

Data Evaluation

During CY 2010, pre-discharge samples were collected during at Ponds A-4, B-5, and C-2 prior to discharge. All pre-discharge sample results indicated that water quality was acceptable for discharge. Subsequent POC sampling during discharge also indicated acceptable water quality for the discharged water.

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 2010. 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 the 2010 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. Five ponds within the COU collect and manage surface-water runoff.⁷ The Site drainages and ponds, including their respective pertinence to this report, are described below and shown on Figure 61.

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, 2010) for the locations included in this report is shown on Figure 62.

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 locally diverted toward the generally east-west trending drainages that bisect these pediments. Groundwater typically discharges at seeps and

⁷ Former Dams A-1, A-2, B-1, B-2, B-3, and B-4 were breached during 2008–2009.

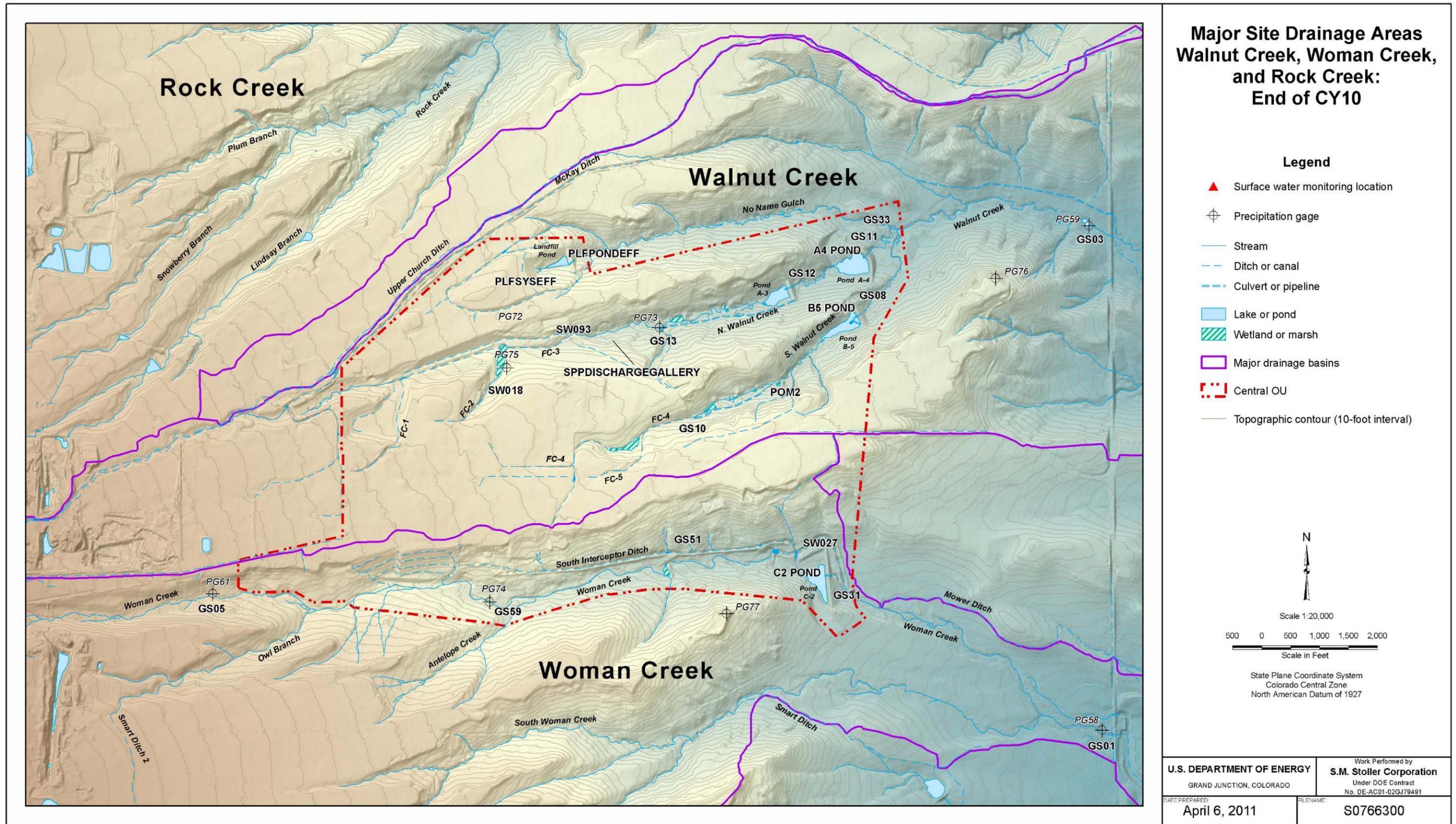
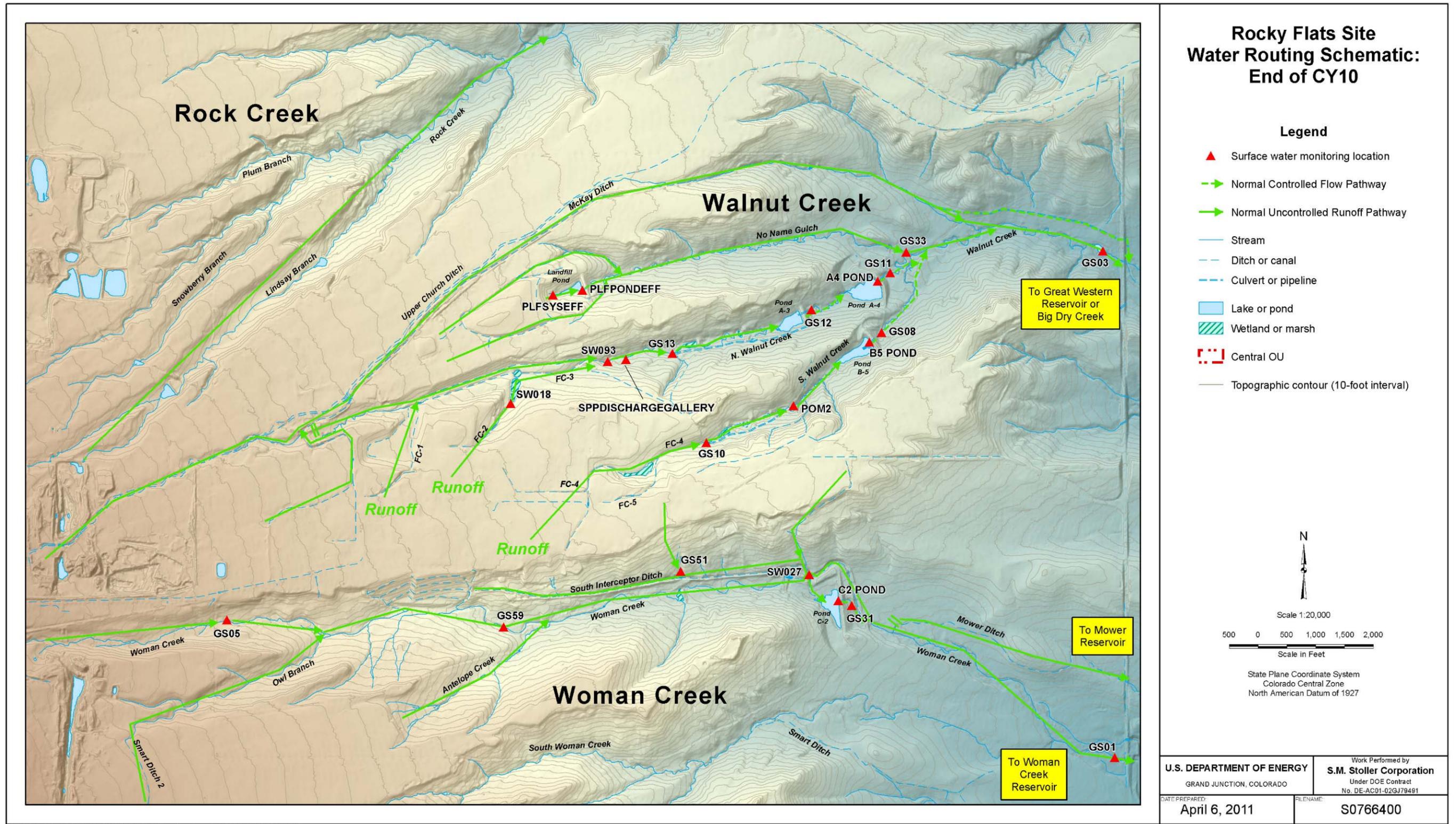


Figure 61. Major Site Drainage Areas—Walnut Creek, Woman Creek, and Rock Creek: End of CY 2010



M:\LTS\1110056\12\008\IS07664\IS0766400.mxd coatesc 04/06/2011 12:52:34 PM

Figure 62. Rocky Flats Site Water Routing Schematic: End of CY 2010

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 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 and County 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 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 Present 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 immediately 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. The combined capacity of the A-series ponds is approximately 174,000 cubic meters (m³).

(46 million gallons, or 141 acre-feet). In the normal operational configuration, Ponds A-1 and A-2 receive flow for storm water attenuation and wetland habitat; the stoplog structures control water levels in these ponds, with water subsequently flowing to Pond A-3. Pond A-3 is normally operated in flow-through to the A-series “terminal pond” Pond A-4. If routine discharge of retained water is warranted, Pond A-4 is pre-discharge 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 2010f).

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. The combined capacity of the South Walnut Creek B-series ponds is approximately 93,000 m³ (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 pre-discharge 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 a 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. Woman Creek water does not enter Pond C-2, but is diverted around Pond C-2 through the Woman Creek Diversion Canal. If routine discharge of retained water is warranted, Pond C-2 is pre-discharge 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,⁸ 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.

⁸ Stage is the water level (in units such as feet or meters) in a conveyance structure.

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, 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 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.⁹
- **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.

⁹ Drainage area maps show Site configuration at the end of CY 2010.

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 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 CY10” 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

Sitewide Discharge Summary

Discharge summaries for the two major Site drainages receiving flow from the COU (Walnut and Woman Creeks) are given on Figure 63 and Figure 64.¹⁰ Walnut Creek flows are measured at GS03 and Woman Creek flows are measured at GS01. Figure 65 shows the relative total CY 1997–2010 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.

¹⁰ The pre-closure period is for the dates 1/1/97–10/1/05; the post-closure period is for the dates 10/1/05–12/31/10.

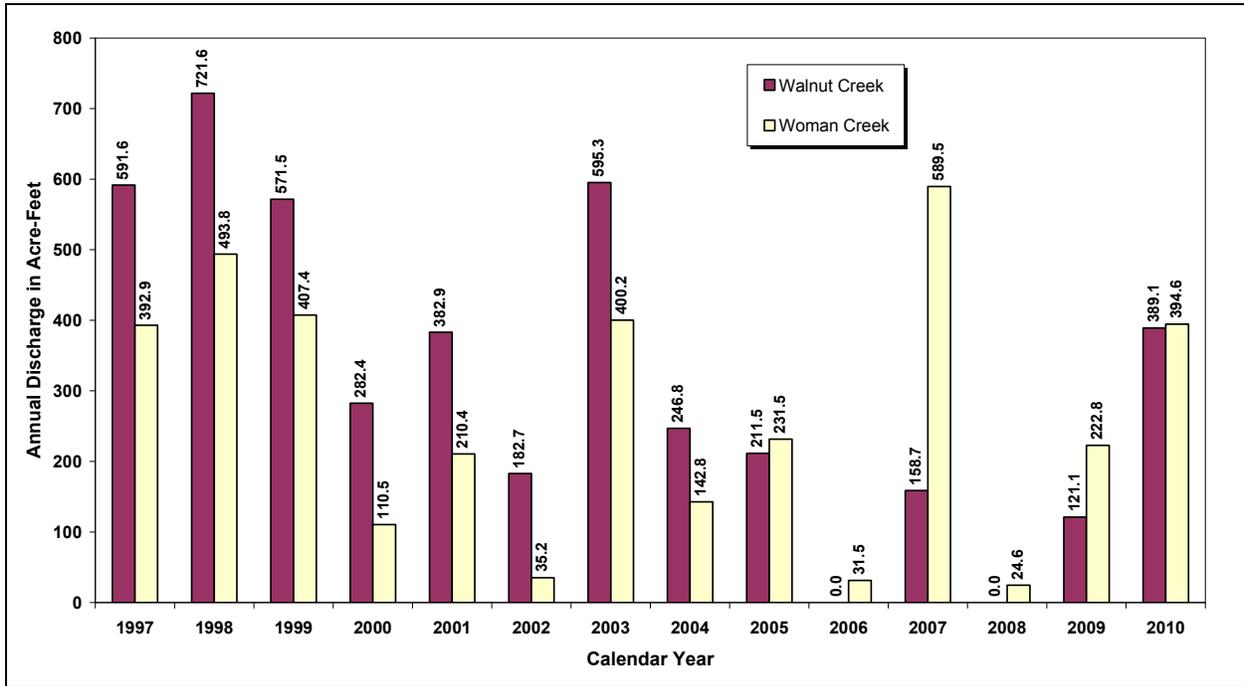


Figure 63. Annual Discharge Summary from Major Site Drainages: CY 1997–2010

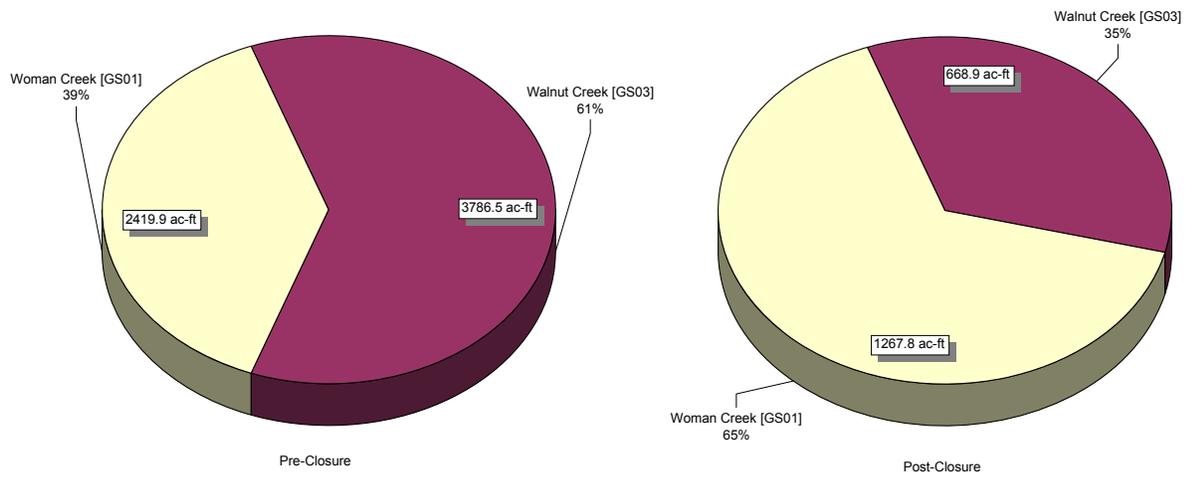


Figure 64. Relative Total Discharge Summary from Major Site Drainages: Pre- and Post-Closure Periods

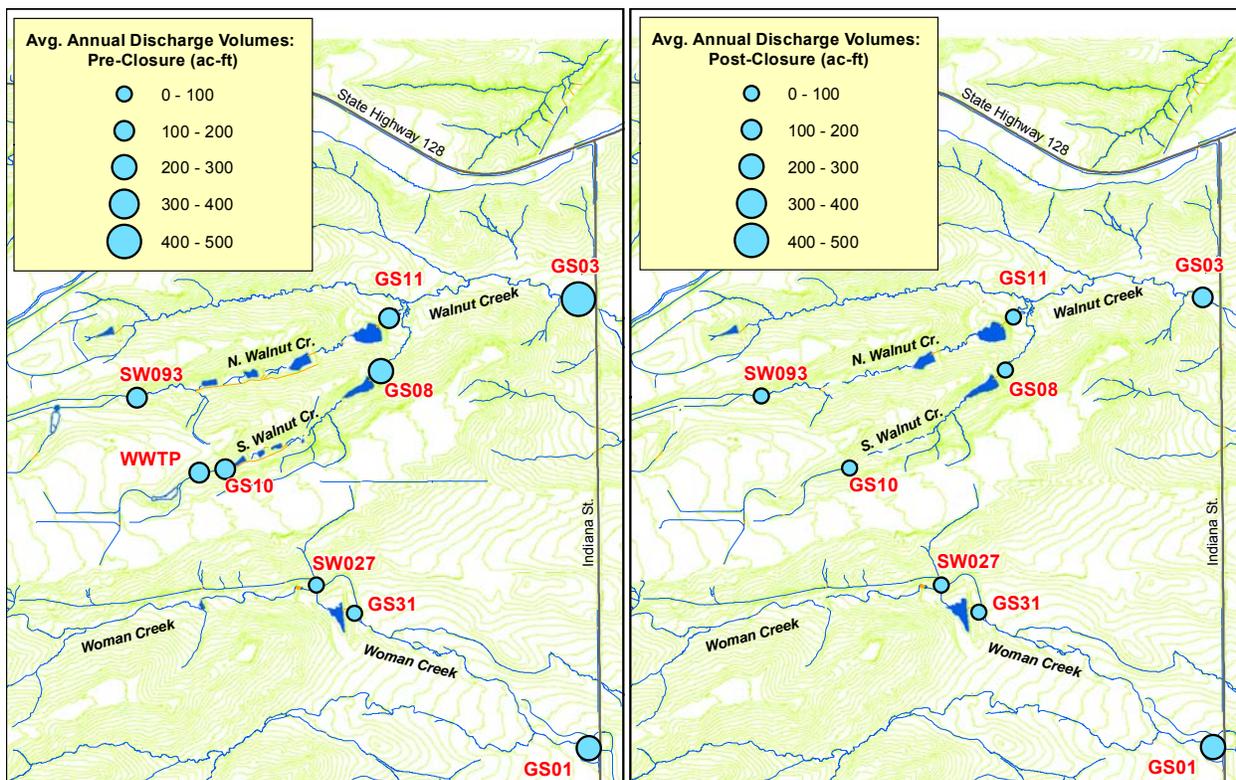


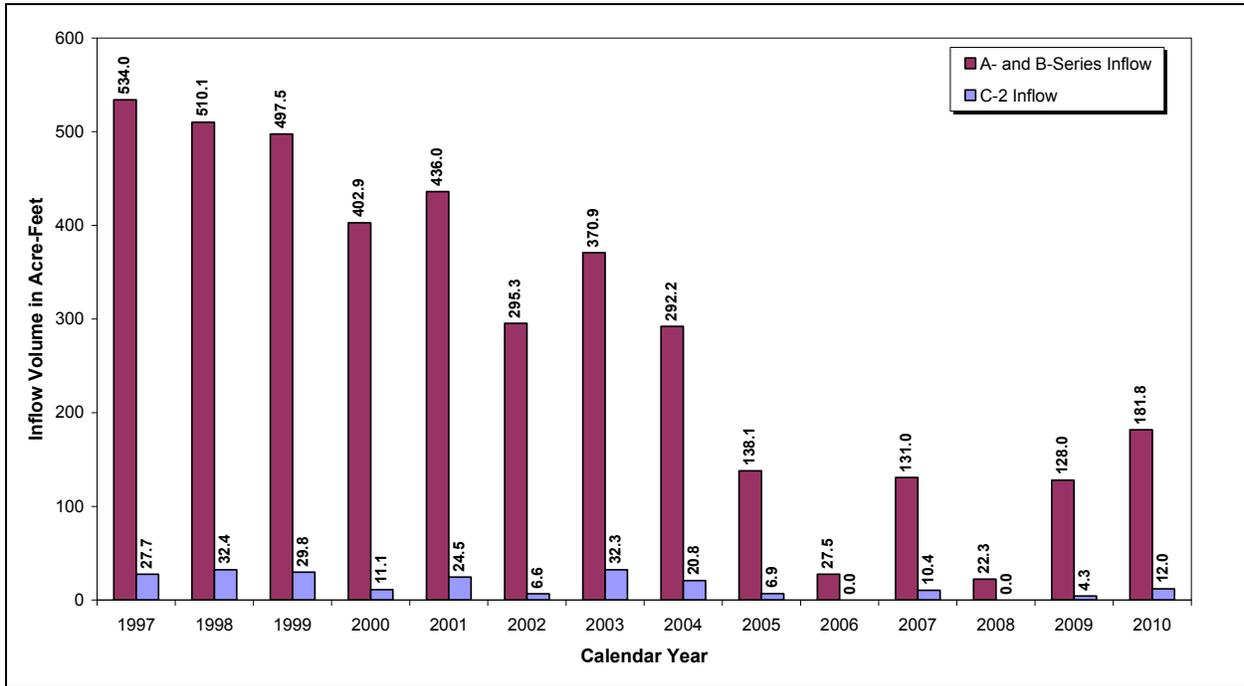
Figure 65. Map Showing Relative CY 1997–2010 Average Annual Discharge Volumes for POEs and POCs: Pre- and Post-Closure Periods

Pond Discharge Summary

Figure 66 and Figure 67 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 68 and Figure 69 show the relative total CY 1997–2010 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]).^{11, 12} 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.

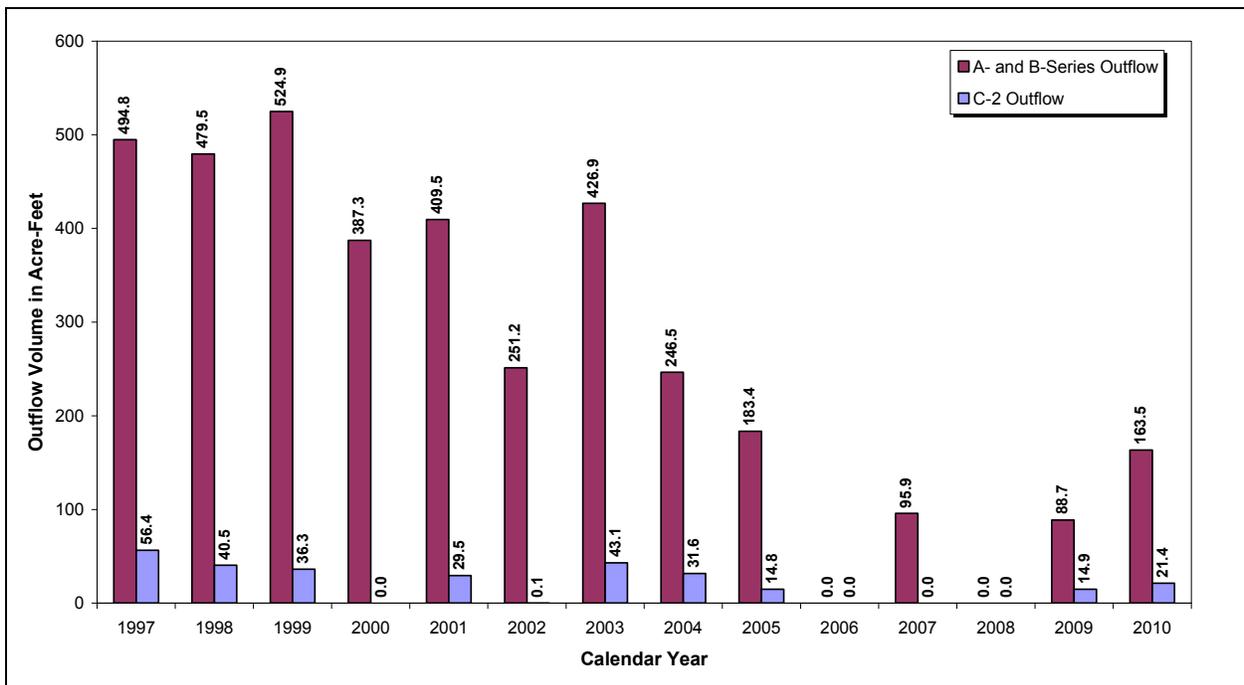
¹¹ The WWTP was removed from service on November 4, 2004.

¹² The pre-closure period is for the dates 1/1/97–10/1/05; the post-closure period is for the dates 10/1/05–12/31/10.



