 00797 in the vicinity of the 881 Hillside) to over 213 years (from well P419689 to well 11502 in the former IA). However, these are estimated velocities for pure water; and second, the hydraulic gradients can be seen to change significantly from season to season between wells in some well pairs as a result of the recharge pattern, as discussed above in the text on hydrographs. For example, the gradients mentioned above between wells P419689 and 11502 (0.001 and 0.011 for second and fourth quarters, respectively) lead to corresponding calculated velocities of 2.51 ft/yr and 34.50 ft/yr—travel times of over 213 years and about 15.5 years. Obviously, these estimates are very sensitive to measured water levels.

In general, the velocities calculated for 2009 are comparable to those calculated prior to Site closure (e.g., K-H 2004b), and are also similar to those presented in 2008 (DOE 2009g). For a more detailed discussion of flow between well pairs by area, refer to the 2006 and 2007 annual reports (DOE 2007f and 2008d, respectively).

Table 3–40. Calculated Flow Velocities for 2009

Well Pair	Area	2009 Quarter	Geological Unit	WL Elevation, Well 1	WL Elevation, Well 2	dh (ft)	dl (ft)	dh/dl (hydraulic gradient)	Calculated K (cm/s)	Velocity (ft/yr)	Time to Traverse Transect (yr)
P115589-P114689	North IA	2	Qrf	6006.23	5996.92	9.31	550.14	0.017	4.18E-04	73.19	7.52
P115589-P114689	North IA	4	Qrf	6004.73	5995.17	9.56	550.14	0.017	4.18E-04	75.15	7.32
P114689-21605	North IA/B559	2	Qrf / Qrf/KaKlclst	5996.92	5965.65	31.27	503.78	0.062	3.14E-04	201.47	2.50
P114689-21605	North IA/B559	4	Qrf / Qrf/KaKlclst	5995.17	5967.25	27.92	503.78	0.055	3.14E-04	180.05	2.80
56305-21505	B559	2	Qrf/KaKlclst	5988.22	5967.26	20.96	319.61	0.066	2.09E-04	142.11	2.25
56305-21505	B559	4	Qrf/KaKlclst	5987.25	5963.33	23.92	319.61	0.075	2.09E-04	161.84	1.97
18199-20505	B771	2	KaNo.1ss / KaKlclst	5970.06	5920.68	49.38	500.43	0.099	3.94E-04	402.70	1.24
18199-20505	B771	4	KaNo.1ss / Qrf/KaKlclst	5973.7	5932.96	40.74	500.43	0.081	4.99E-04	420.07	1.19
P416589-80105	OLF	2	Qrf / Qrf/KaKlclst	6010.2	5936.76	73.44	846.63	0.087	3.14E-04	281.56	3.01
P416589-80105	OLF	4	Qrf / Qrf/KaKlclst	6013.03	5940	73.03	846.63	0.086	3.14E-04	280.24	3.02
40305-39605	South IA	2	Qrf/KaKlslt / KaKlclst	6006.62	5991.43	15.19	1126.39	0.013	1.12E-04	15.65	71.99
40305-39605	South IA	4	Qrf/KaKlslt / KaKlclst	6004.27	5996.18	8.09	1126.39	0.007	1.12E-04	8.32	135.34
40005-P419689	South IA	2	Qrf/KaKlclst / Qrf/KaNo.1ss	6005.73	6002.53	3.2	478.87	0.007	4.06E-04	28.09	17.05

Table 3−40 (continued). Calculated Flow Velocities for 2009

Well Pair	Area	2009 Quarter	Geological Unit	WL Elevation, Well 1	WL Elevation, Well 2	dh (ft)	dl (ft)	dh/dl (hydraulic gradient)	Calculated K (cm/s)	Velocity (ft/yr)	Time to Traverse Transect (yr)
40005-P419689	South IA	4	Qrf/KaKlclst / Qrf/KaNo.1ss	6006.63	6002.41	4.22	478.87	0.009	4.06E-04	37.04	12.93
P419689-11502	South IA	2	Qrf/KaNo.1ss / KaKlclst	6002.53	6002.1	0.43	535.27	0.001	3.02E-04	2.51	213.28
P419689-11502	South IA	4	Qrf/KaNo.1ss / KaKlclst	6002.41	5996.5	5.91	535.27	0.011	3.02E-04	34.50	15.52
40305-22996	South IA/ 800 Area	2	Qrf/KaKlclst / Qrf	6006.62	5979.71	26.91	2037.05	0.013	3.14E-04	42.88	47.51
40305-22996	South IA/ 800 Area	4	Qrf/KaKlclst / KaKlclst	6004.27	5976.19	28.08	2037.05	0.014	1.05E-04	15.00	135.82
88205-00797	881 Hillside	2	Qrf/KaKlclst / Qrf	5969.04	5923.76	45.28	343.12	0.132	3.14E-04	428.73	0.80
88205-00797	881 Hillside	4	Qrf/KaKlclst / Qrf	5970.12	5924.48	45.64	343.12	0.133	3.14E-04	432.14	0.79
00191-00491	903 Pad-Lip	2	Qrf/KaKlclst	5947.8	5886.3	61.5	816.98	0.075	2.09E-04	163.12	5.01
00191-00491	903 Pad-Lip	4	Qrf/KaKlclst	5951.16	5889.66	61.5	816.98	0.075	2.09E-04	162.78	5.02
07391-10304	Ryan's Pit/ Woman Ck.	2	Qrf/KaKlclst / Qc/KaKlclst	5941.26	5810.79	130.47	948.74	0.138	1.28E-04	182.50	5.20
07391-10304	Ryan's Pit/ Woman Ck.	4	Qrf/KaKlclst / Qc/KaKlclst	5941.92	5809.29	132.63	948.74	0.140	1.28E-04	185.14	5.12
91105-91203	Oil Burn Pit #2	2	Qrf/KaKlslt / KaKlclst	5942.91	5929.74	13.17	242.17	0.054	1.12E-04	63.10	3.84
91105-91203	Oil Burn Pit #2	4	Qrf/KaKlslt / KaKlclst	5947.38	5933.06	14.32	242.17	0.059	1.12E-04	68.52	3.53
P210189-79102	SEPs	2	Qrf/KaKlslt / KaKlclst	5964.47	5947.98	16.49	301.98	0.055	1.12E-04	63.36	4.77