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 66. Pond Inflows: CY 1997–2010



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

Figure 67. Pond Outflows: CY 1997–2010

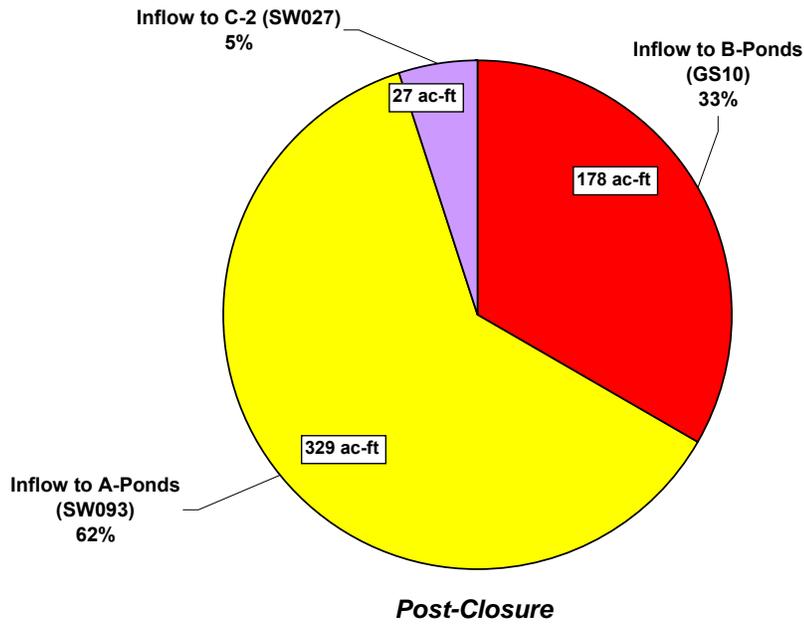
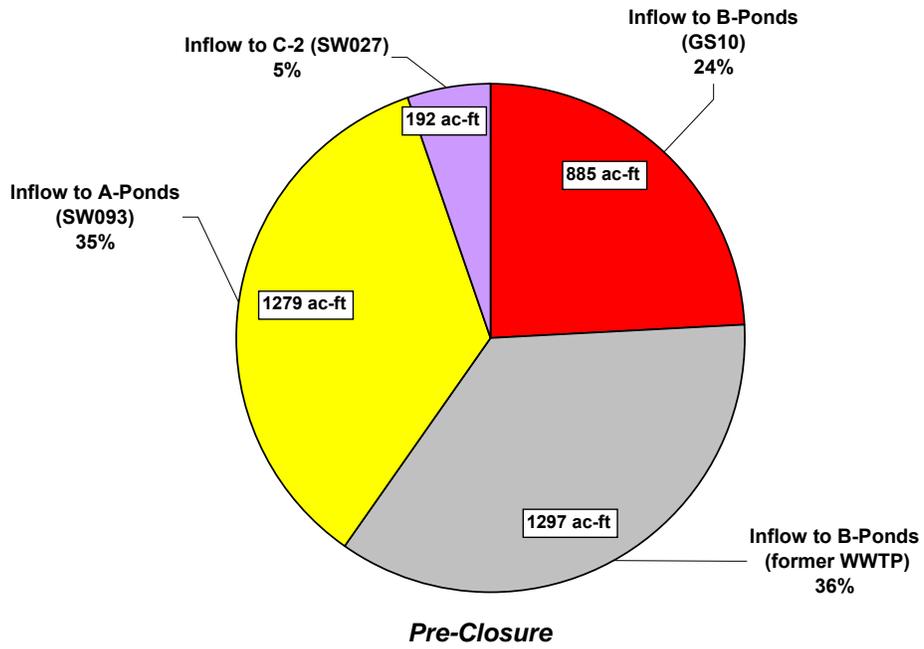


Figure 68. Relative Total Inflow Volumes for Site Ponds: Pre- and Post-Closure Periods

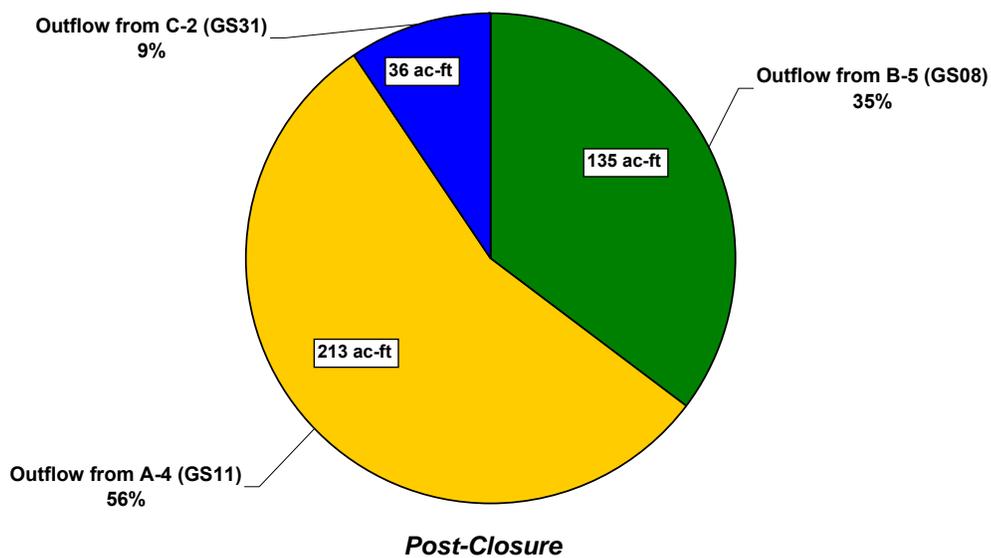
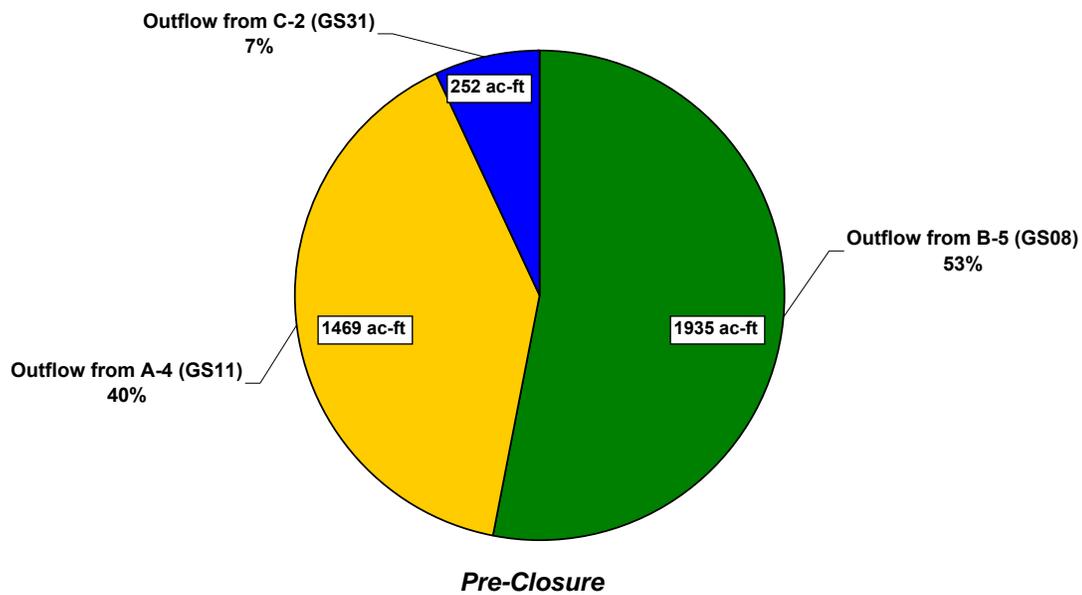


Figure 69. Relative Total Outflow Volumes for Site Ponds: Pre- and Post-Closure Periods

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.

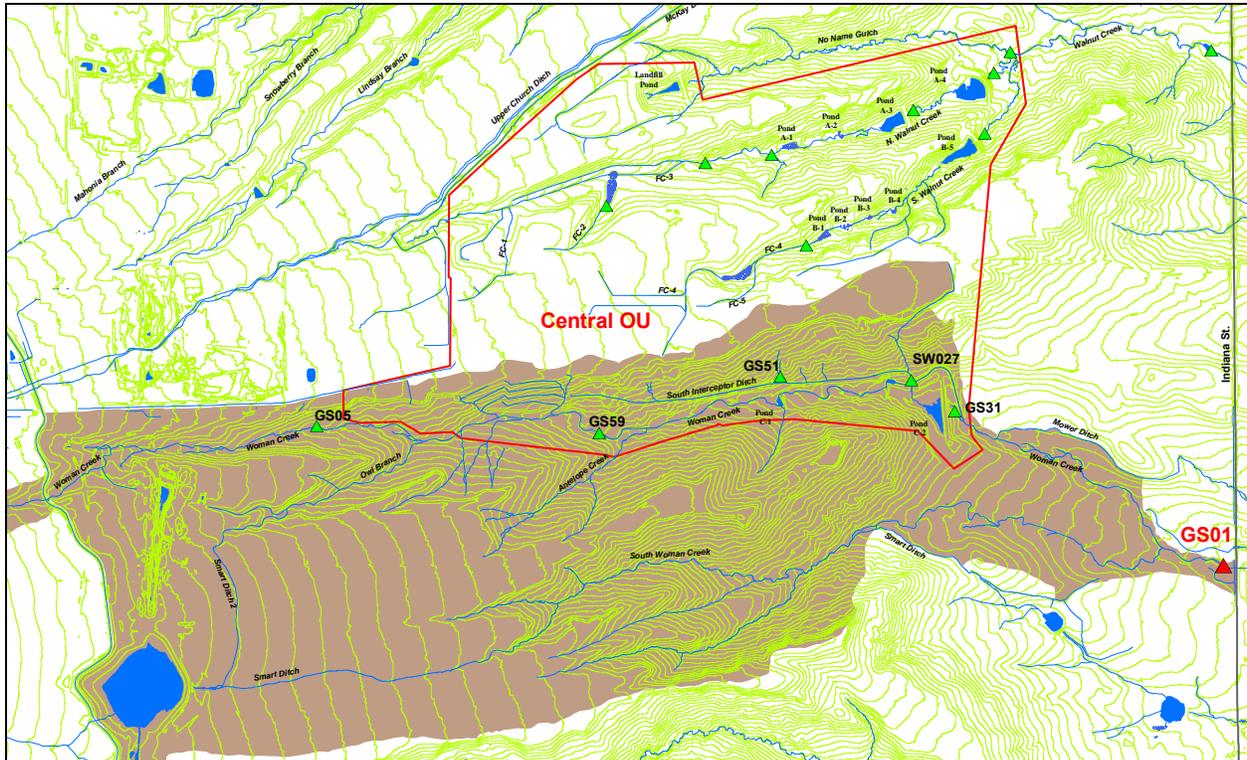


Figure 70. GS01 Drainage Area

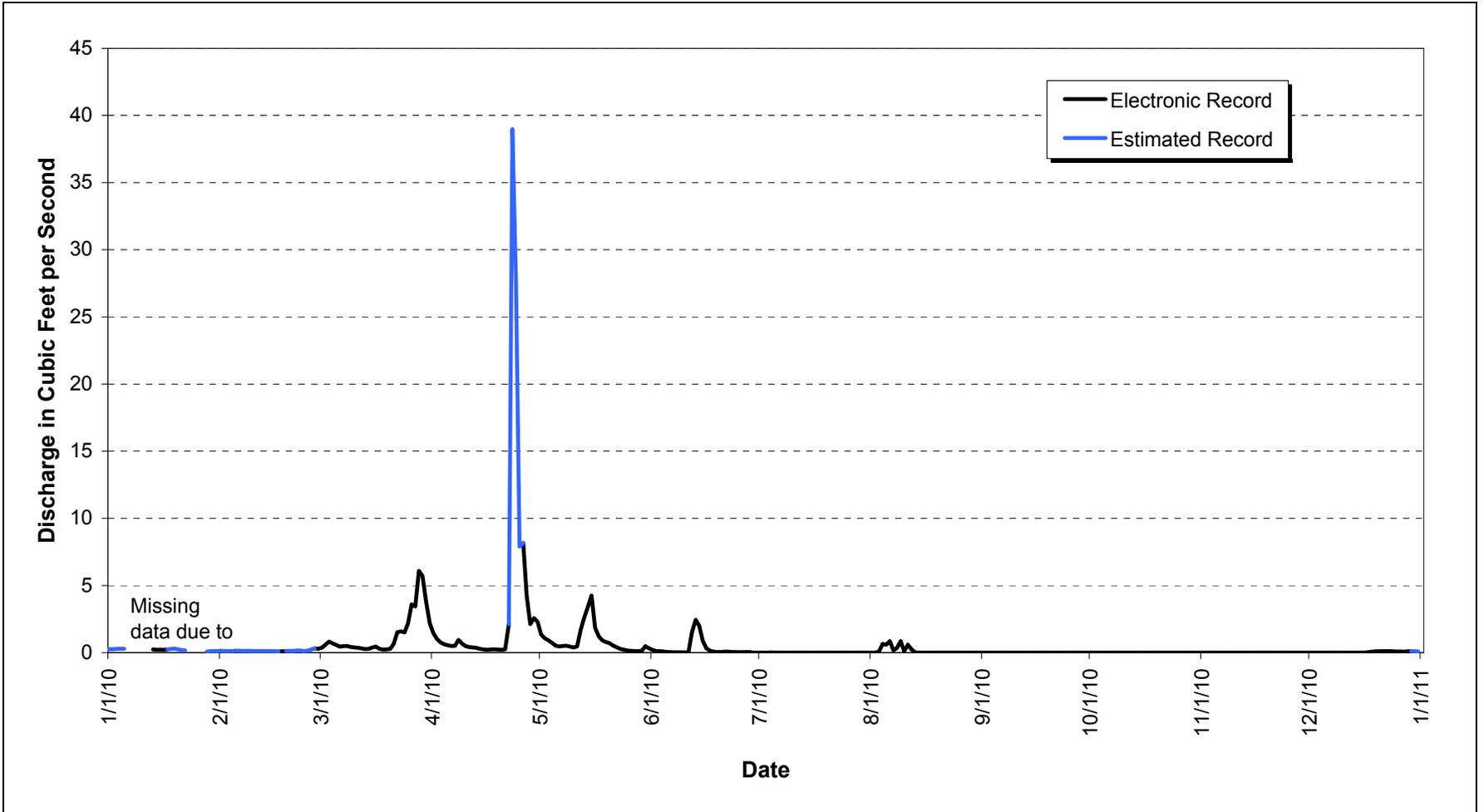


Figure 71. CY 2010 Mean Daily Hydrograph at GS01: Woman Creek at Indiana Street

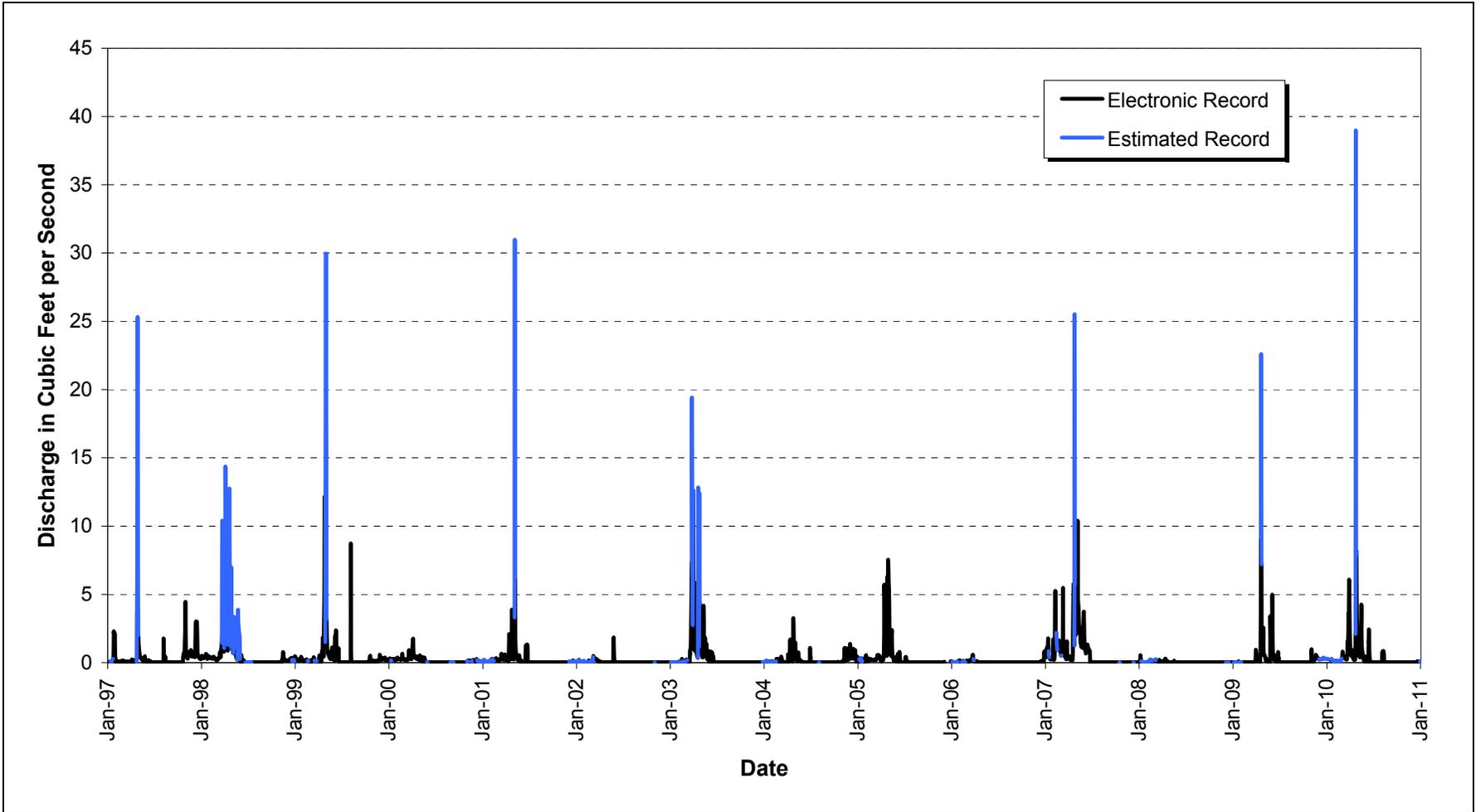


Figure 72. CY 1997–2010 Mean Daily Hydrograph at GS01: Woman Creek at Indiana Street

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.

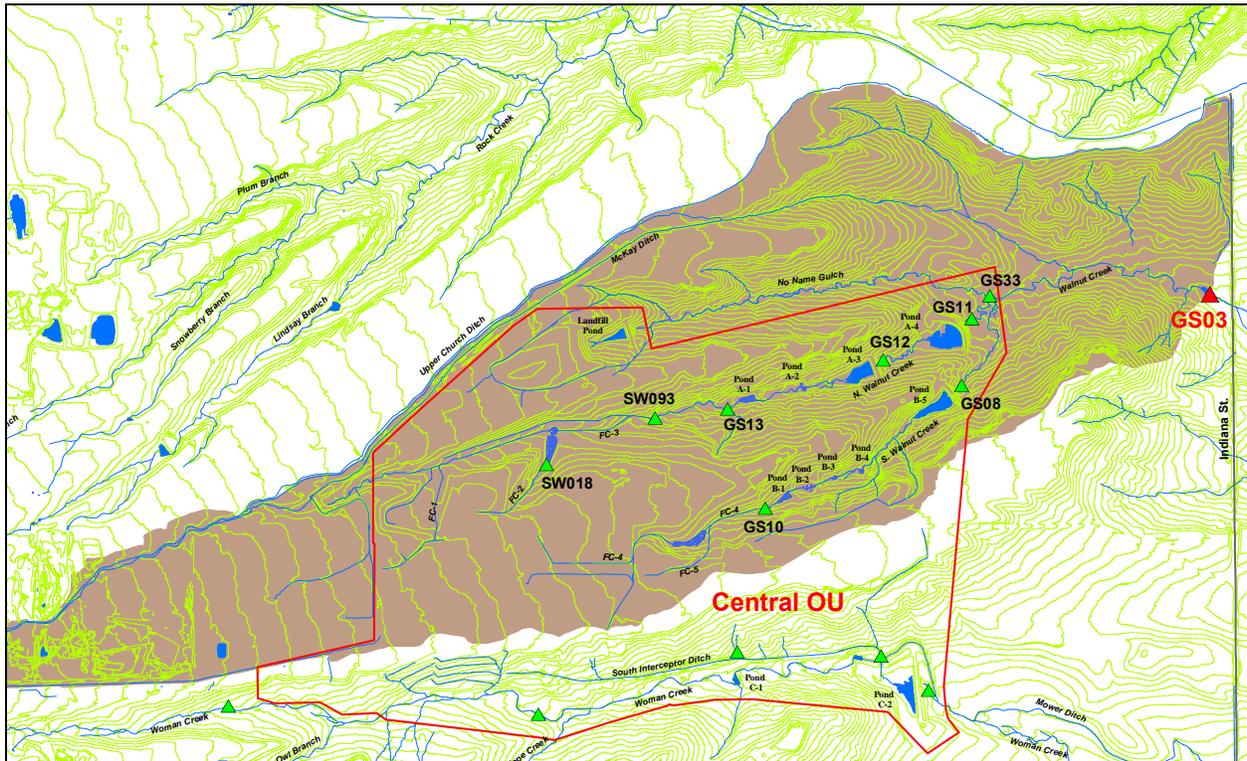


Figure 73. GS03 Drainage Area

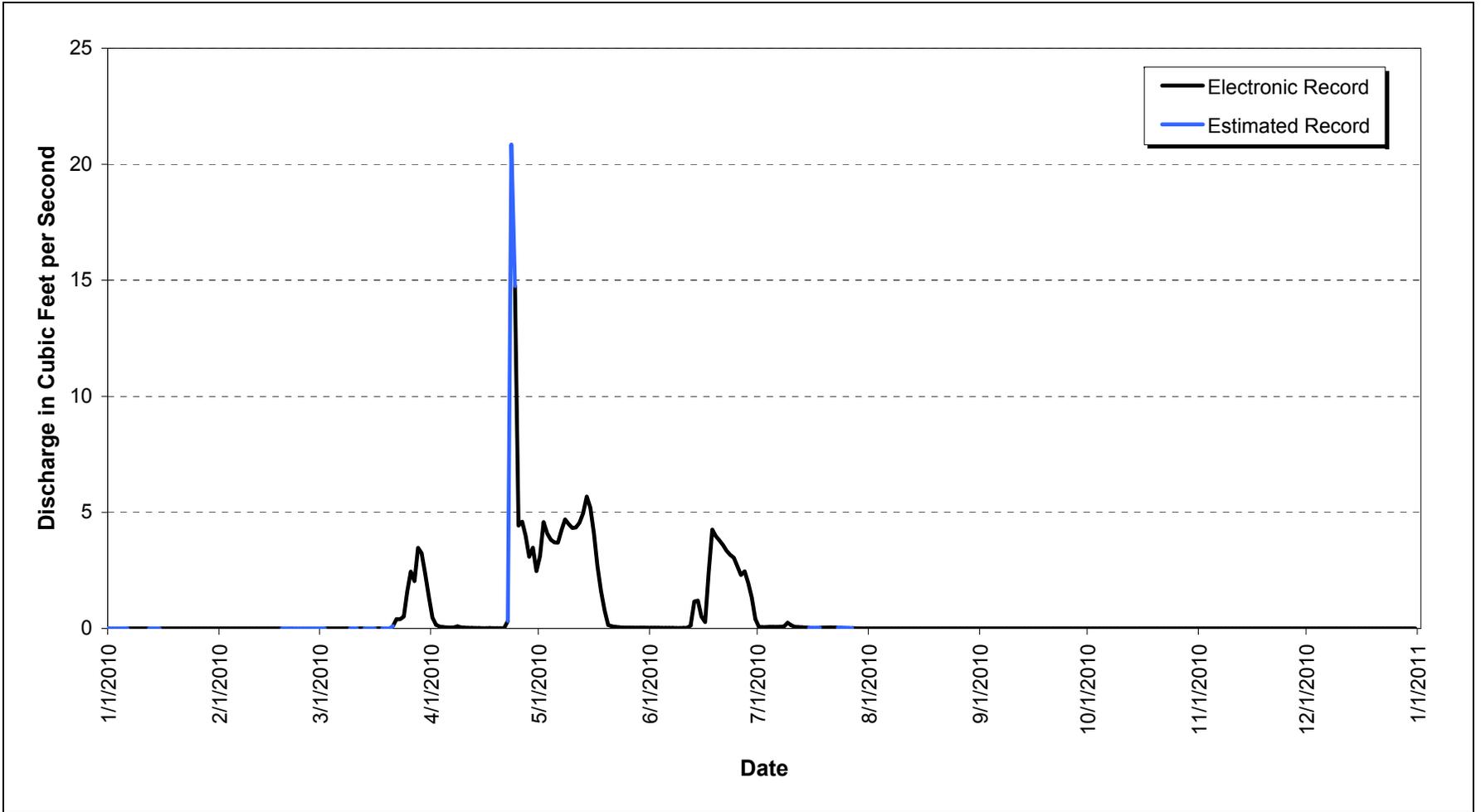


Figure 74. CY 2010 Mean Daily Hydrograph at GS03: Walnut Creek at Indiana Street

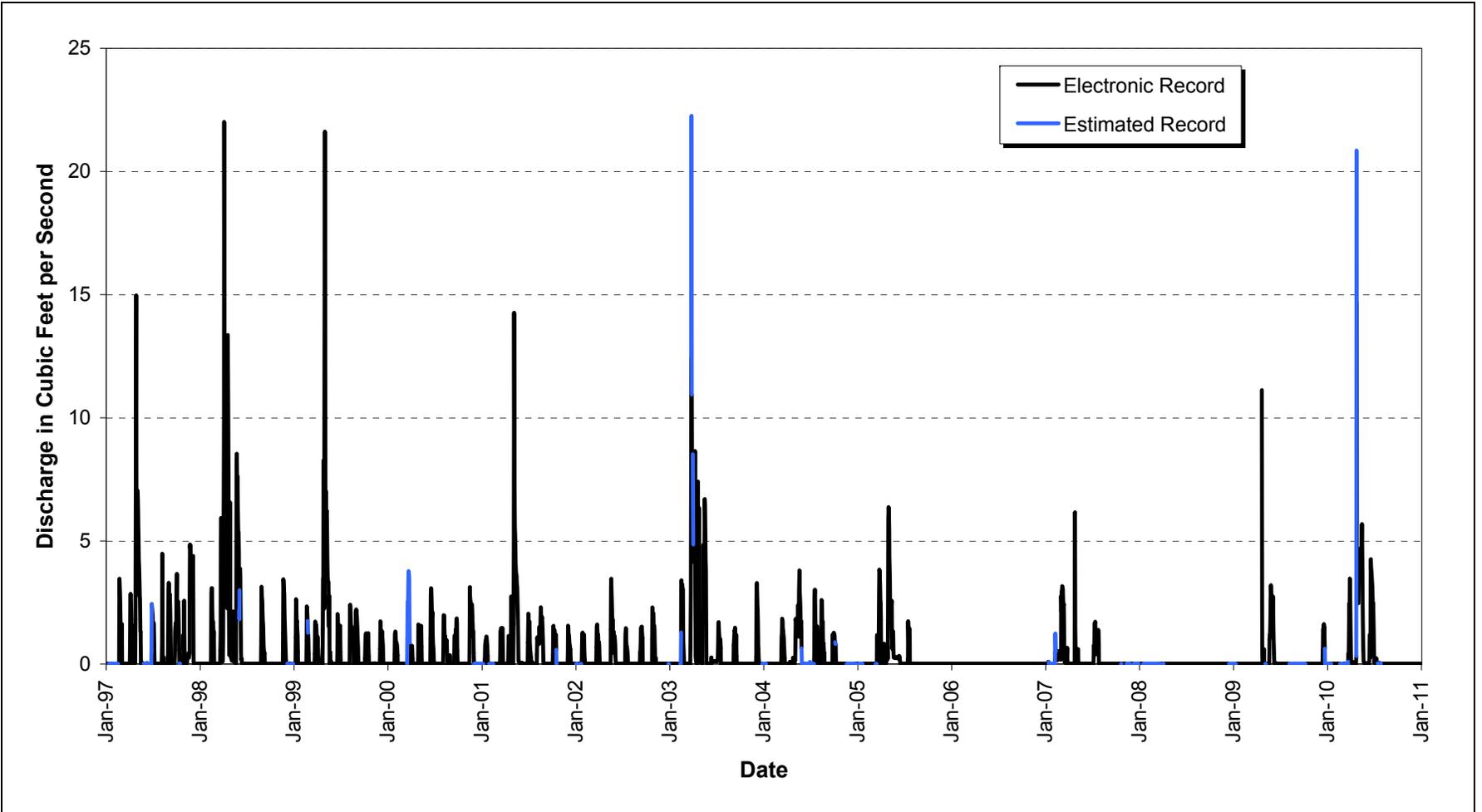


Figure 75. CY 1997–2010 Mean Daily Hydrograph at GS03: Walnut Creek at Indiana Street

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.

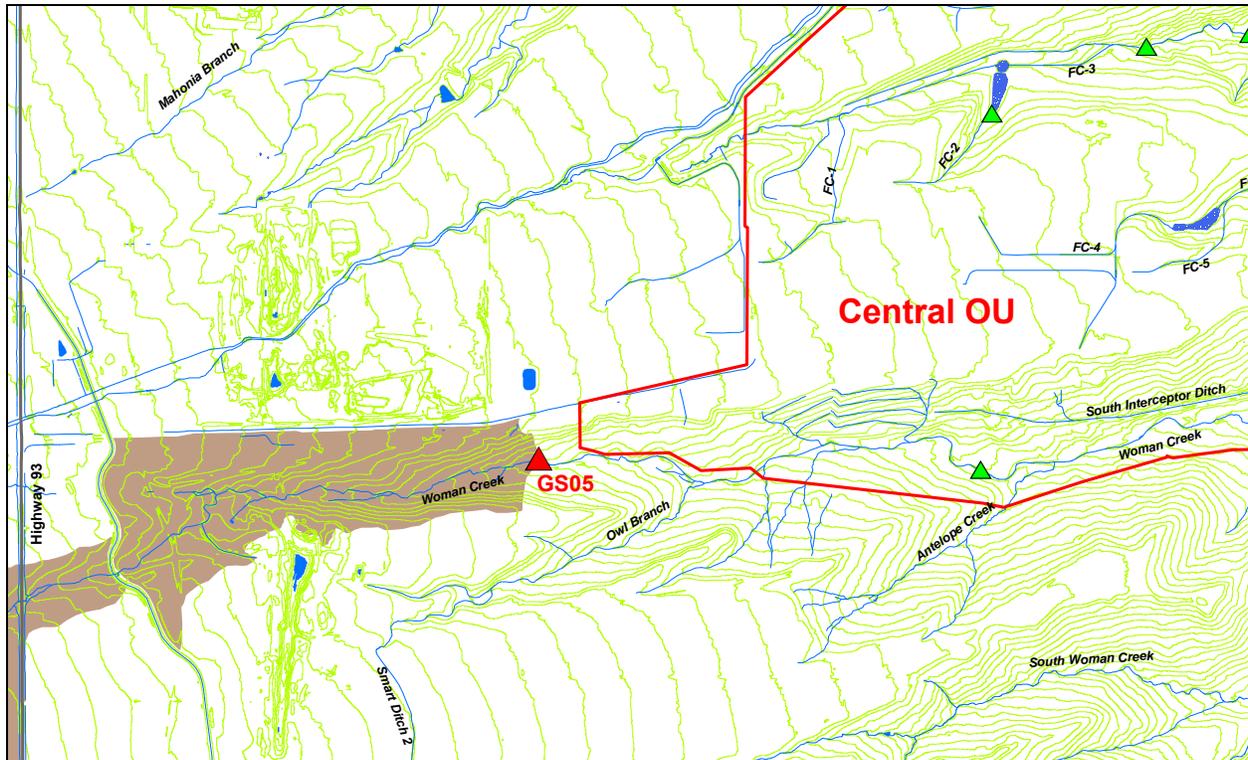


Figure 76. GS05 Drainage Area

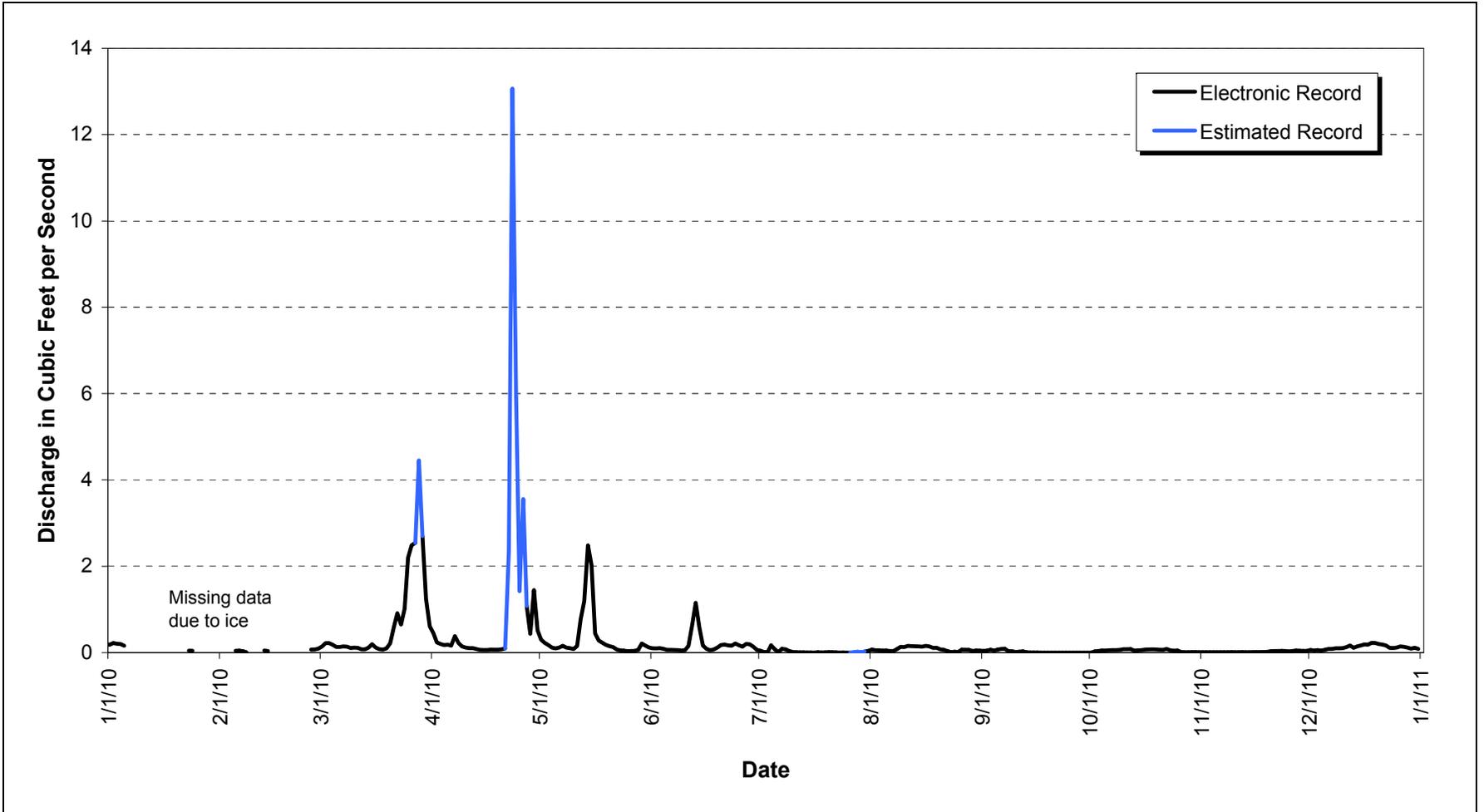


Figure 77. CY 2010 Mean Daily Hydrograph at GS05: North Woman Creek at West Fence Line

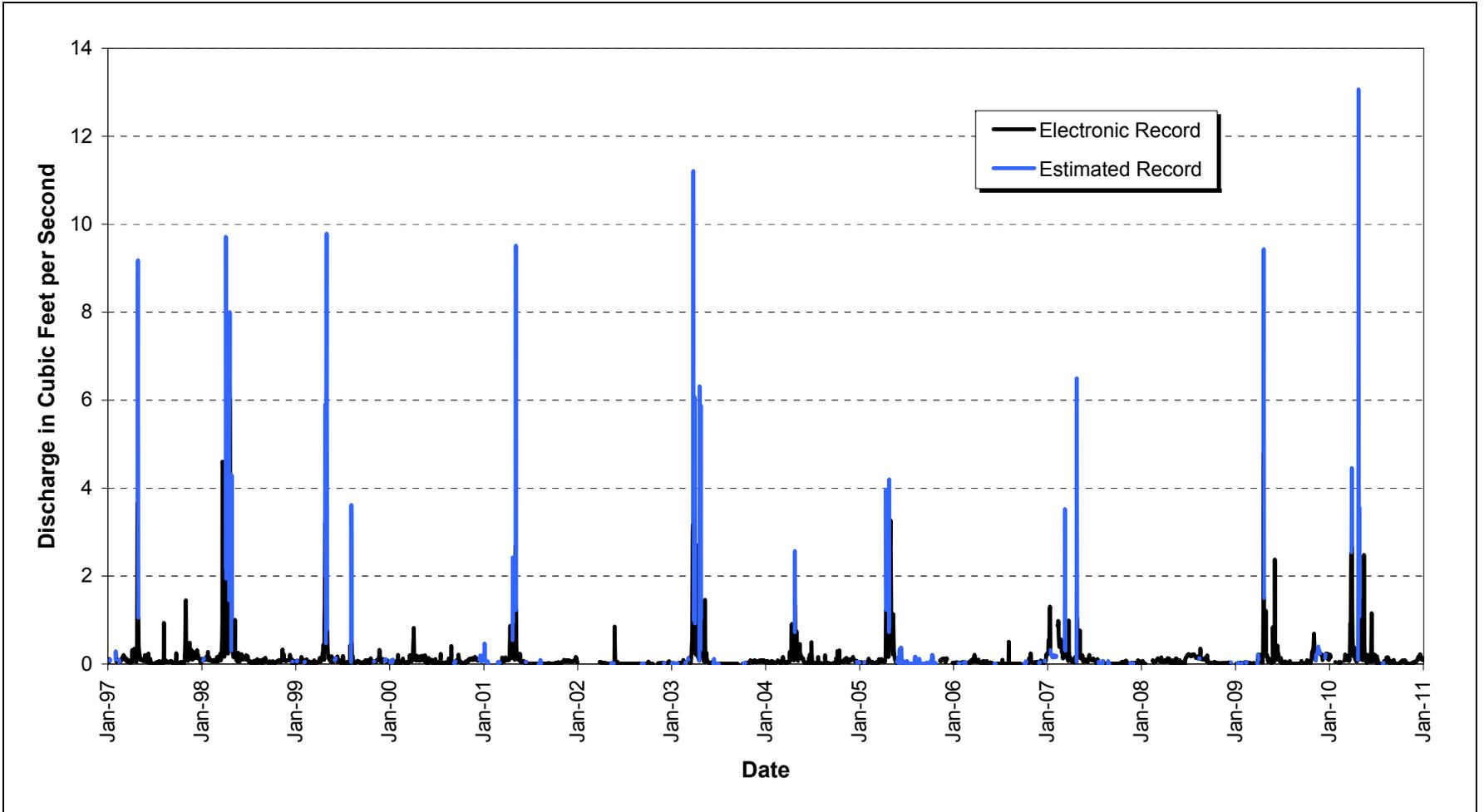


Figure 78. CY 1997–2010 Mean Daily Hydrograph at GS05: North Woman Creek at West Fence Line

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.

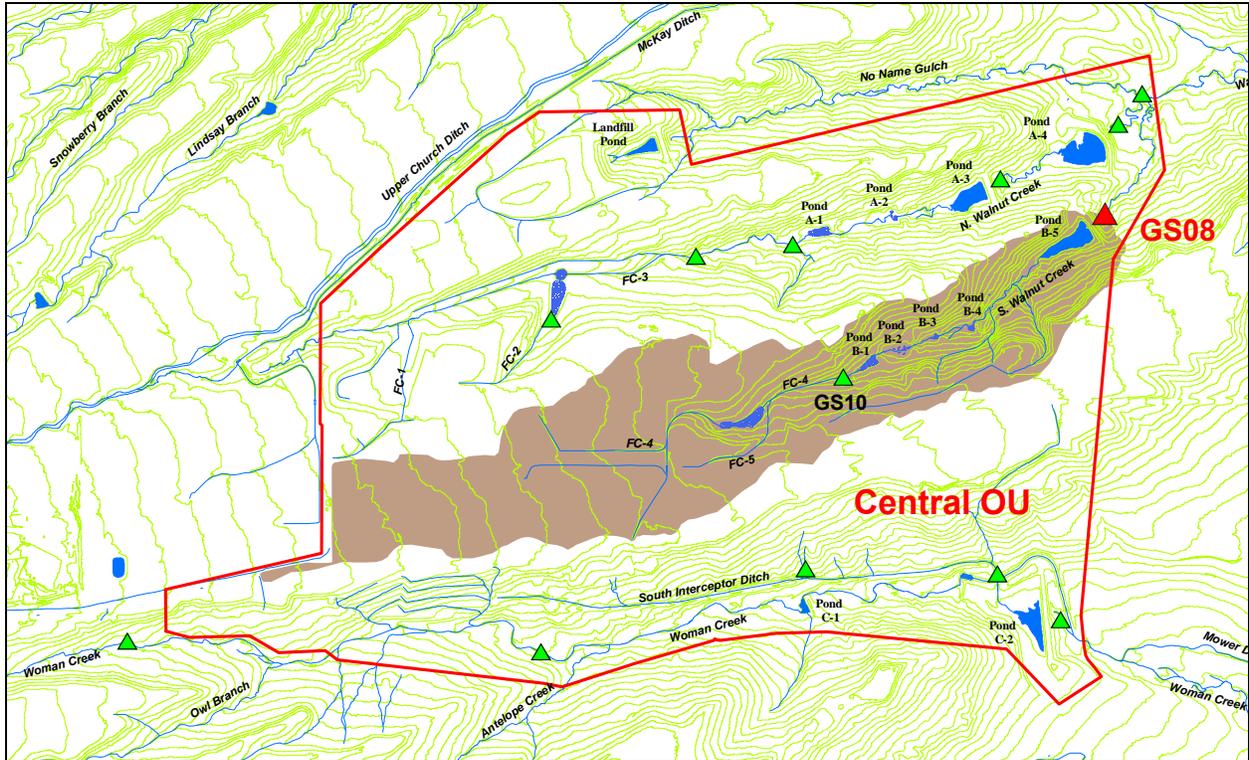


Figure 79. GS08 Drainage Area

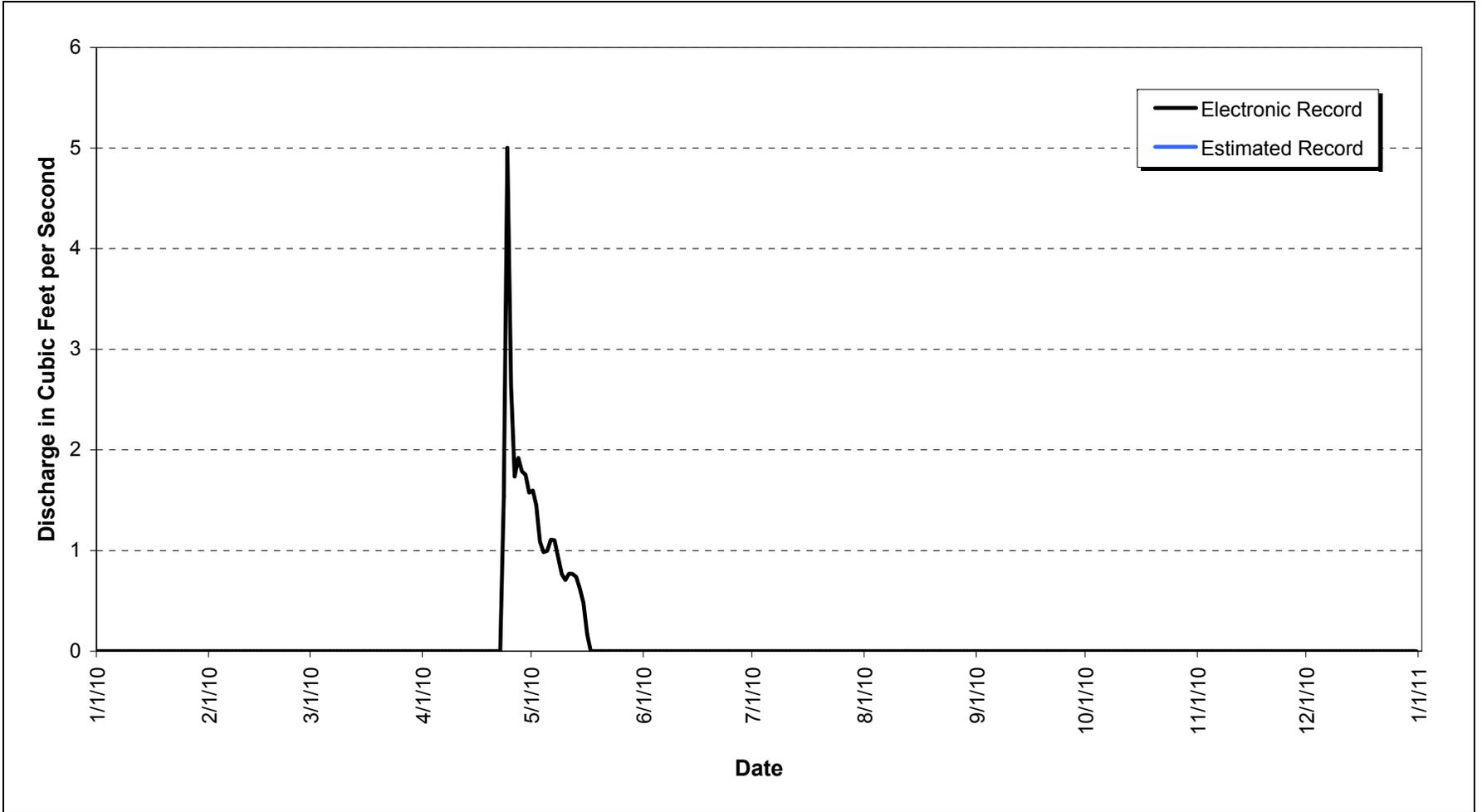


Figure 80. CY 2010 Mean Daily Hydrograph at GS08: South Walnut Creek at Pond B-5 Outlet

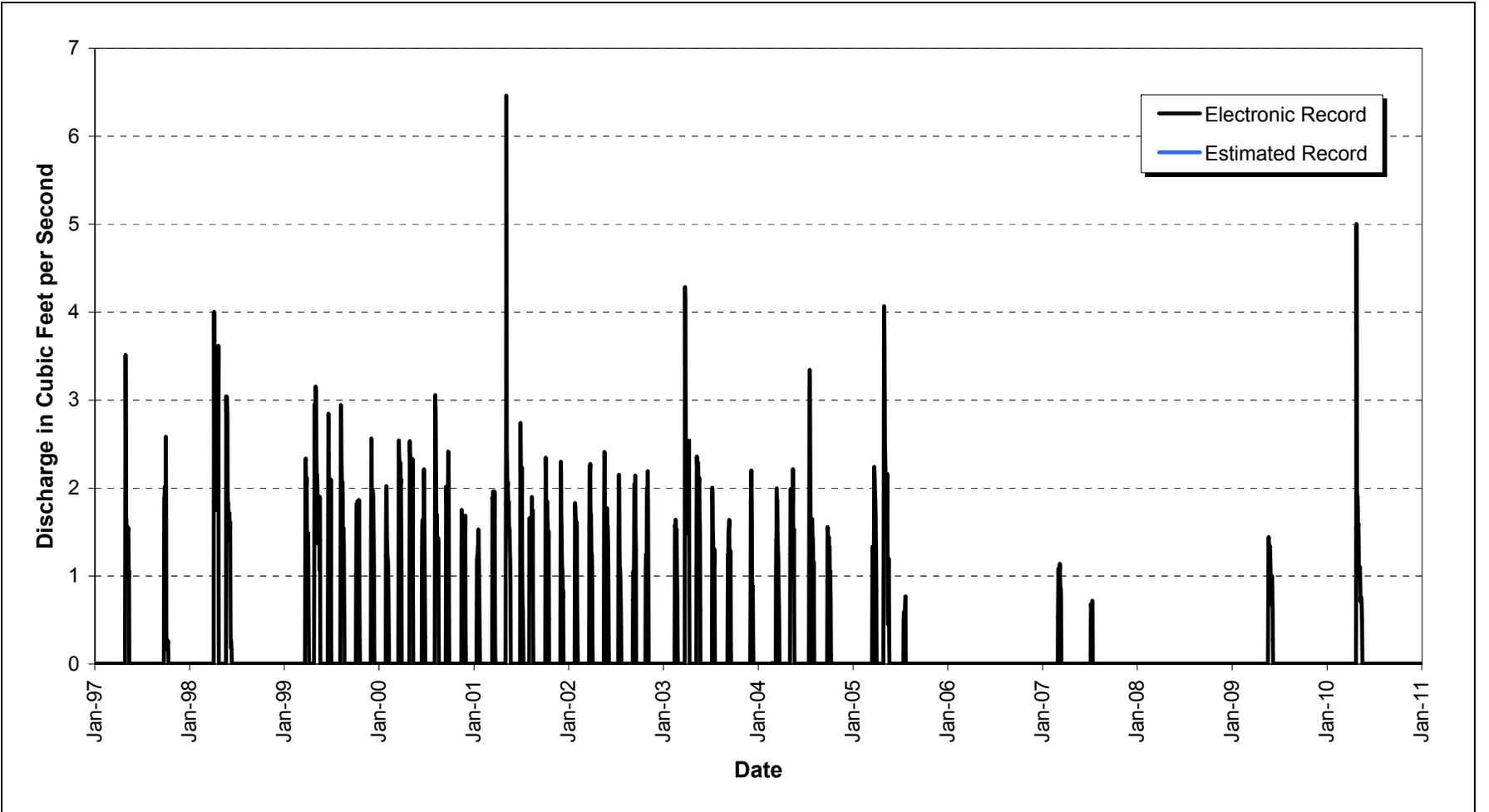


Figure 81. CY 1997–2010 Mean Daily Hydrograph at GS08: South Walnut Creek at Pond B-5 Outlet

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.