Table 3−40 (continued). Calculated Flow Velocities for 2009

Well Pair	Area	2009 Quarter	Geological Unit	WL Elevation, Well 1	WL Elevation, Well 2	dh (ft)	dl (ft)	dh/dl (hydraulic gradient)	Calculated K (cm/s)	Velocity (ft/yr)	Time to Traverse Transect (yr)
P210189-79102	SEPs	4	Qrf/KaKlslt / KaKlclst	5968.27	5948.37	19.9	301.98	0.066	1.12E-04	76.36	3.95
79102-22205	North of SEPs	2	KaKlclst / KaKlslt	5947.98	5914.47	33.51	235.62	0.142	1.48E-05	21.78	10.82
79102-22205	North of SEPs	4	KaKlclst / KaKlslt	5948.37	5916.12	32.25	235.62	0.137	1.48E-05	20.96	11.24
79502-99305	SEPs/B991	2	KaKlclst / Qrf/KaKlclst	5961.56	5926.92	34.64	532.37	0.065	1.05E-04	70.80	7.52
79502-99305	SEPs/B991	4	KaKlclst / Qrf/KaKlclst	5960.72	5929.63	31.09	532.37	0.058	1.05E-04	63.44	8.39
70393-70693	PU&D/PLF	2	Qrf	5986.35	5978.12	8.23	410.48	0.020	4.18E-04	86.71	4.73
70393-70693	PU&D/PLF	4	Qrf	5987.98	5973.82	14.16	410.48	0.034	4.18E-04	149.19	2.75
30900-30002	PU&D/ N. Walnut Ck.	2	Qrf/KaNo.1ss / KaKlclst	5994.1	5913.43	80.67	1890.74	0.043	3.02E-04	133.29	14.19
30900-30002	PU&D/ N. Walnut Ck.	4	Qrf/KaNo.1ss / KaKlclst	5993.94	5922.95	70.99	1890.74	0.038	3.02E-04	117.32	16.12

In the one case mentioned above where a well pairing changed from that presented in 2008 (i.e., current well pair P114689-21605, which replaced pair P114689-56305), calculated flow velocities increased as a result of the change. The previous pairing produced an average 2008 flow velocity of approximately 85.3 ft/yr; the current pairing and 2009 data yield a velocity of approximately 190.76 ft/yr. This change was made because well pair P114689-21605 reflects what appears to be a more viable flow path (more nearly perpendicular to potentiometric contours) than the previous pairing. The increase in velocity noted is largely due to the significantly lower elevation of the downgradient well in the new pairing relative to that of the previous pairing.

Velocities and travel times were calculated for a well pair in the Ryan’s Pit Plume (source-area Evaluation well 07391 to AOC well 10304). Both were sampled in 2009. As with samples collected in 2008 from well 10304, analytical data from samples collected in 2009 did not confirm a detection of TCE reported in 2007. This continues to suggest that the 2007 result was not an indication that the leading edge of the Ryan’s Pit/903 Pad Plume had reached this well. See Section 3.1.5.3 for additional discussion of this plume.

In the Individual Hazardous Substance Site (IHSS) 118.1 area, data from well 20505 (downgradient from source-area well 18199) continued to show no detections of carbon tetrachloride or chloroform, the most notable contaminants from IHSS 118. Seepage velocities summarized in Table 3–40 indicate that these contaminants could have been detected in well 20505 beginning in 2006, but this has still not occurred. This may be evidence of contaminant retardation, or it could indicate that groundwater is being diverted in another direction or that these constituents are being degraded before they reach well 20505. While the flow path from 18199 to 20505 appears reasonable, groundwater may be diverted by the presence of disrupted foundation drains and associated corridors, the backfilled B771, and backfilled/disrupted subsurface utility corridors around the sides of the building. Given this possibility, the detection of carbon tetrachloride in the May 2009 sample from well 20205 (located adjacent to former Bowman’s Pond, east of well 20505) is notable. The concentration was estimated (J-qualified) at 0.2 μg/L; this constituent was also detected at J-qualified concentrations in 2008 (0.657 μg/L and 0.47 μg/L in second and fourth quarters, respectively). The November 2009 sample did not report a detection of carbon tetrachloride. The potentiometric surface maps (Figure 3–108 and Figure 3–109) do not support a flowpath from IHSS 118.1 to this well, although other wells that historically monitored this plume and reported elevated concentrations of carbon tetrachloride were more directly upgradient of well 20205. This may indicate that a portion of this plume is migrating to this downgradient Sentinel well, potentially via the former infrastructure of the B771 complex. However, given the low concentrations and lack of detection in the fourth quarter sample, this detection does not serve as confirmation of such a flowpath. As with the other Sentinel wells along the north side of former B771, well 20205 will continue to be monitored and the additional data assessed to evaluate the potential for contaminant migration from IHSS 118.1 to this area.

Overall, groundwater flow paths and flow velocities in 2009 show little change from previous years.