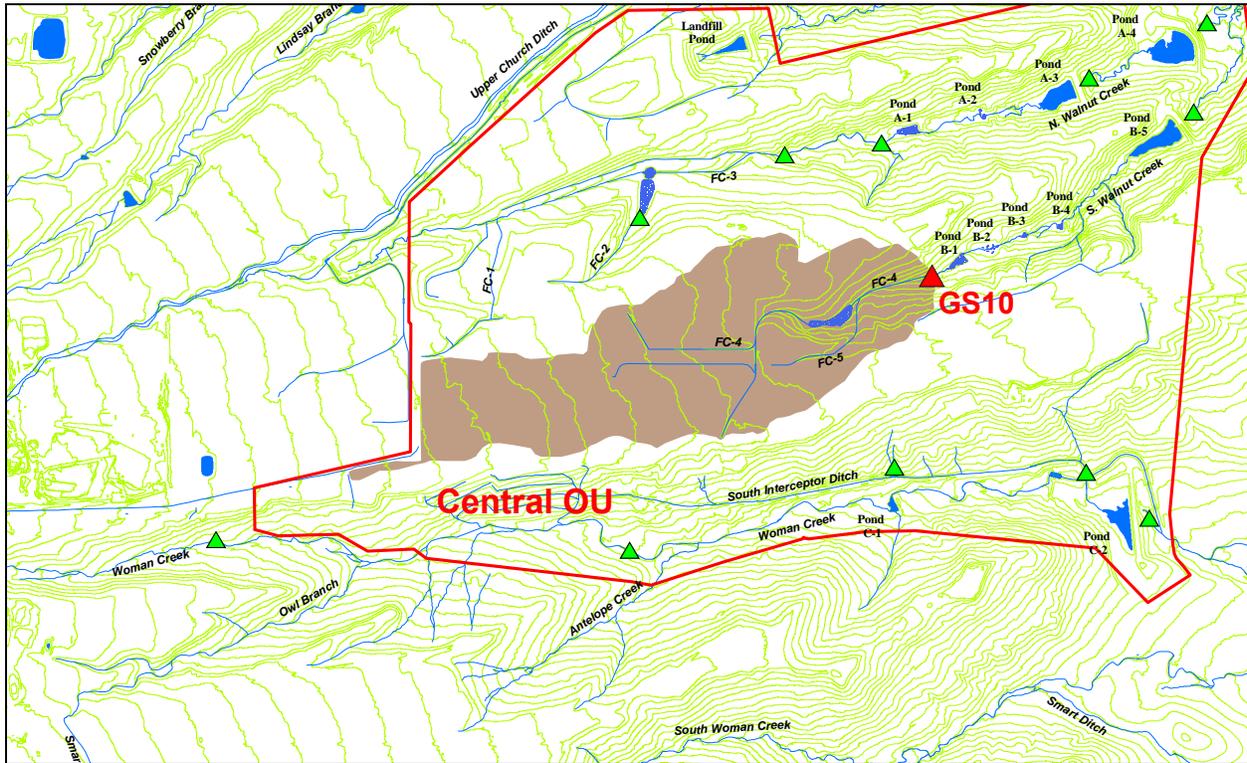


Figure 82. GS10 Drainage Area

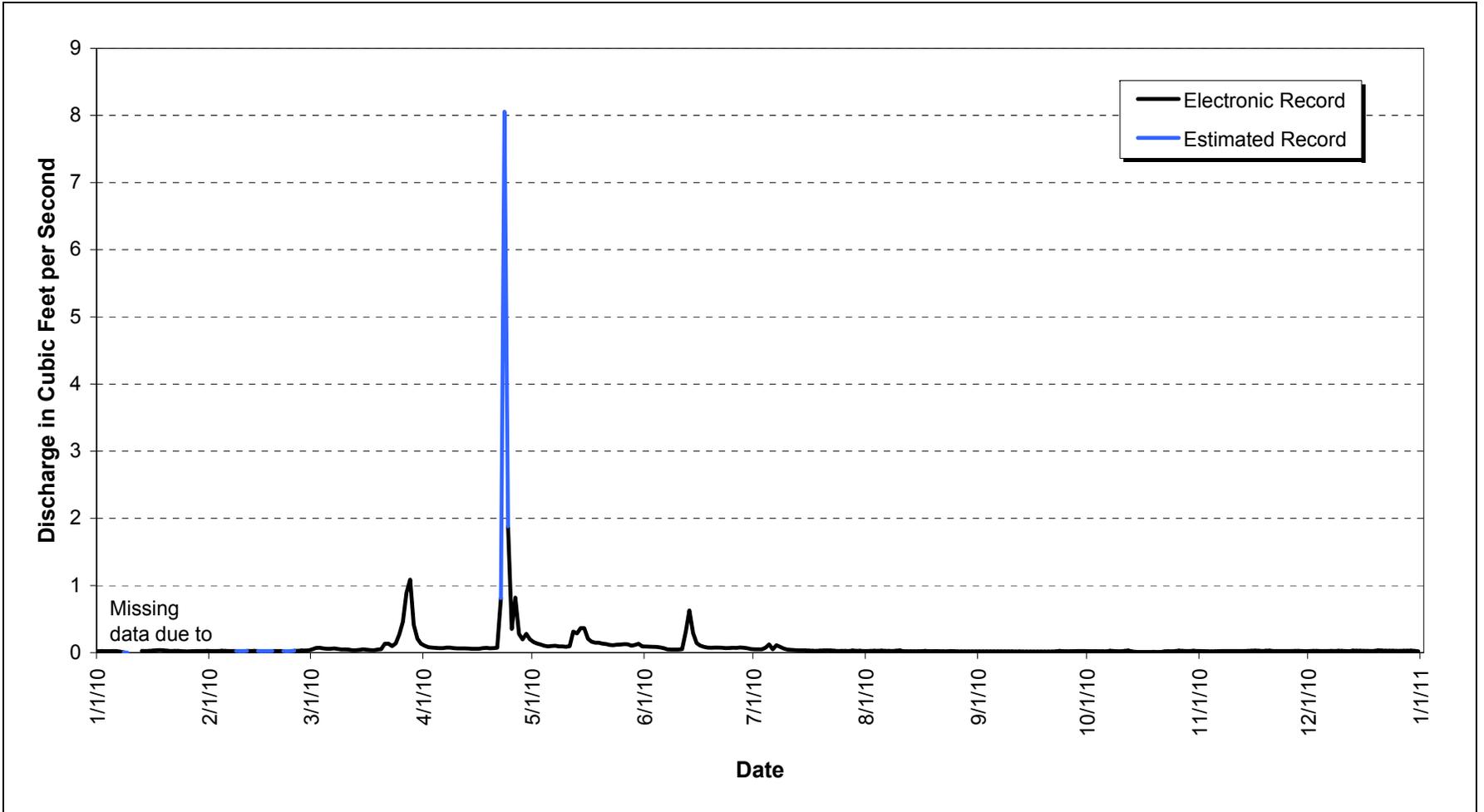


Figure 83. CY 2010 Mean Daily Hydrograph at GS10: South Walnut Creek at Pond B-1

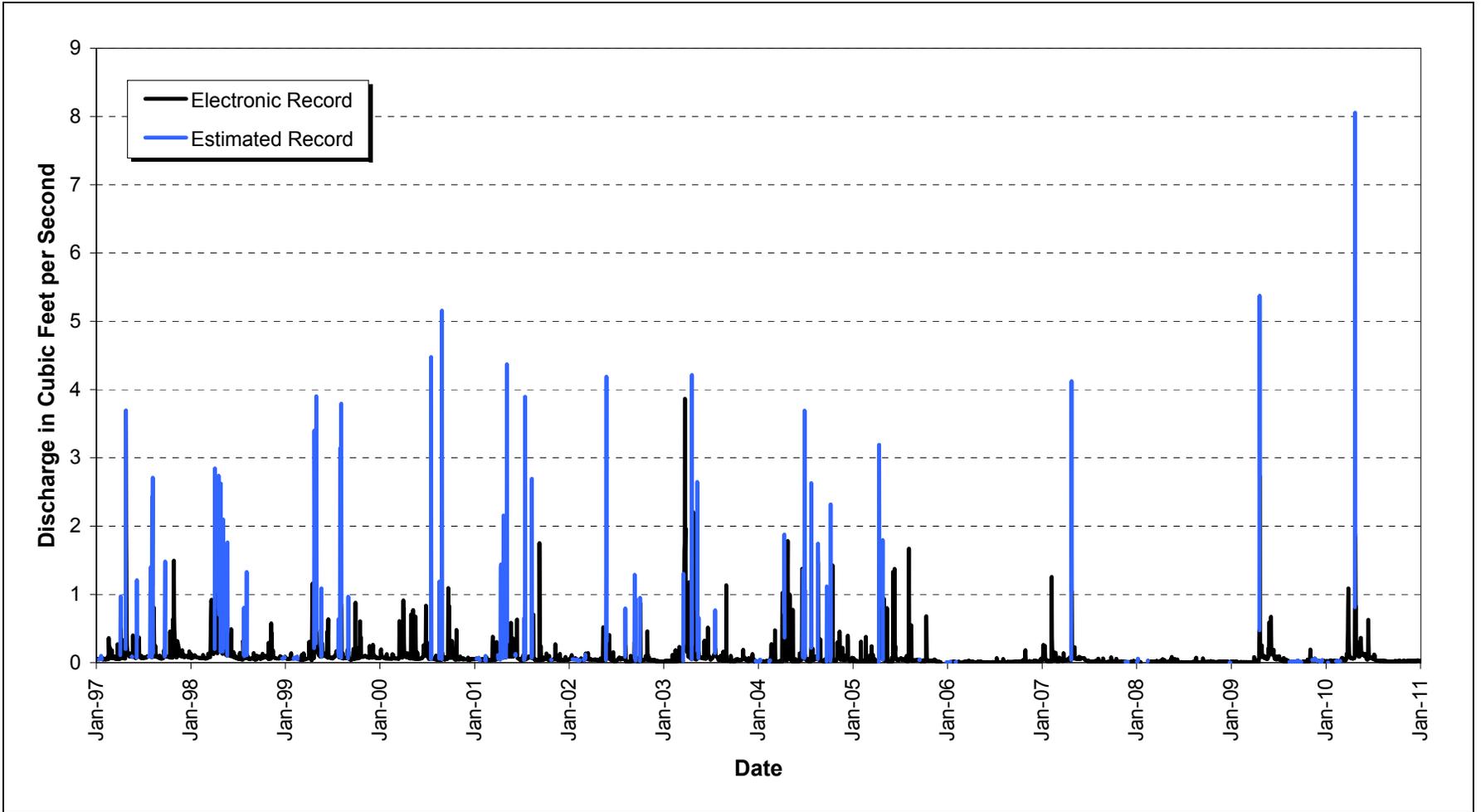


Figure 84. CY 1997–2010 Mean Daily Hydrograph at GS10: South Walnut Creek at Pond B-1

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.

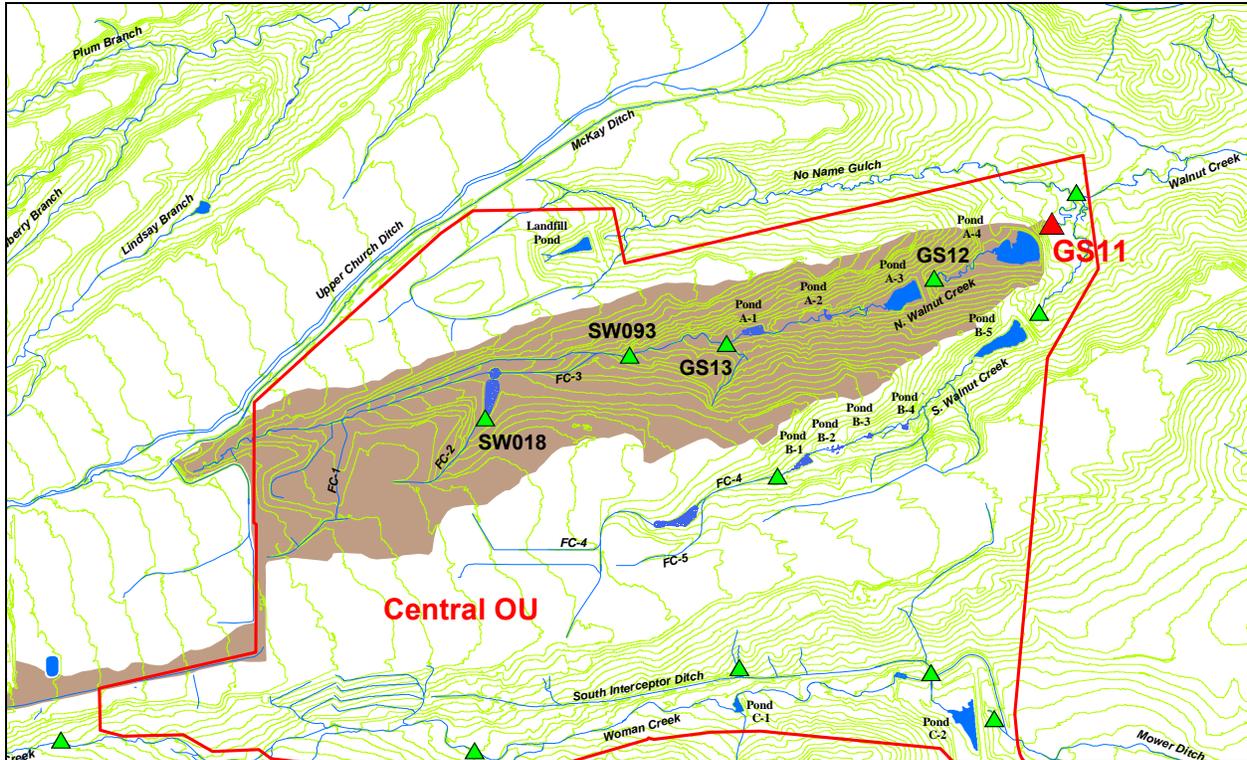


Figure 85. GS11 Drainage Area

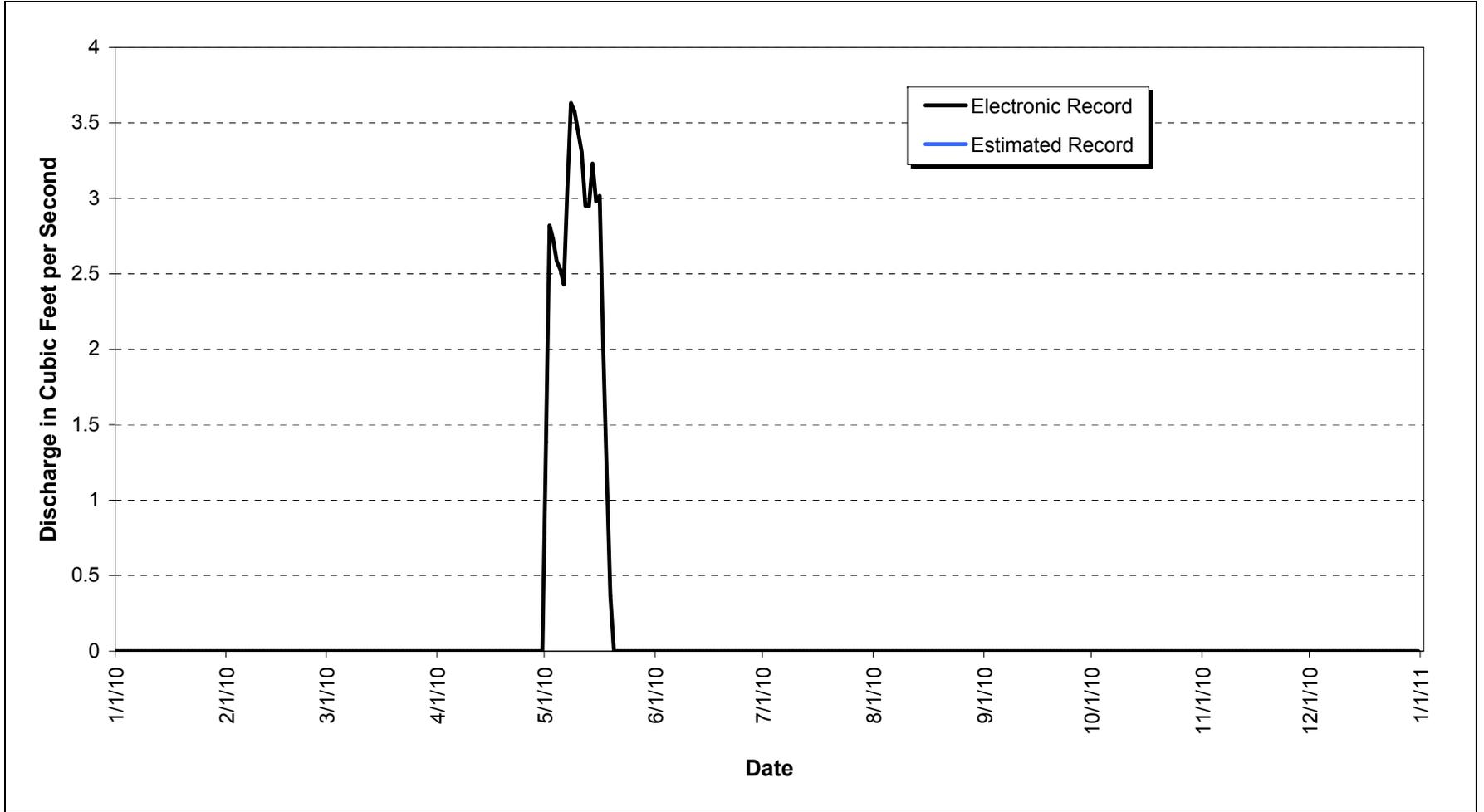


Figure 86. CY 2010 Mean Daily Hydrograph at GS11: North Walnut Creek at Pond A-4 Outlet

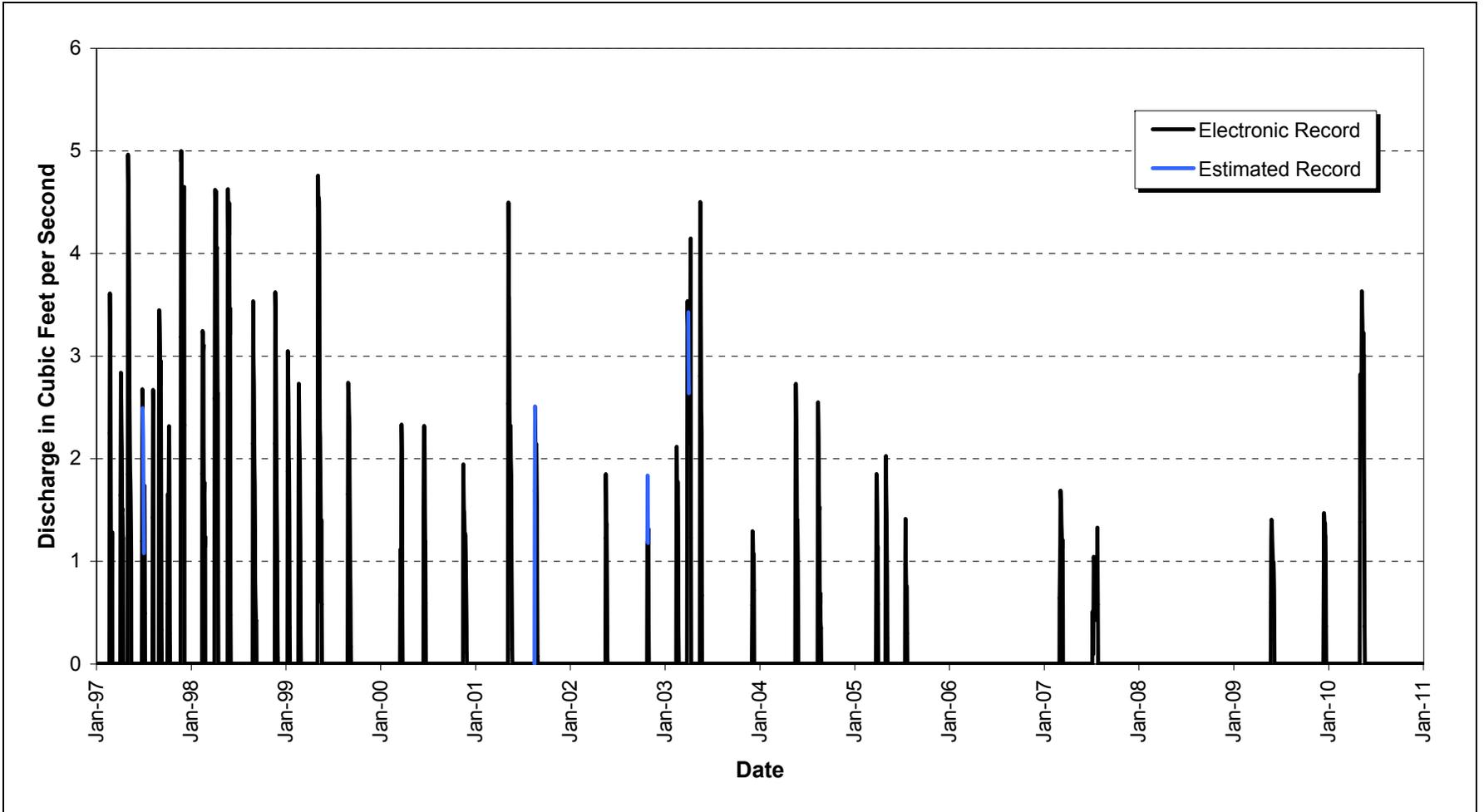


Figure 87. CY 1997–2010 Mean Daily Hydrograph at GS11: North Walnut Creek at Pond A-4 Outlet

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.

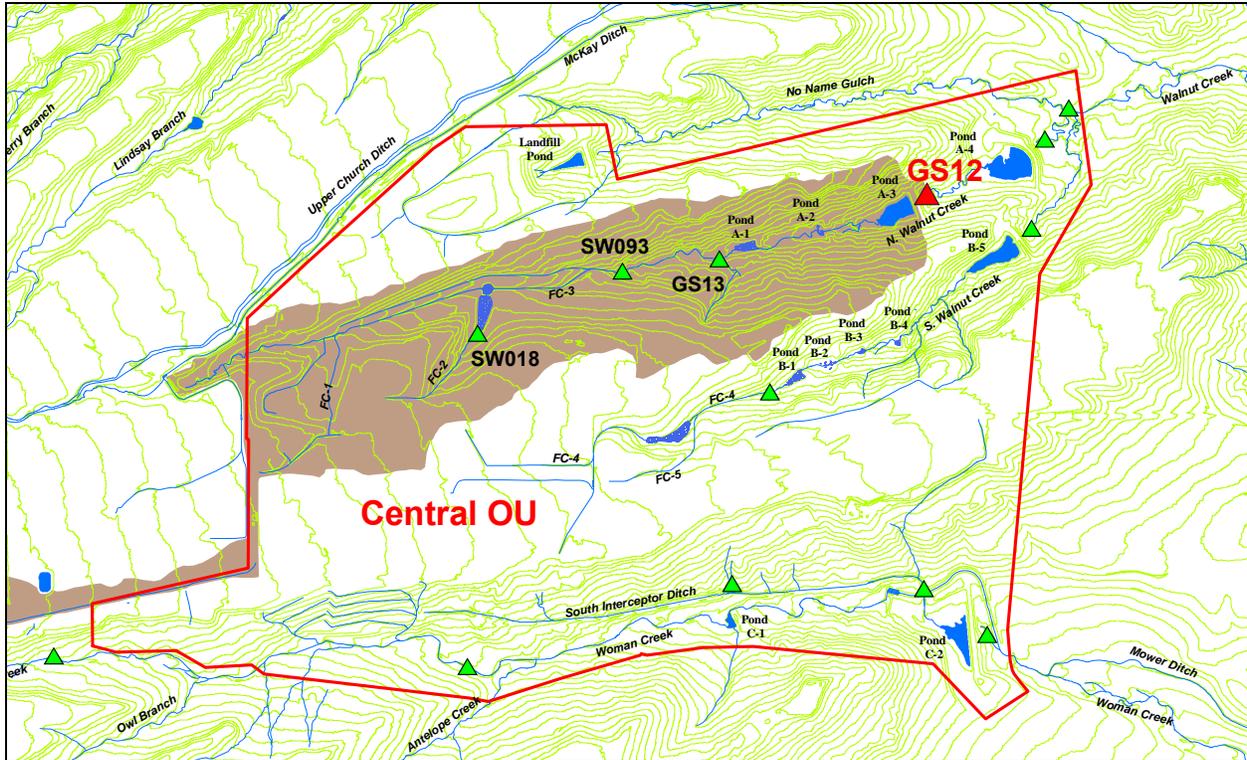


Figure 88. GS12 Drainage Area

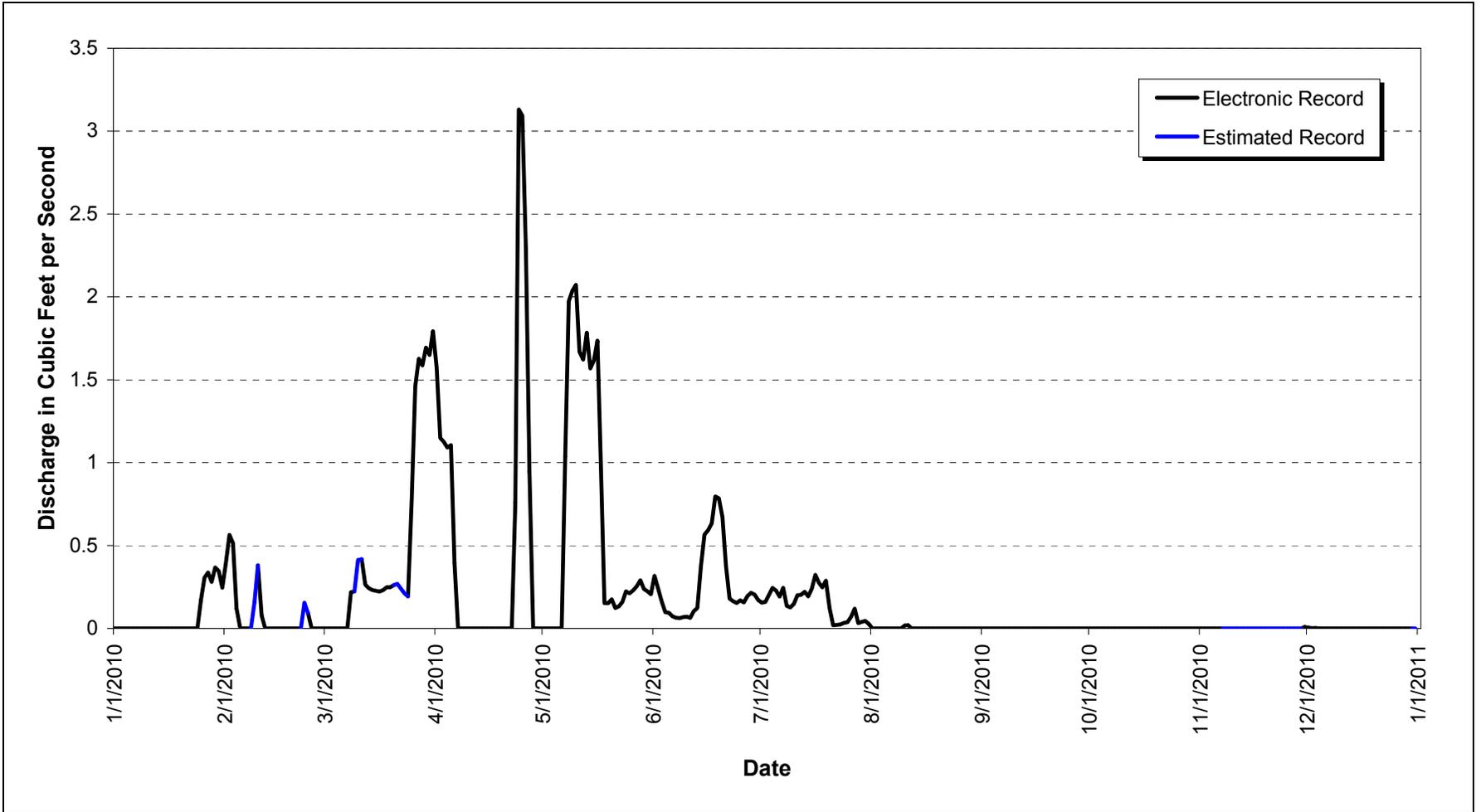


Figure 89. CY 2010 Mean Daily Hydrograph at GS12: North Walnut Creek at Pond A-3 Outlet

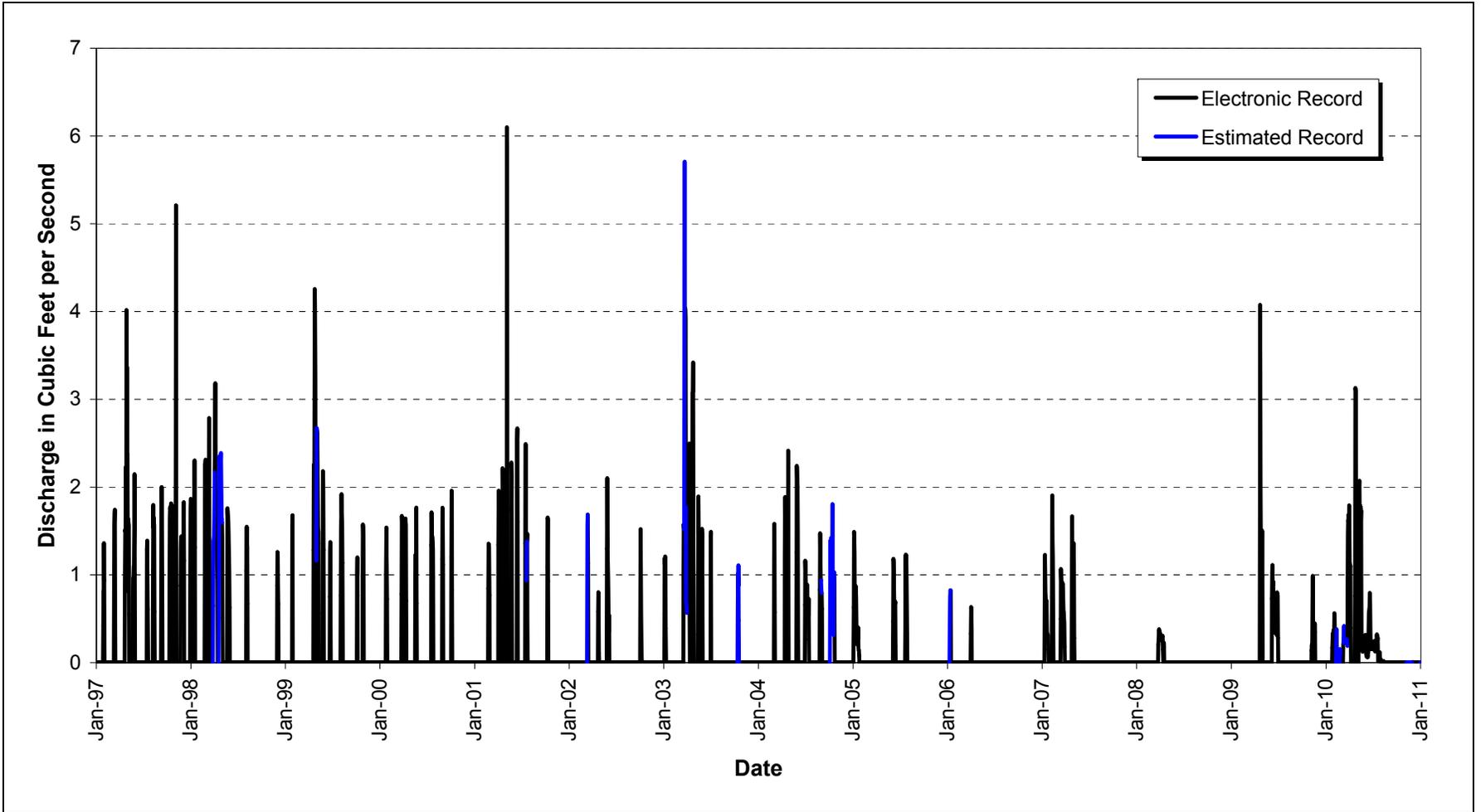


Figure 90. CY 1997–2010 Mean Daily Hydrograph at GS12: North Walnut Creek at Pond A-3 Outlet

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.

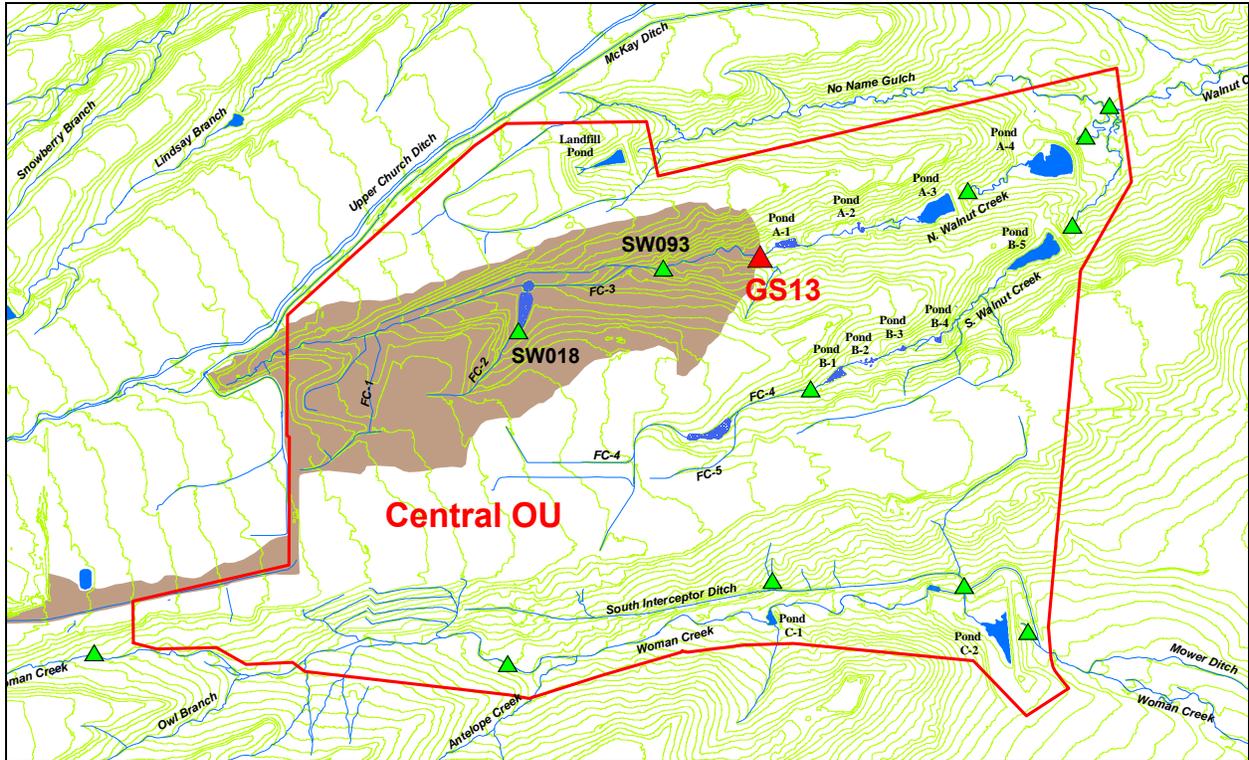


Figure 91. GS13 Drainage Area

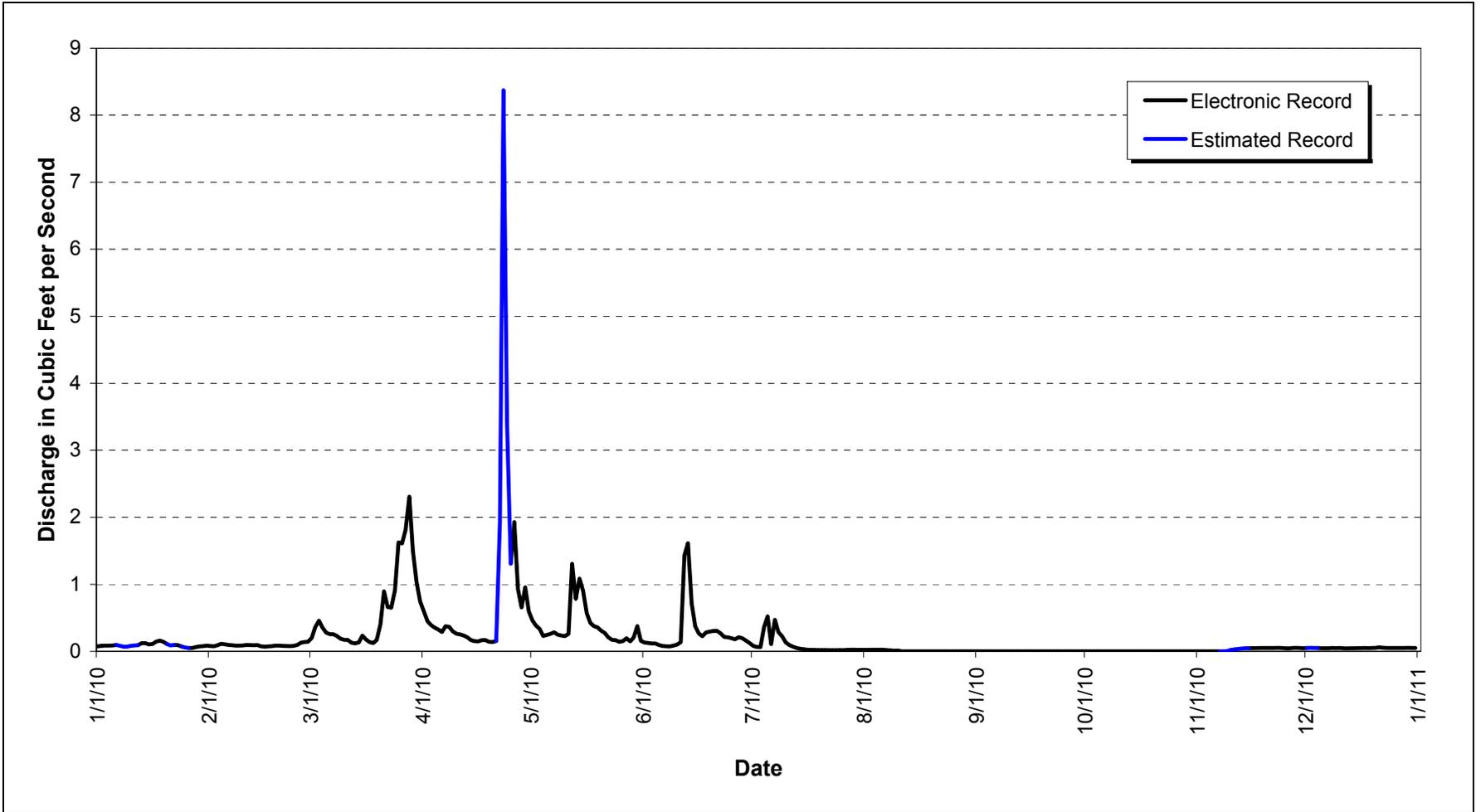


Figure 92. CY 2010 Mean Daily Hydrograph at GS13: North Walnut Creek at Pond A-1 Bypass

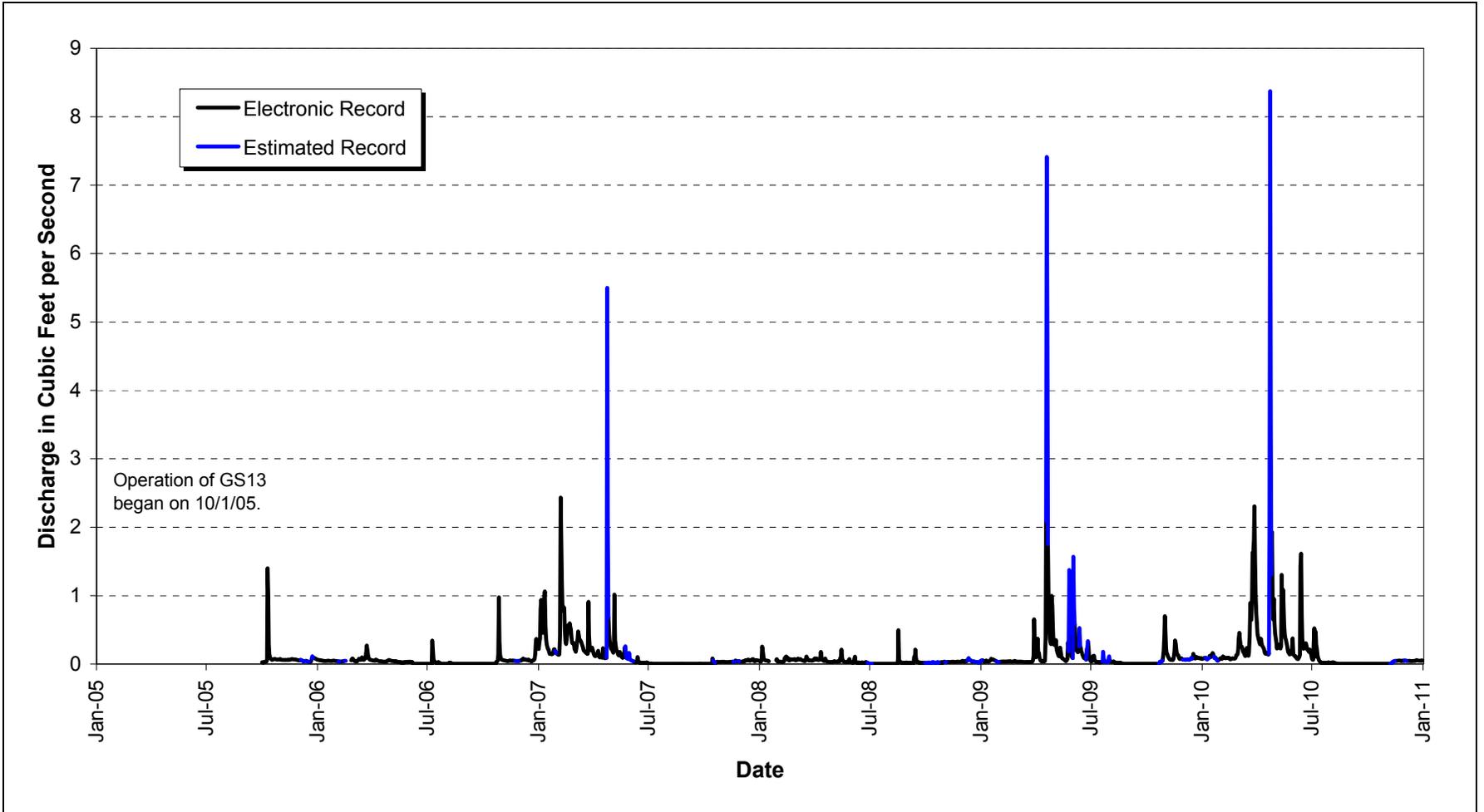


Figure 93. CY 2005–2010 Mean Daily Hydrograph at GS13: North Walnut Creek at Pond A-1 Bypass

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.

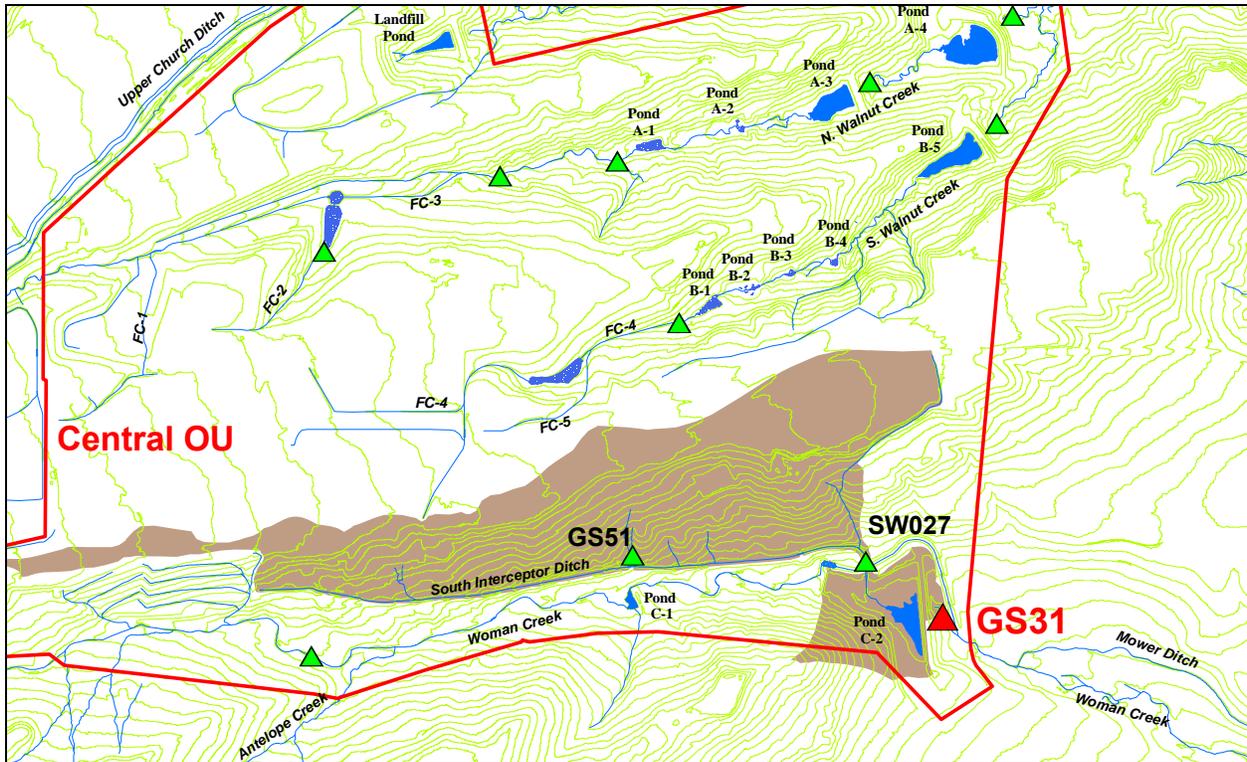


Figure 94. GS31 Drainage Area

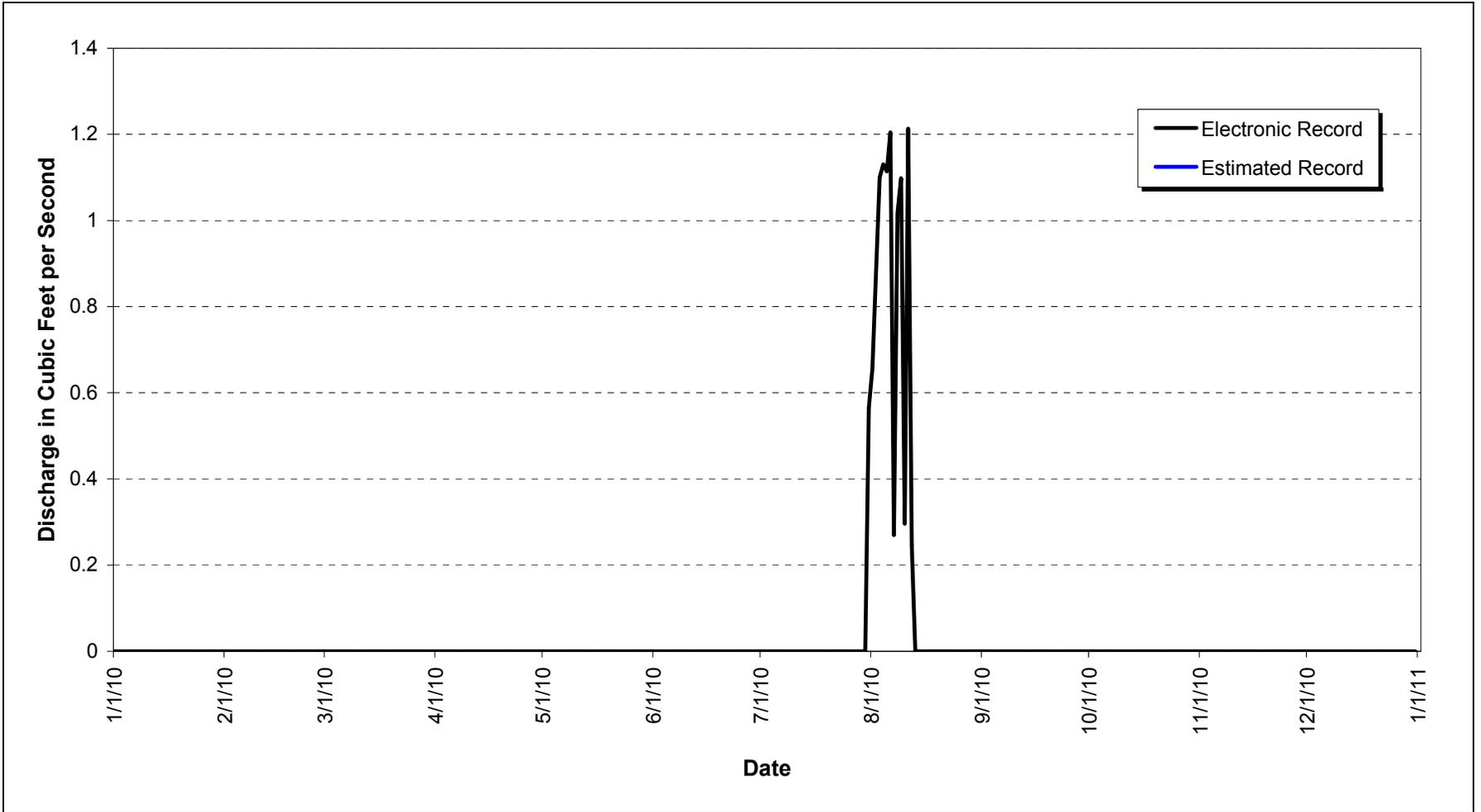


Figure 95. CY 2010 Mean Daily Hydrograph at GS31: Woman Creek at Pond C-2 Outlet

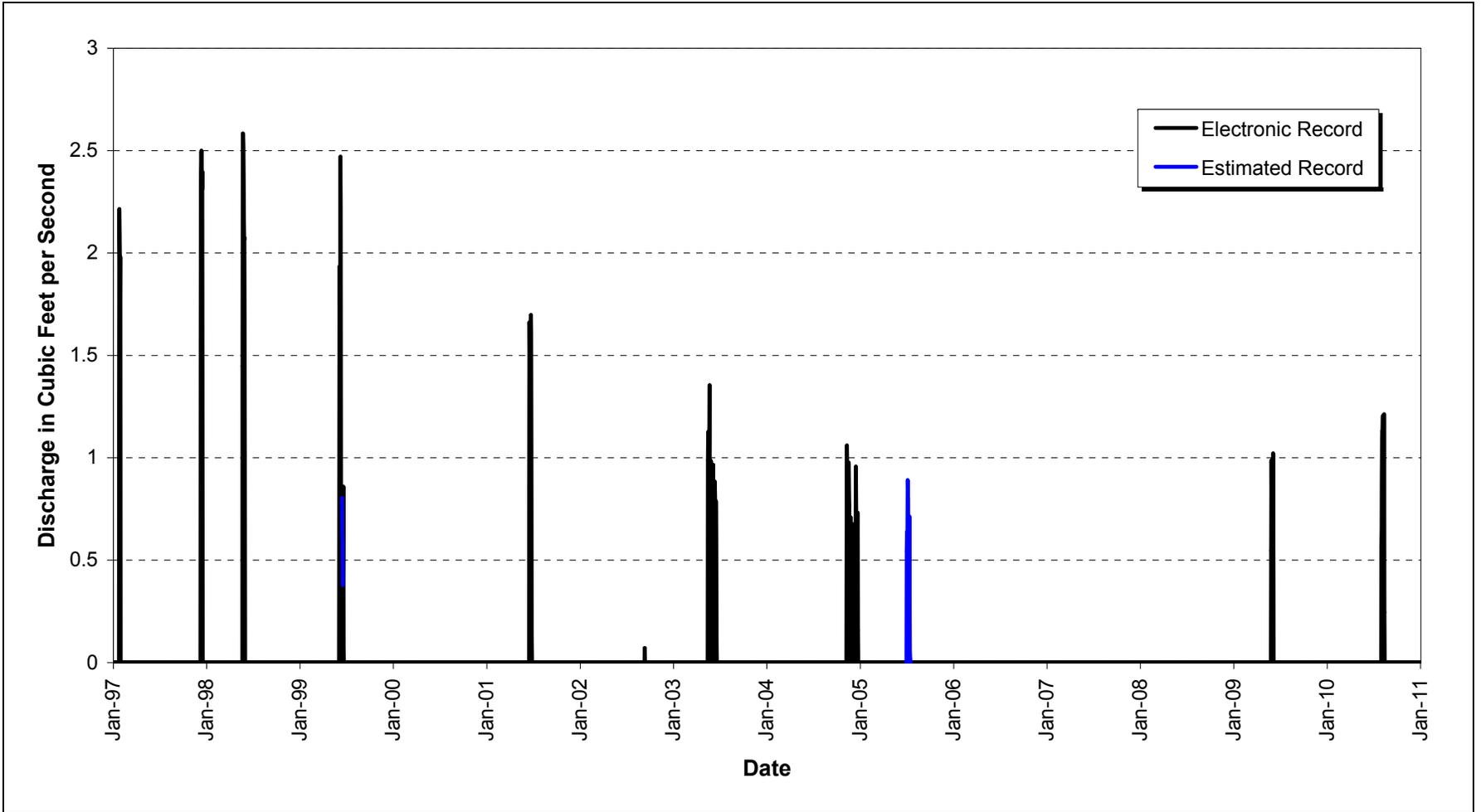


Figure 96. CY 1997–2010 Mean Daily Hydrograph at GS31: Woman Creek at Pond C-2 Outlet

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.

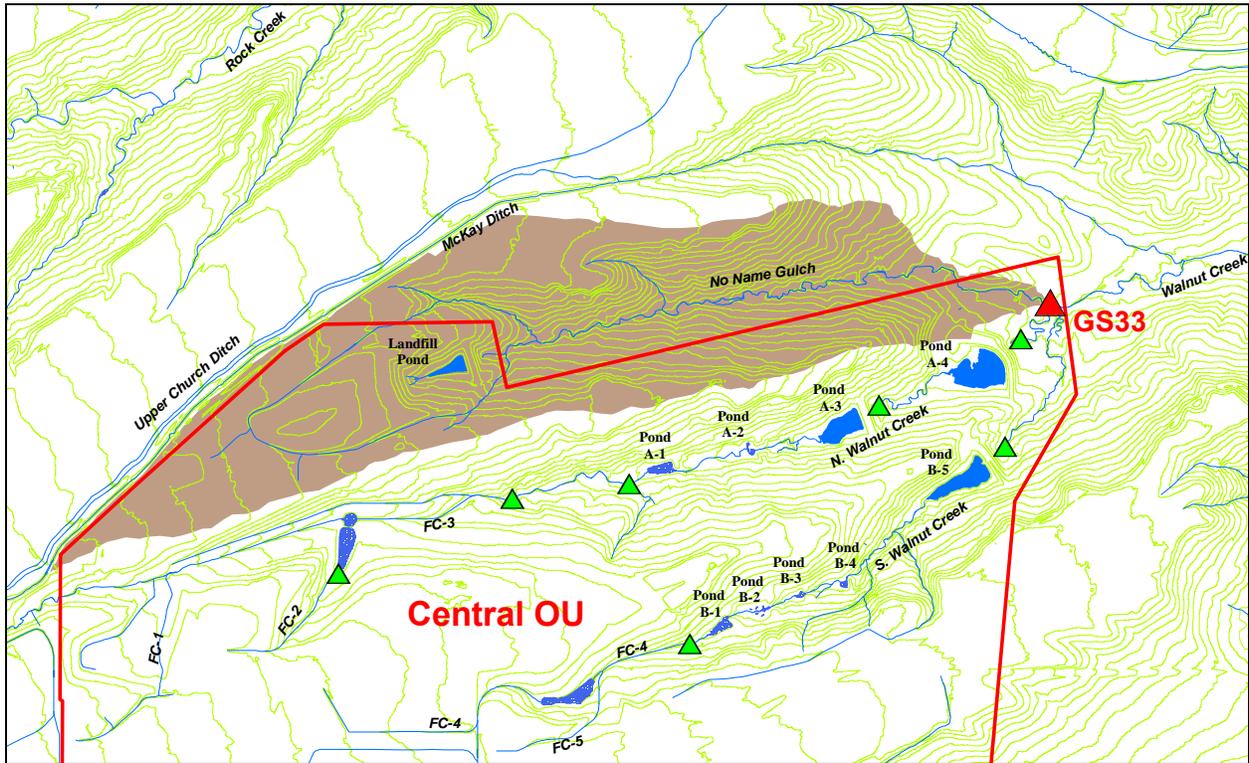


Figure 97. GS33 Drainage Area

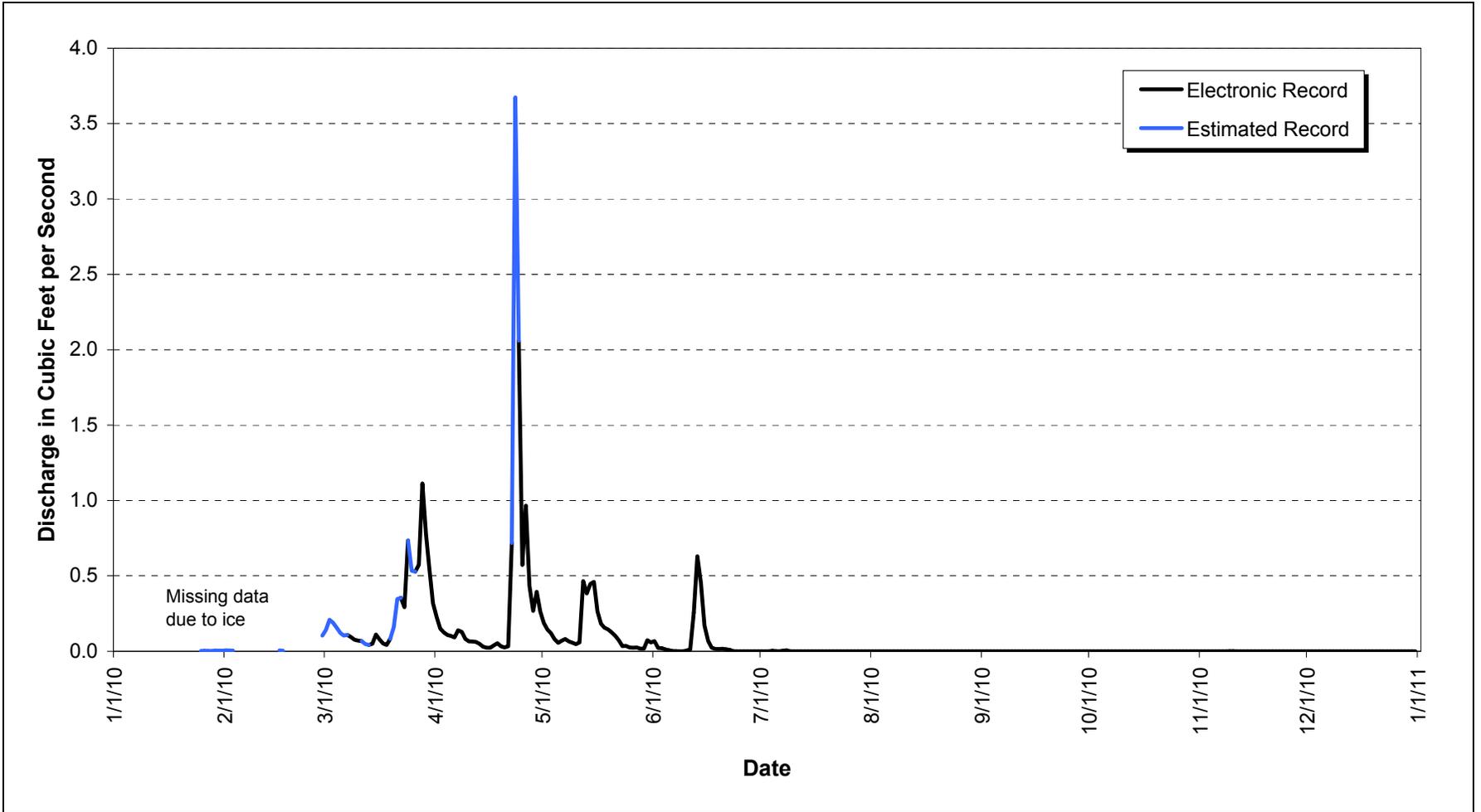


Figure 98. CY 2010 Mean Daily Hydrograph at GS33: No Name Gulch at Walnut Creek

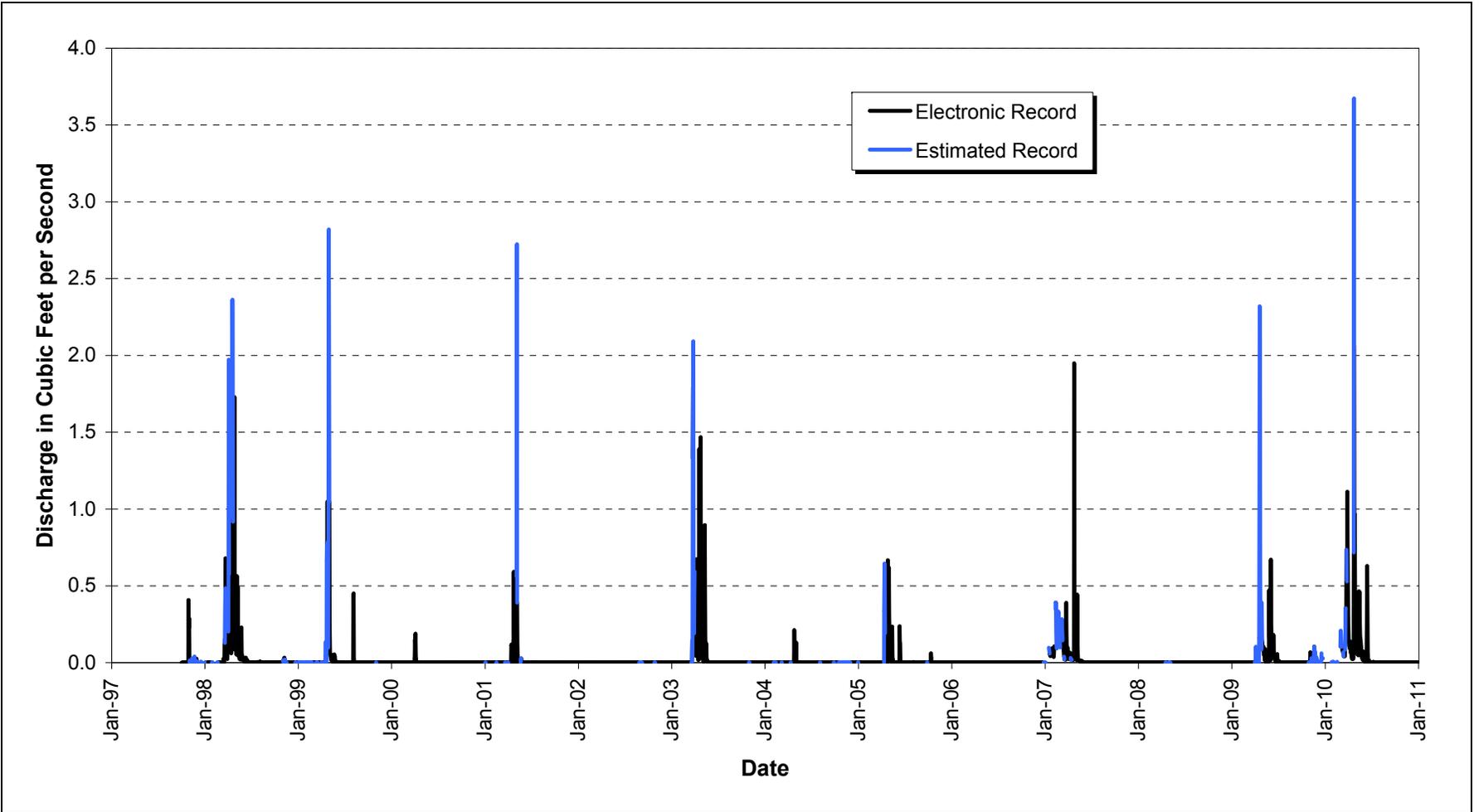


Figure 99. CY 1997–2010 Mean Daily Hydrograph at GS33: No Name Gulch at Walnut Creek

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.

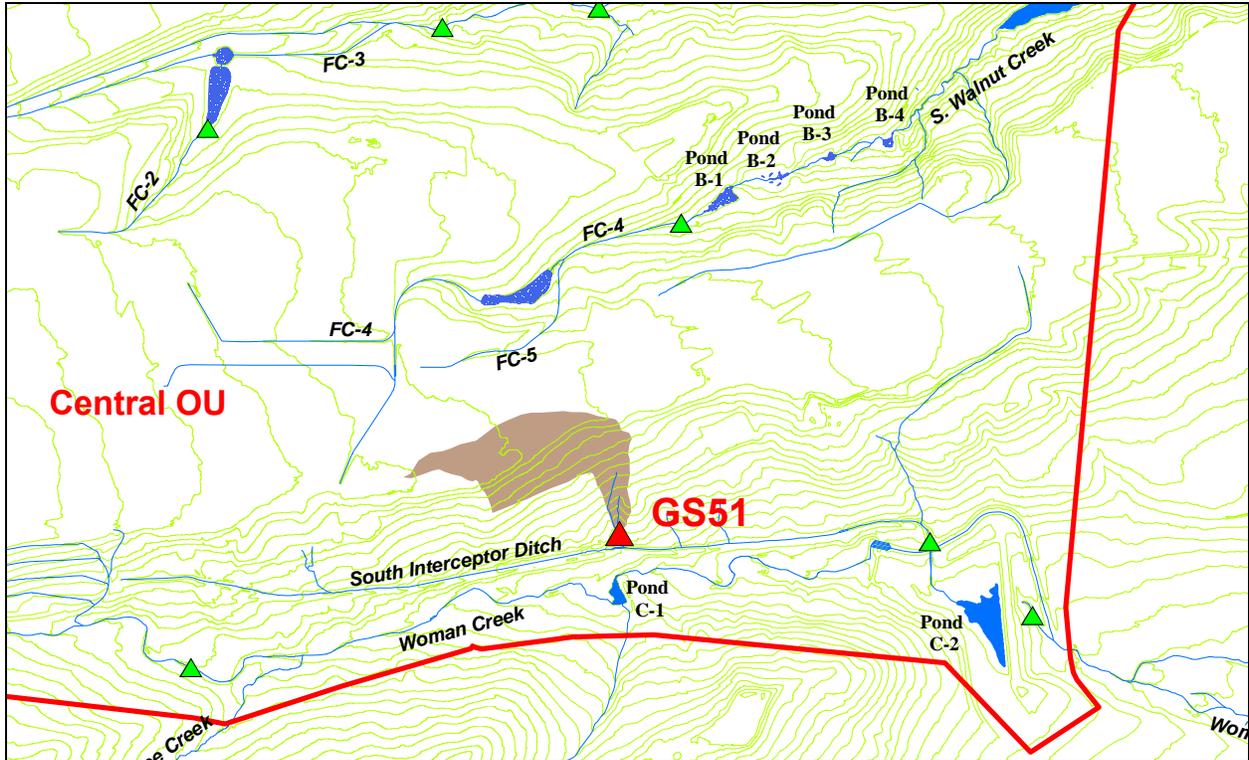


Figure 100. GS51 Drainage Area

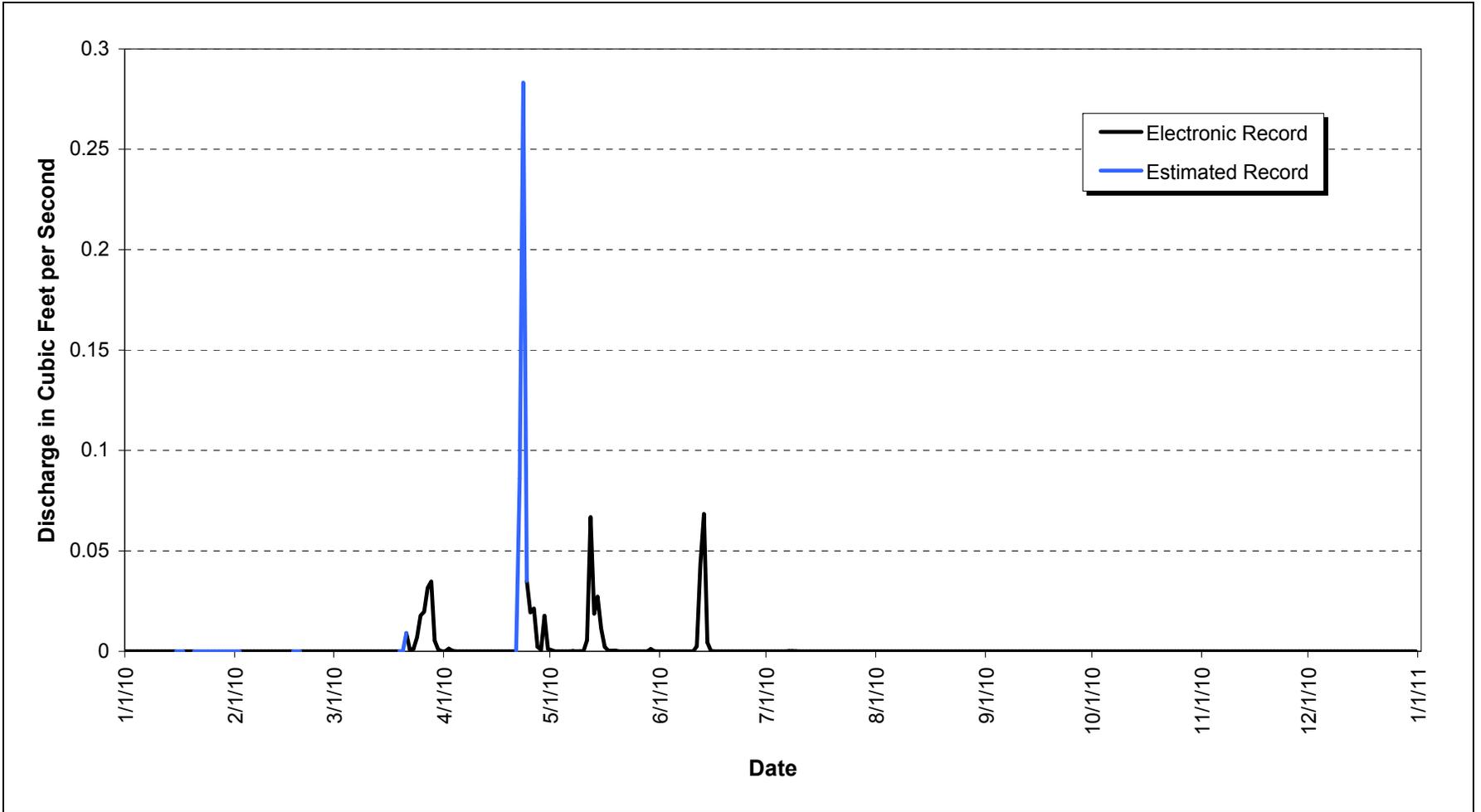


Figure 101. CY 2010 Mean Daily Hydrograph at GS51: Ditch South of 903 Pad

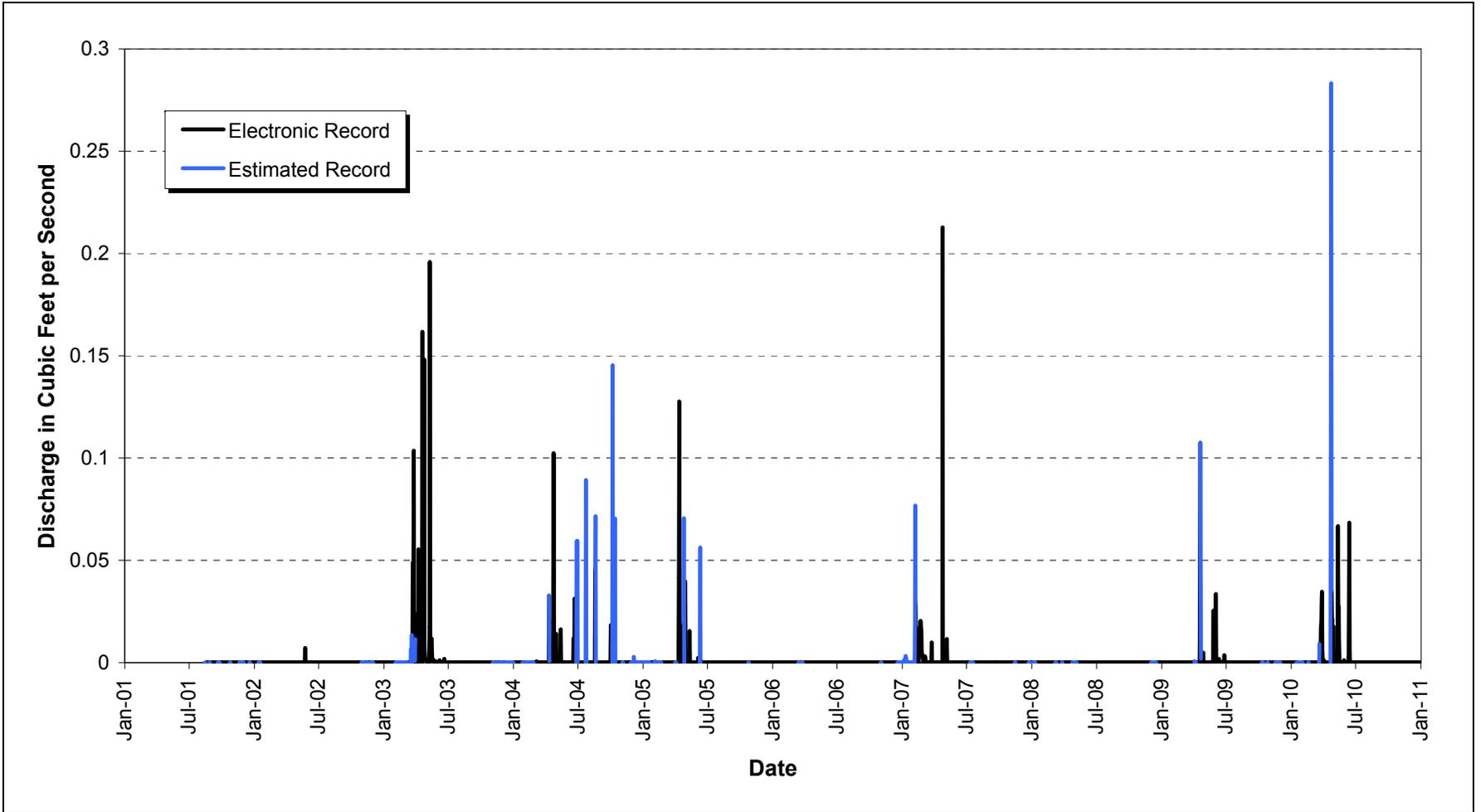


Figure 102. CY 2001–2010 Mean Daily Hydrograph at GS51: Ditch South of 903 Pad

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.

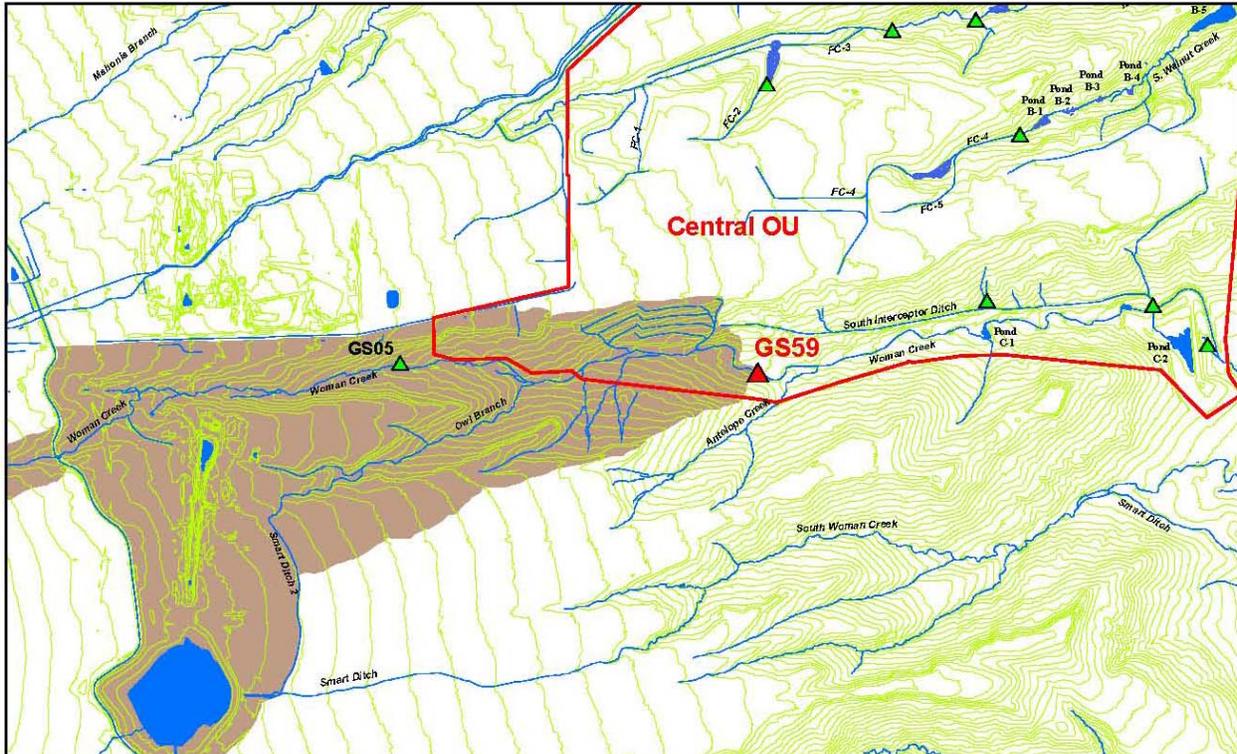


Figure 103. GS59 Drainage Area

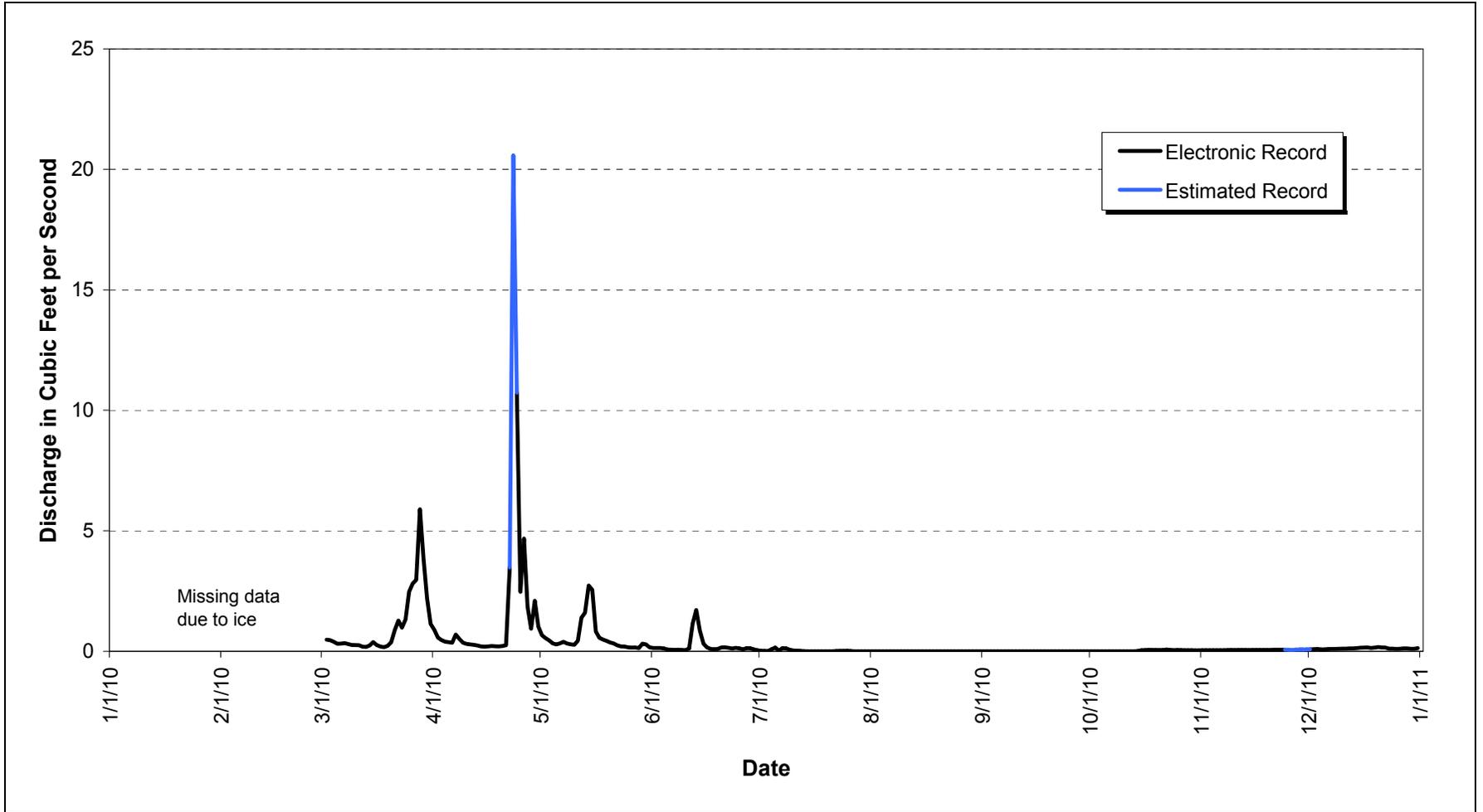


Figure 104. CY 2010 Mean Daily Hydrograph at GS59: Woman Creek Upstream of Antelope Springs Confluence

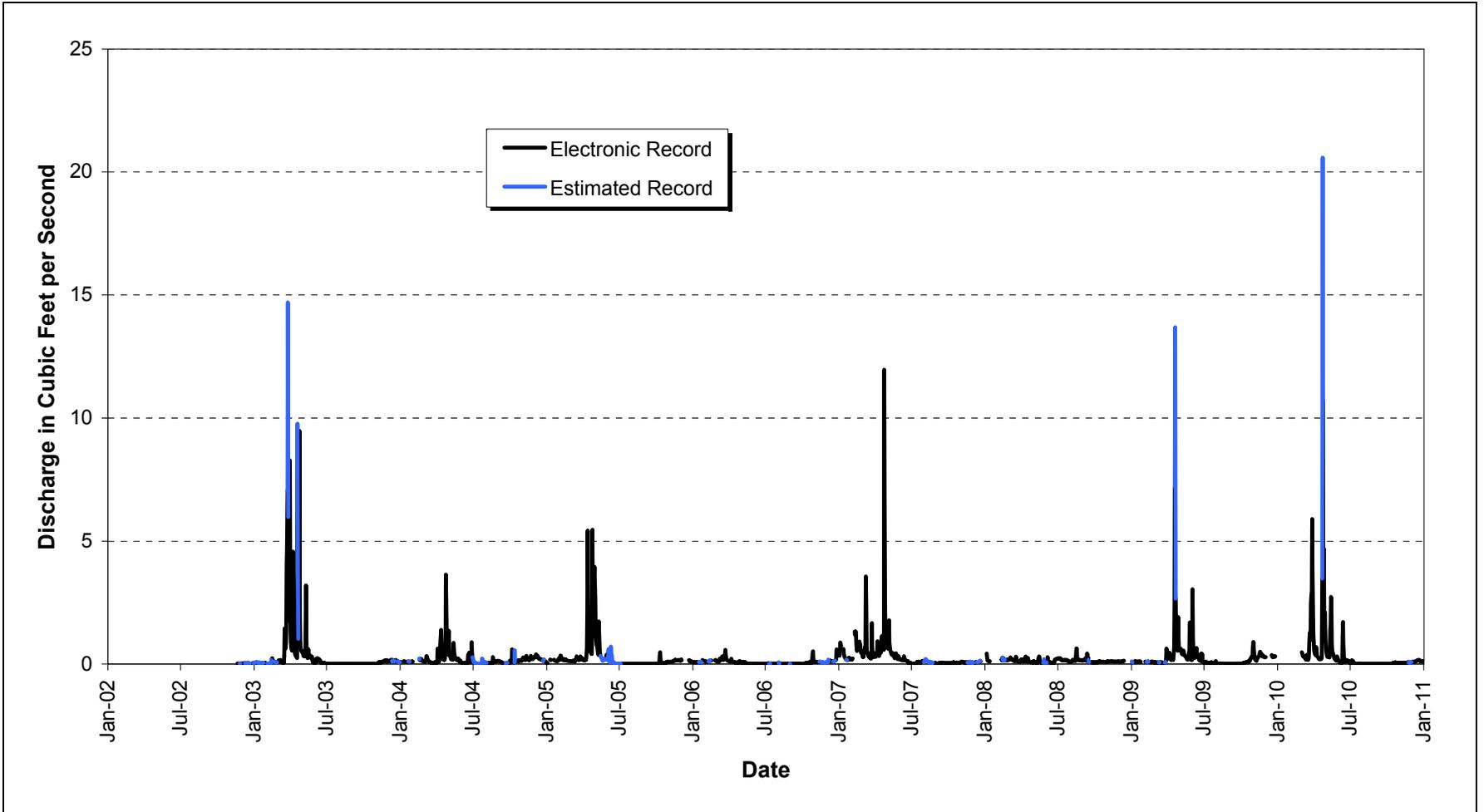


Figure 105. CY 2002–2010 Mean Daily Hydrograph at GS59: Woman Creek Upstream of Antelope Springs Confluence

B5INFLOW: South Walnut Creek Above 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.

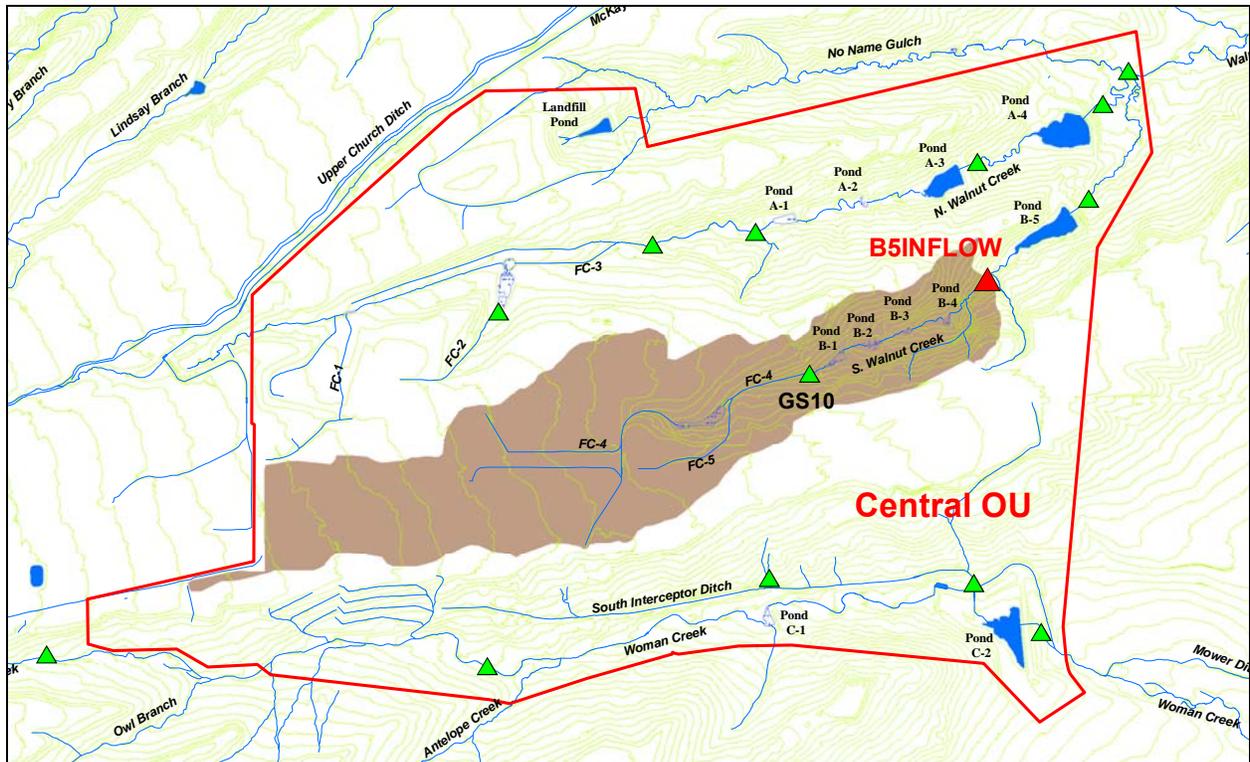


Figure 106. B5INFLOW Drainage Area

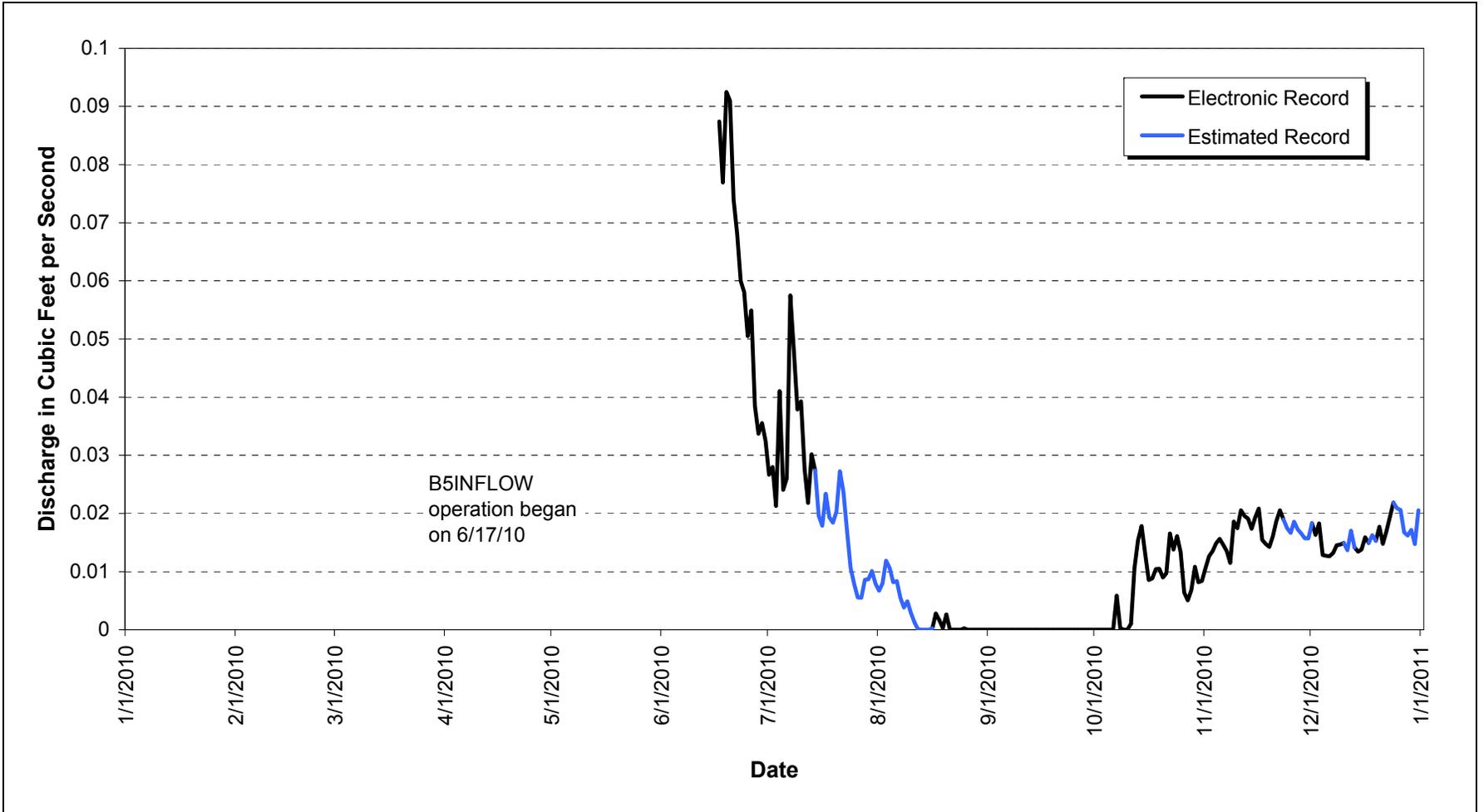


Figure 107. CY 2010 Mean Daily Hydrograph at B5INFLOW: South Walnut Creek Above Pond B-5

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.

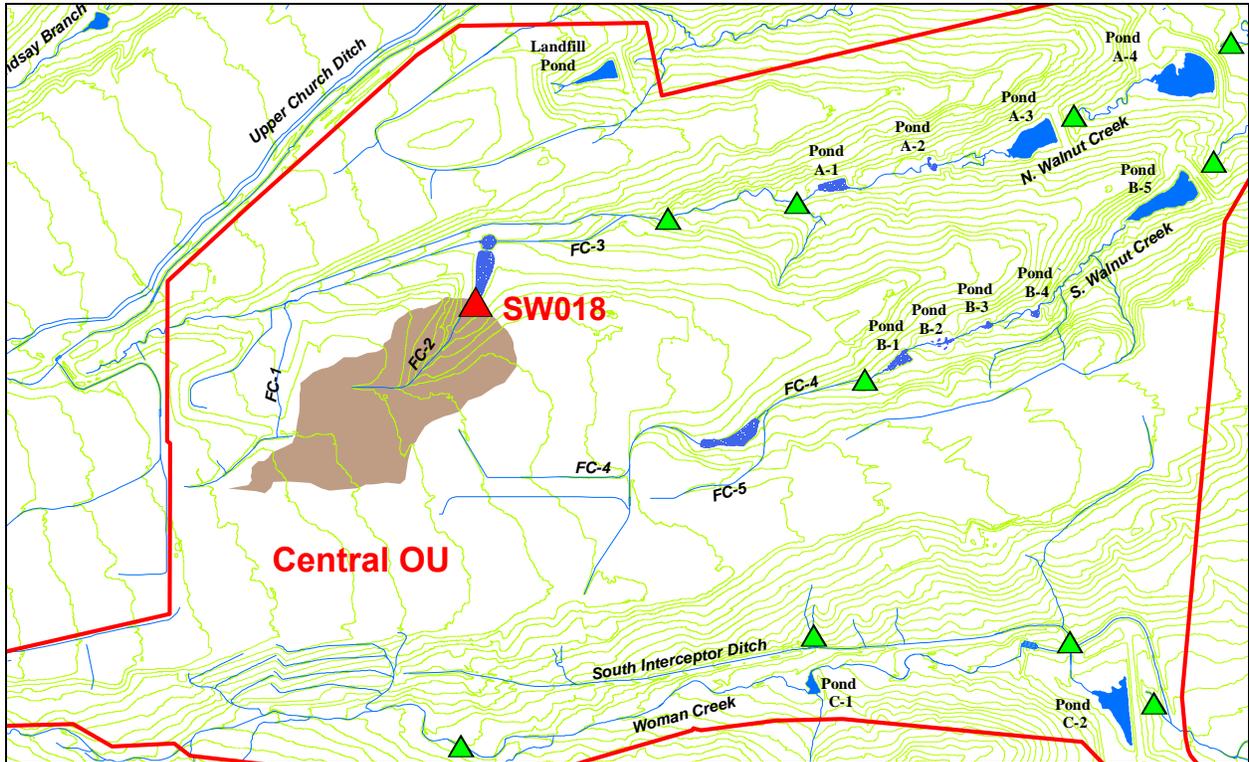


Figure 108. SW018 Drainage Area

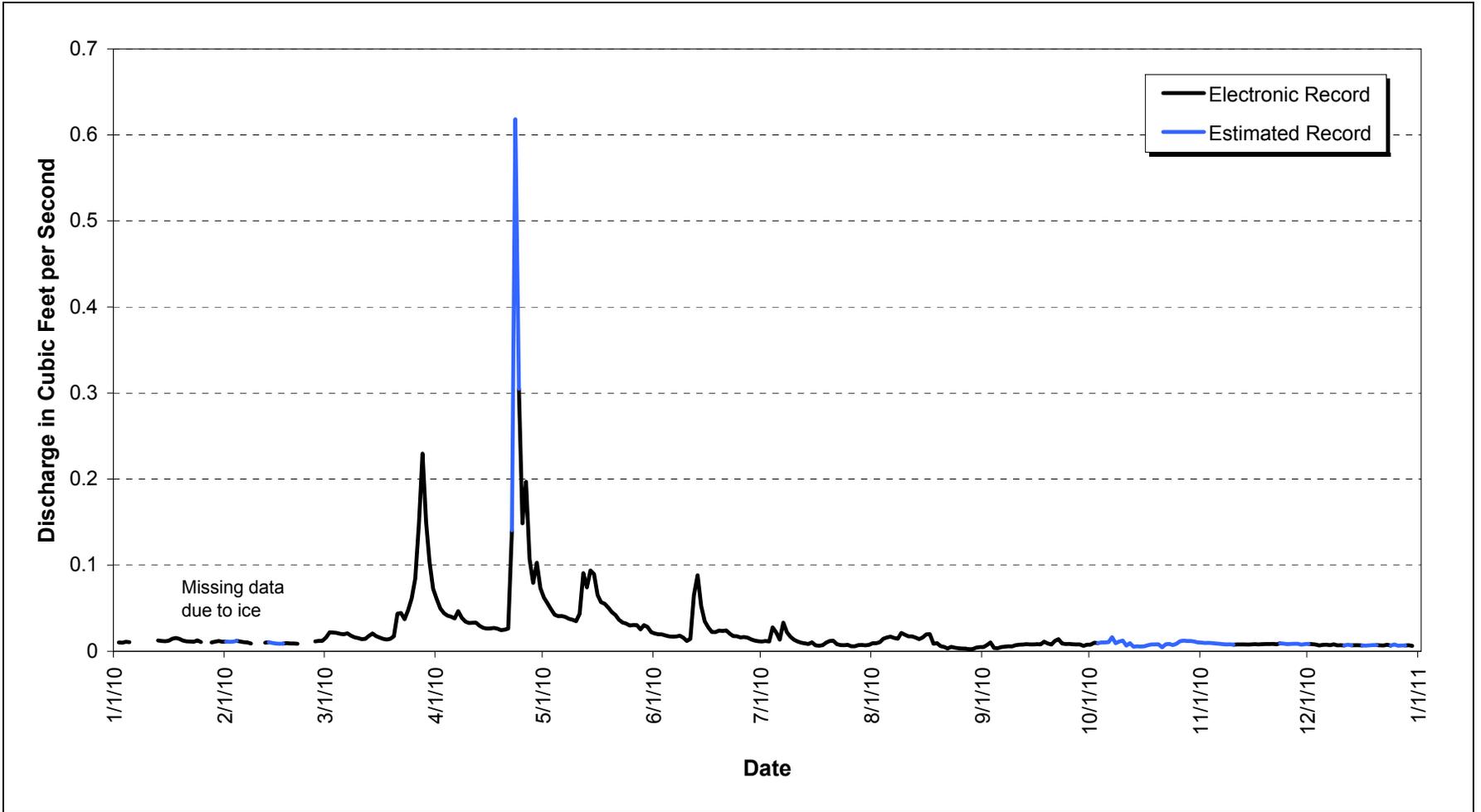


Figure 109. CY 2010 Mean Daily Hydrograph at SW018: FC-2 at FC-2 Wetland

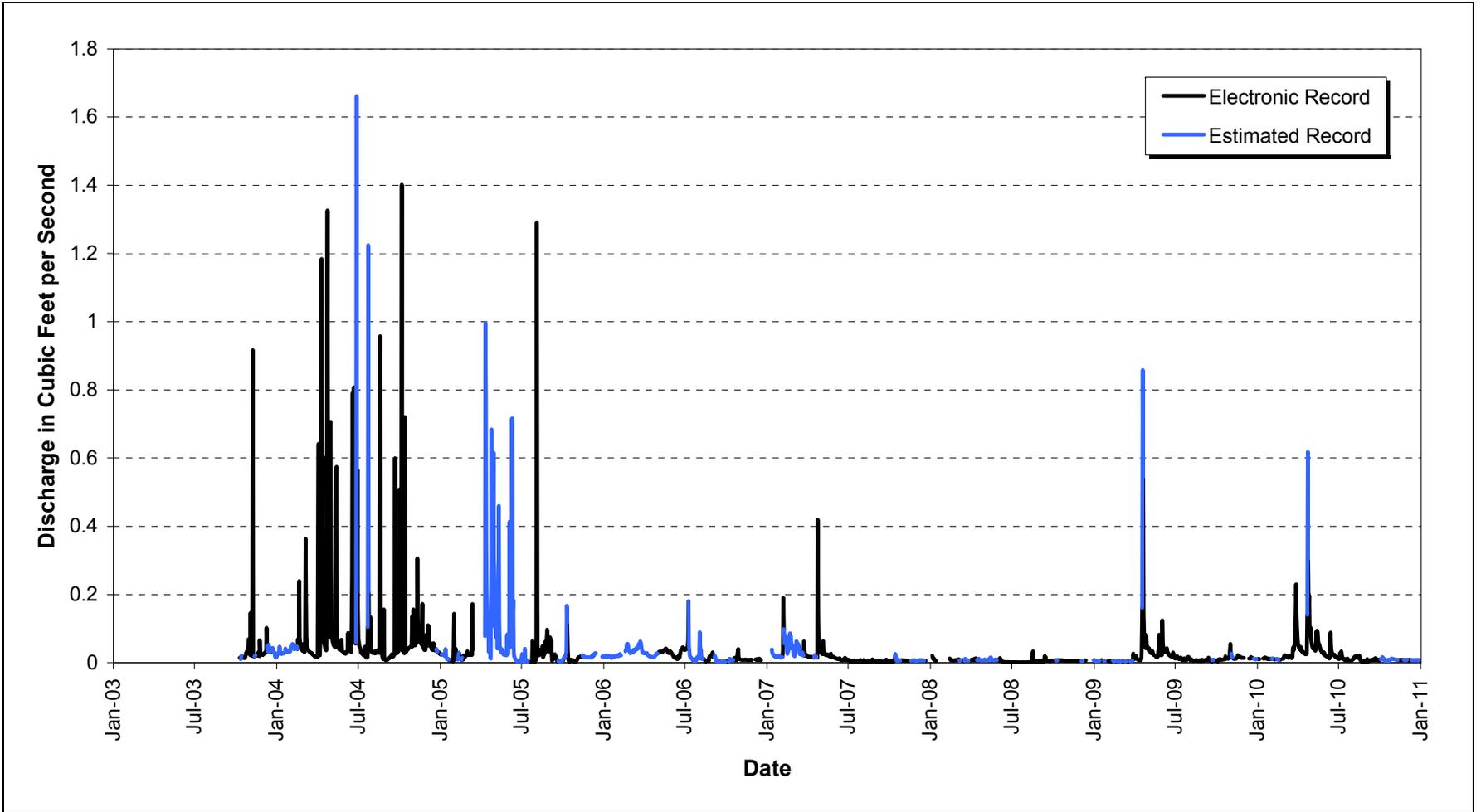


Figure 110. CY 2003–2010 Mean Daily Hydrograph at SW018: FC-2 at FC-2 Wetland

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.

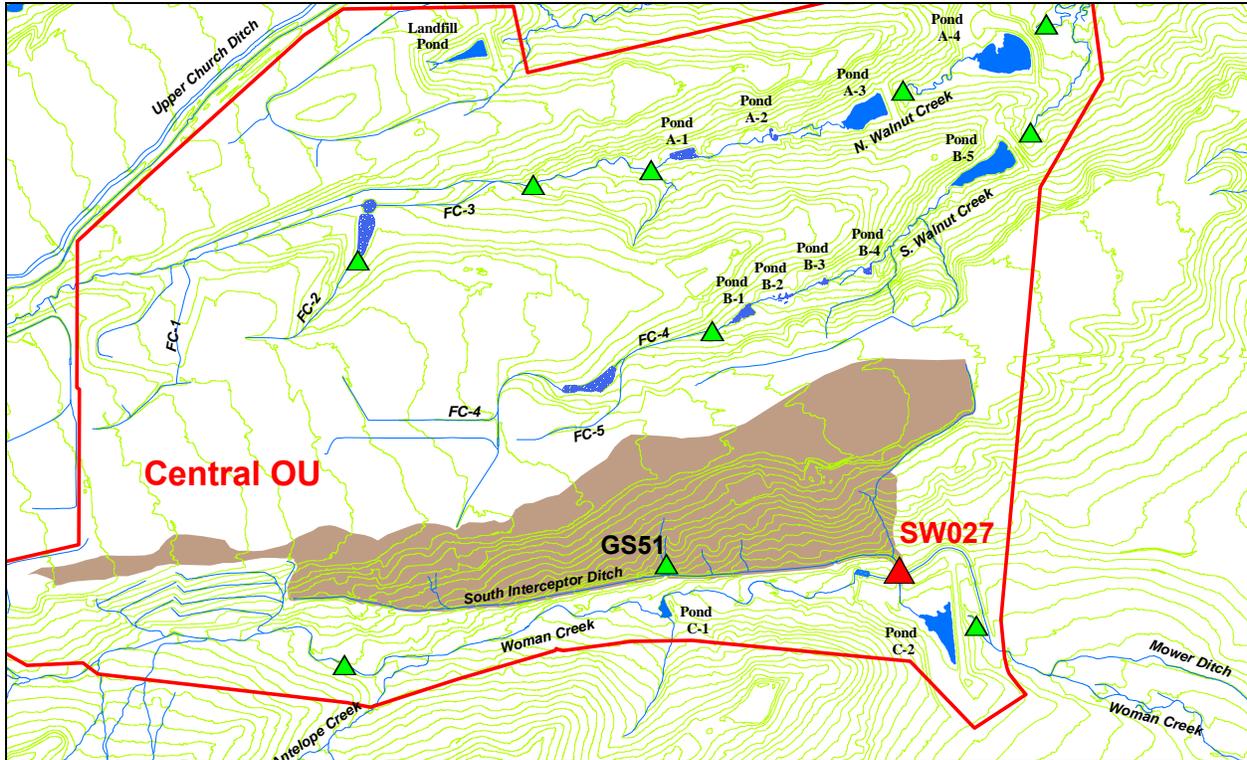


Figure 111. SW027 Drainage Area

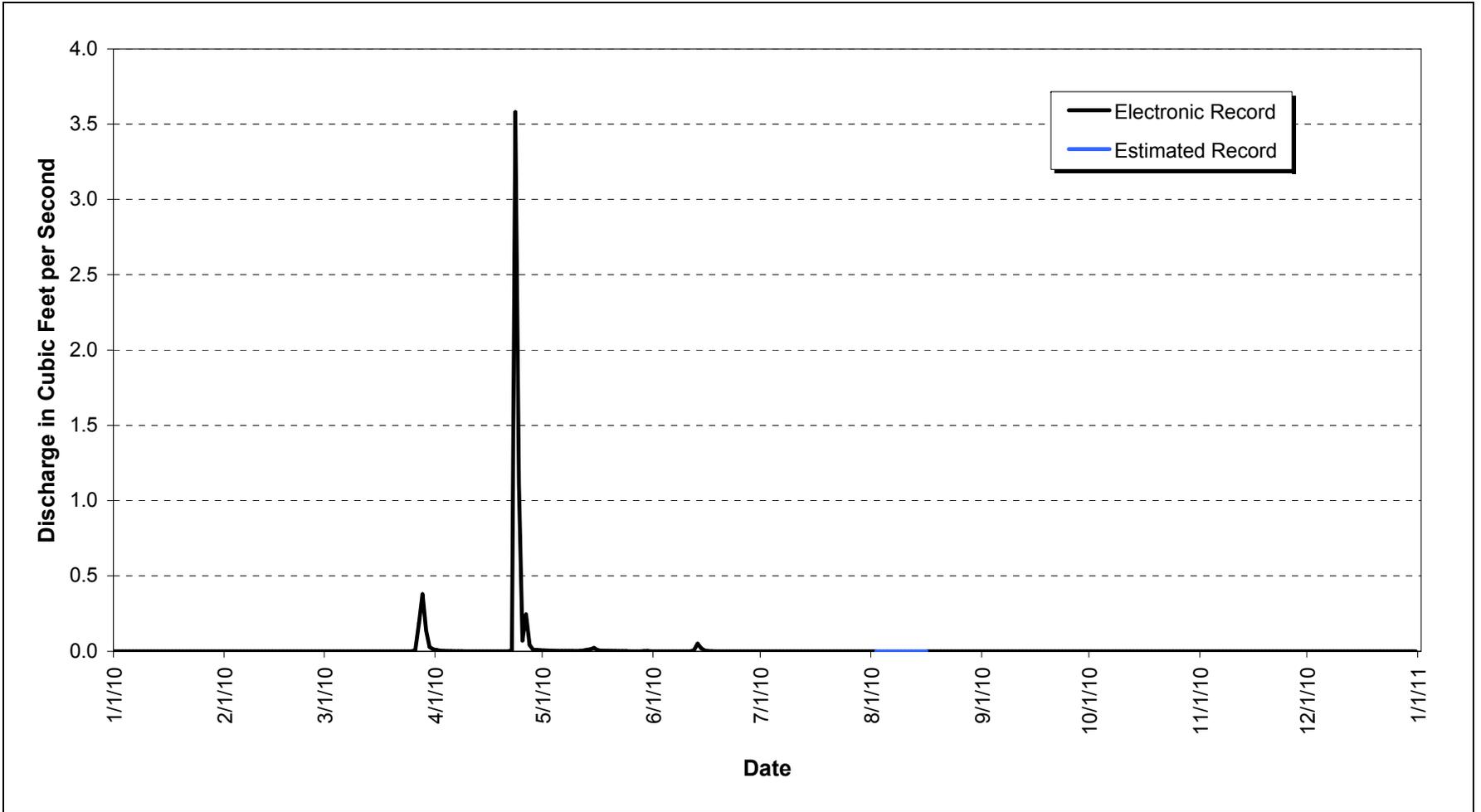


Figure 112. CY 2010 Mean Daily Hydrograph at SW027: SID at Pond C-2

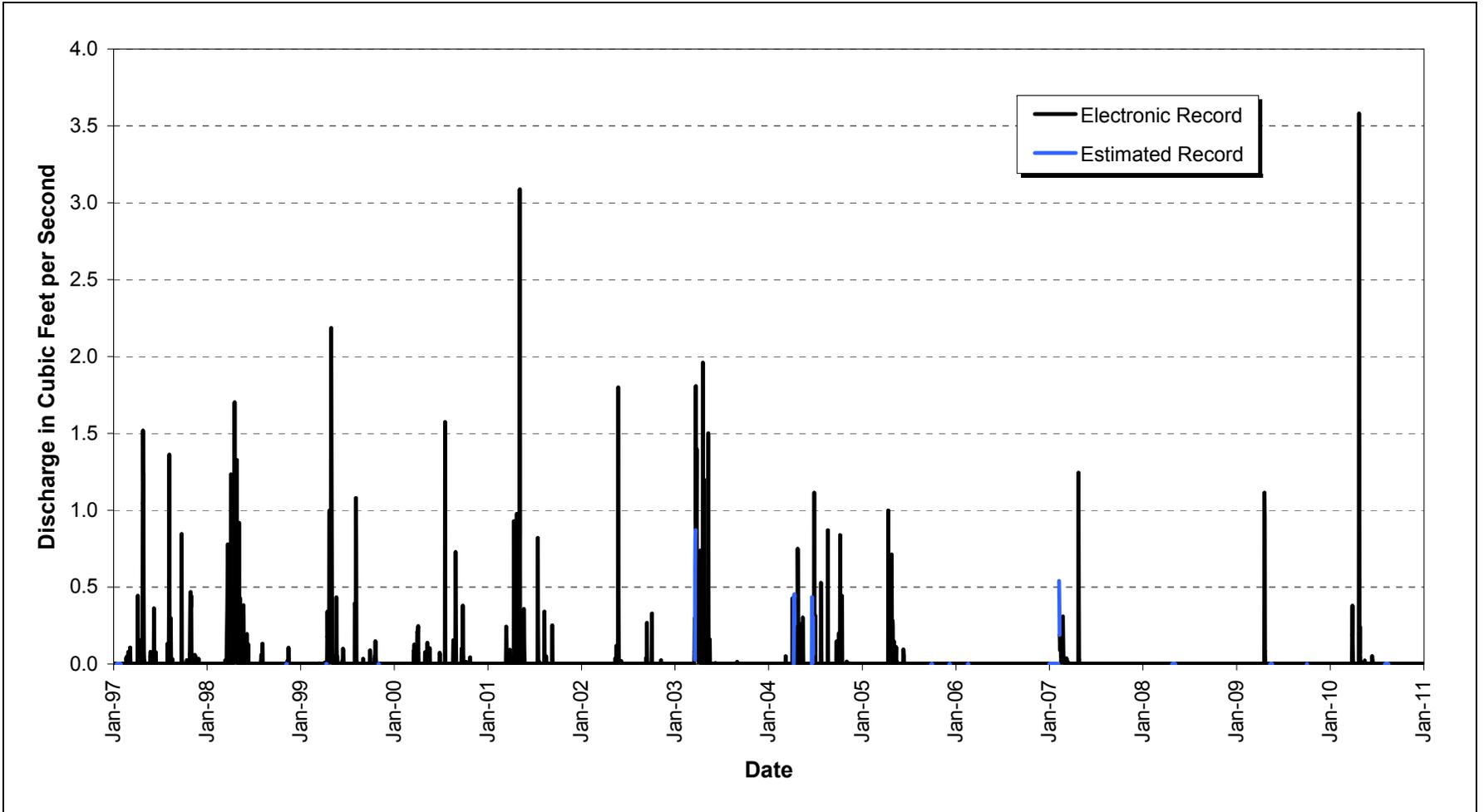


Figure 113. CY 1997–2010 Mean Daily Hydrograph at SW027: SID at Pond C-2

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.

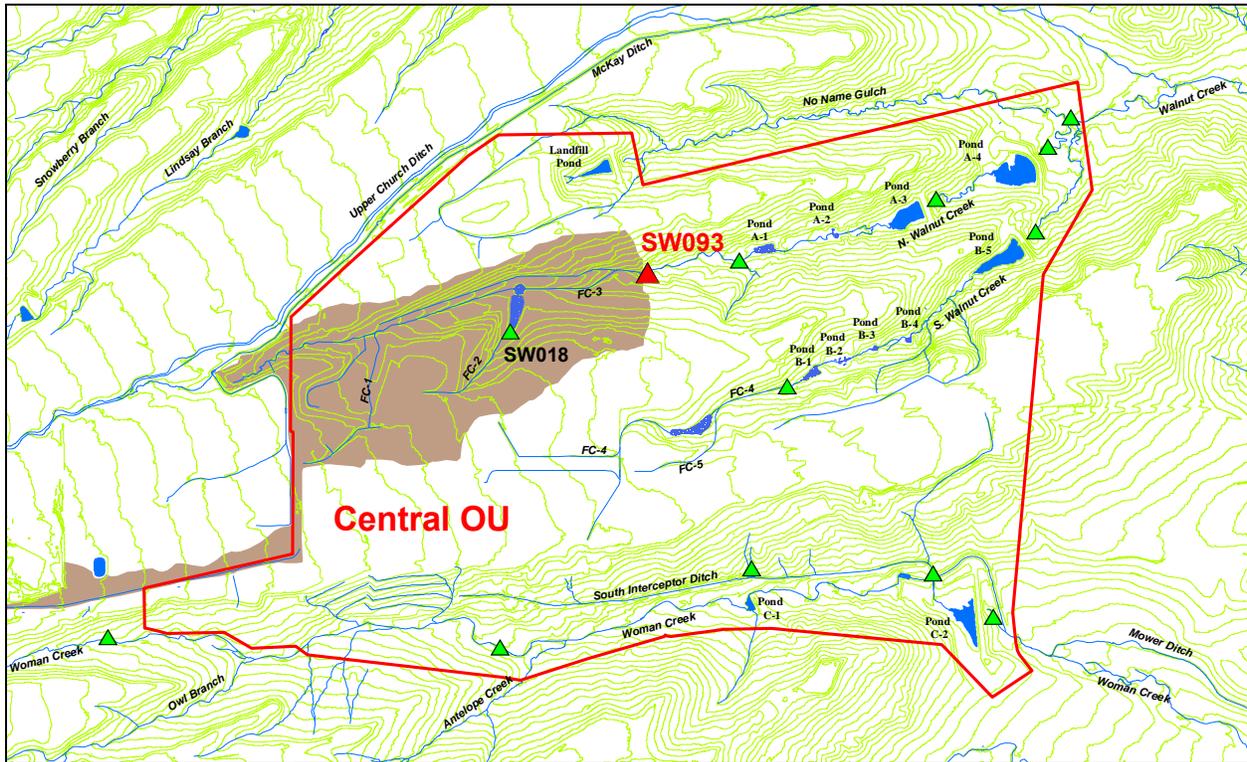


Figure 114. SW093 Drainage Area

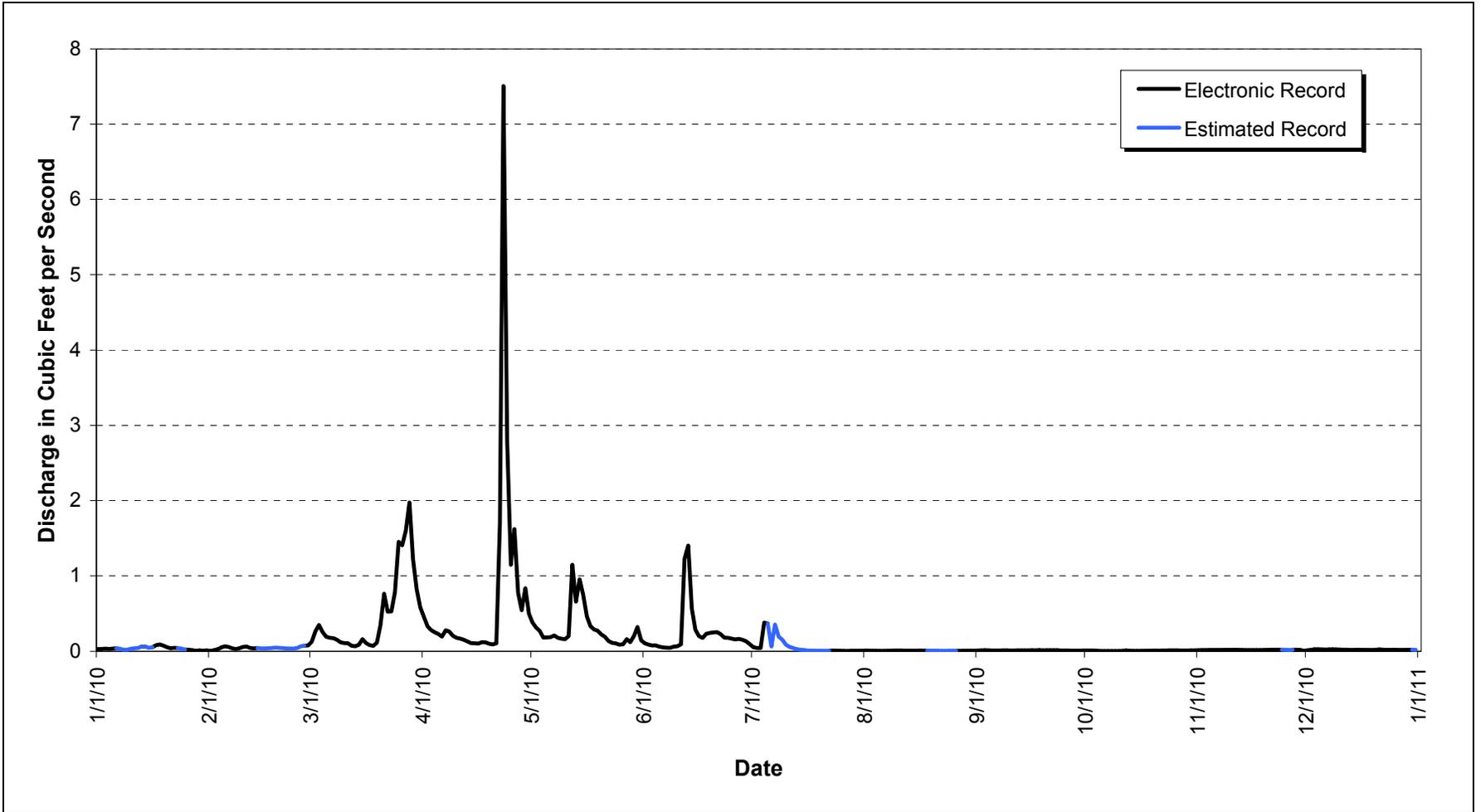


Figure 115. CY 2010 Mean Daily Hydrograph at SW093: North Walnut Creek Upstream of Pond A-1 Bypass

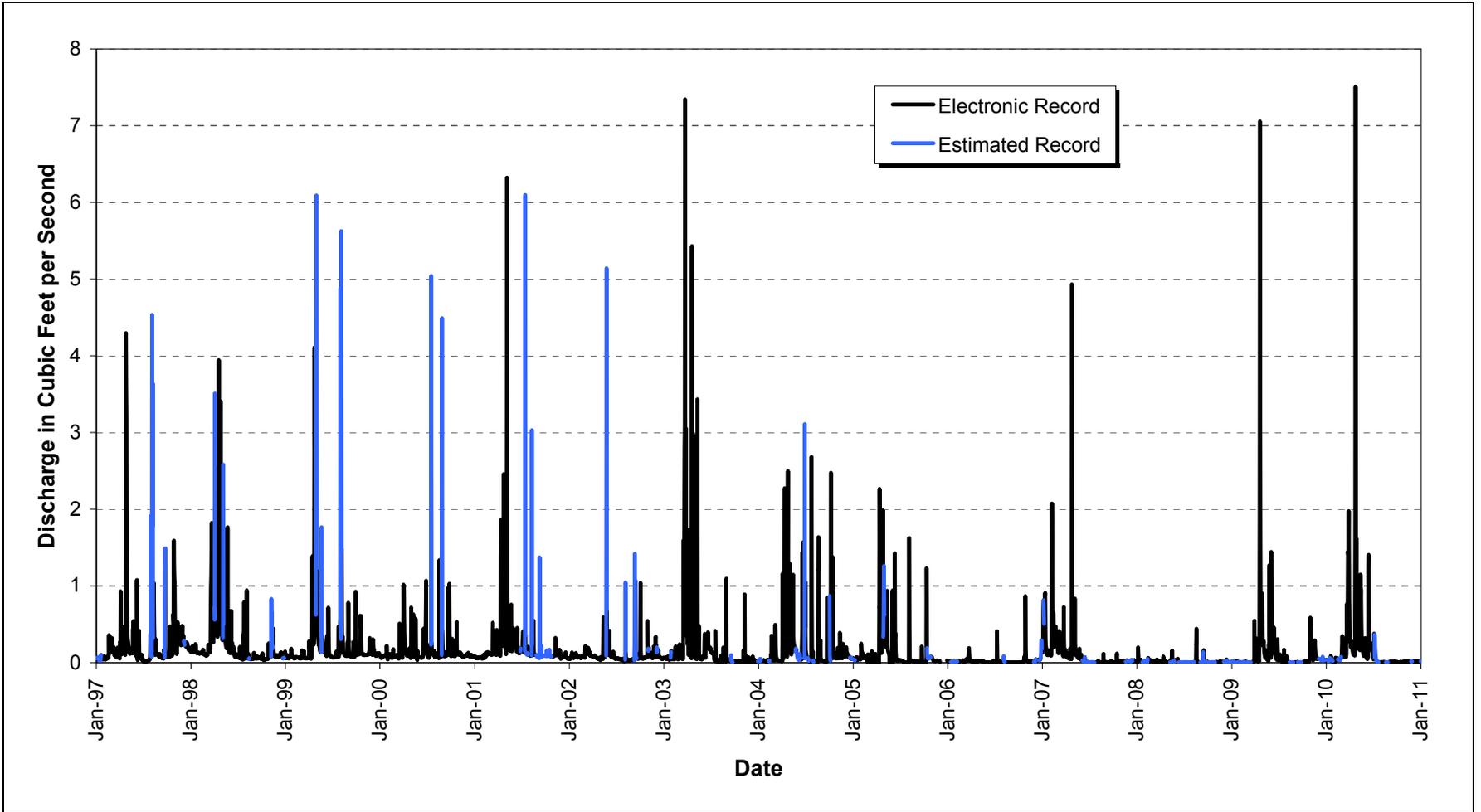


Figure 116. CY 1997–2010 Mean Daily Hydrograph at SW093: North Walnut Creek Upstream of Pond A-1 Bypass

3.1.3.4 Precipitation Data

During CY 2010, eight precipitation gages were operated as part of the automated surface-water monitoring network (Table 36 and Figure 117). 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 118, Figure 119, Figure 120, Figure 121, Figure 122, and Figure 123) summarizing the precipitation data collected for CY 1997–2010.

Table 36. 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

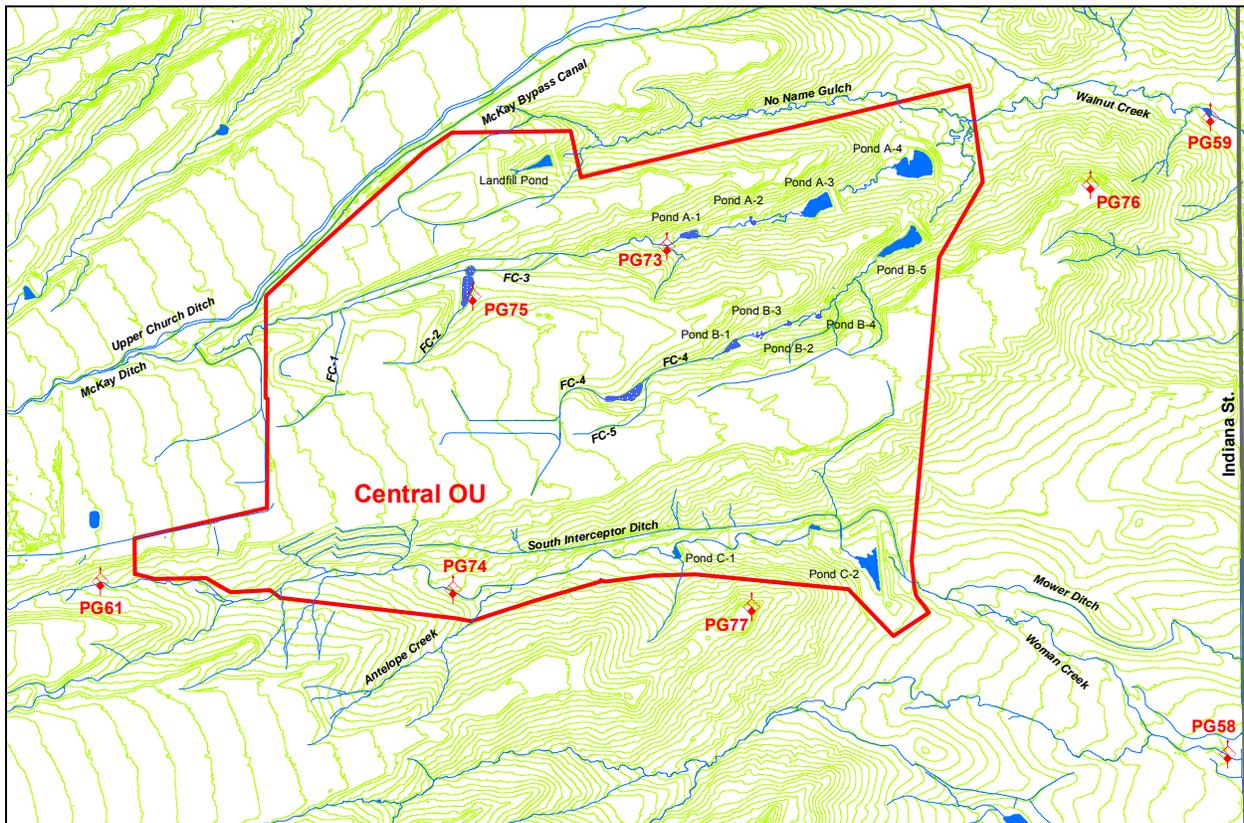
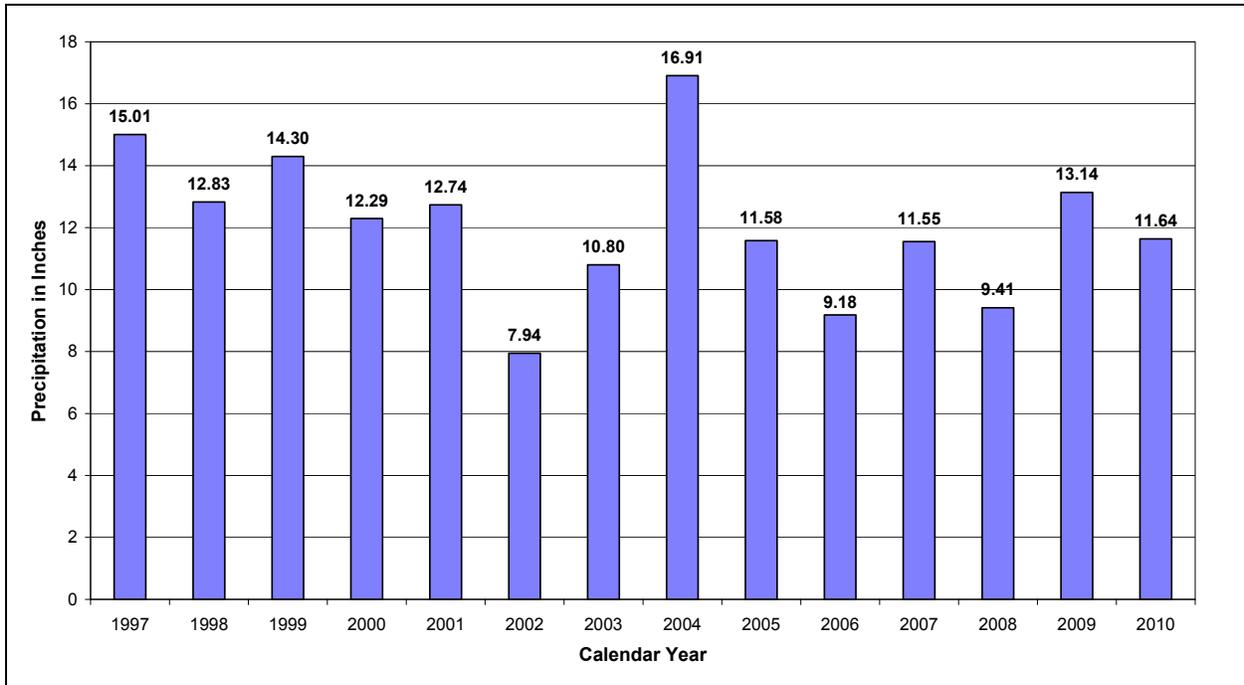


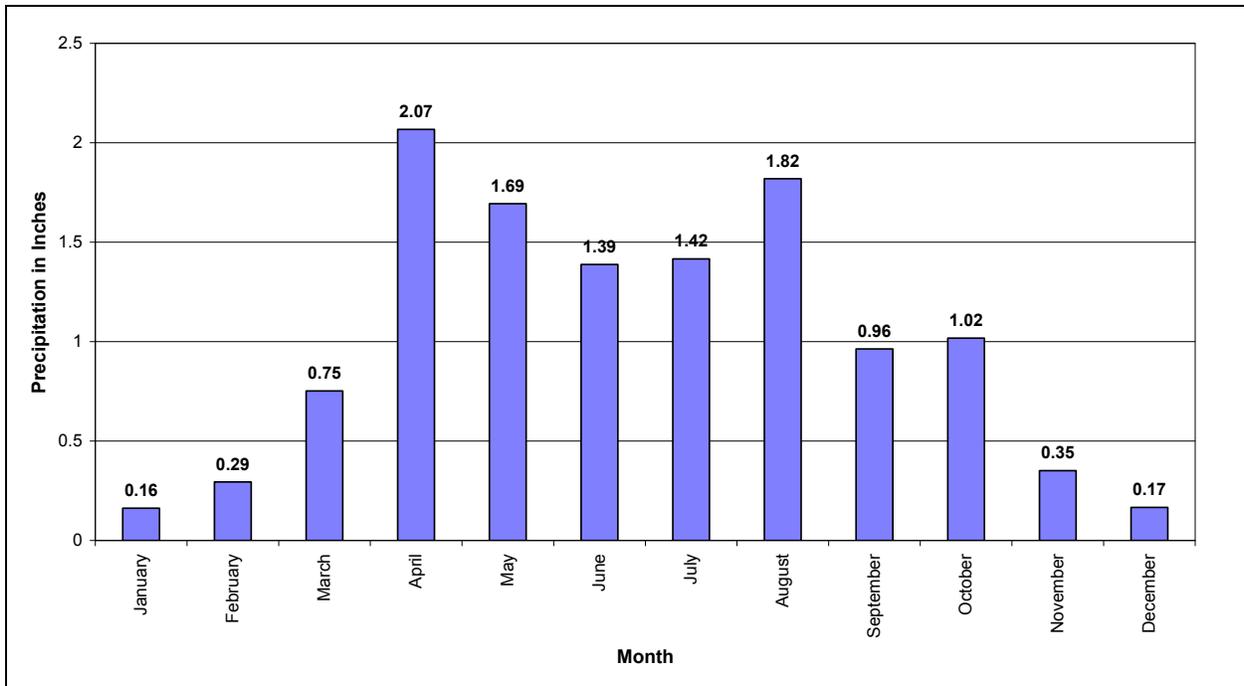
Figure 117. Site Precipitation Gages: CY 2010

CY 1997–2010 Summary



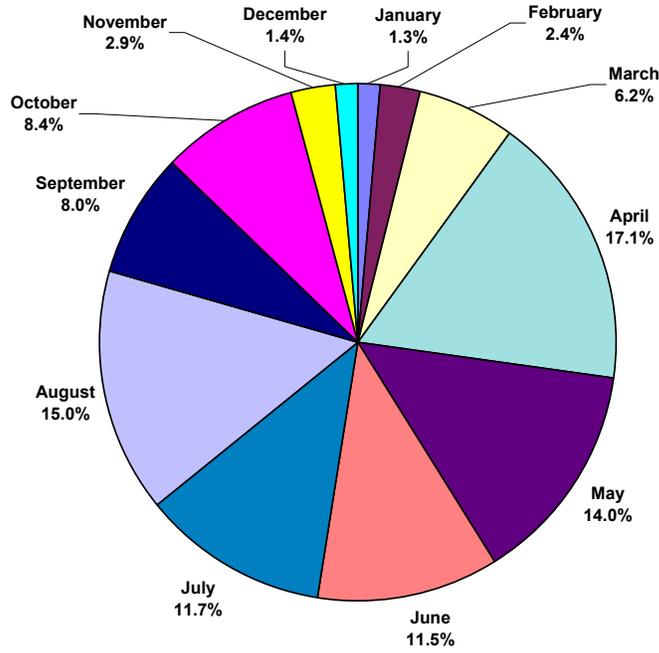
Note: Arithmetic average of gages in operation.

Figure 118. Annual Total Precipitation for CY 1997–2010



Note: Arithmetic average of gages in operation.

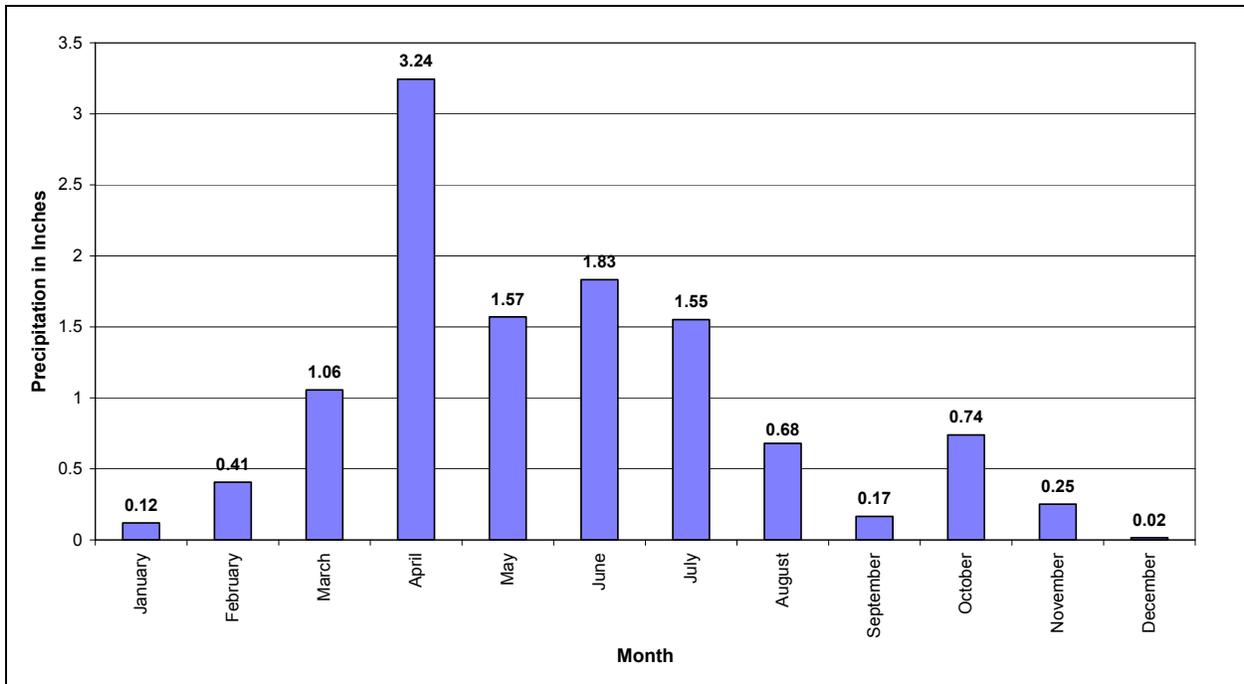
Figure 119. Average Monthly Precipitation for CY 1997–2010



Note: Arithmetic average of gages in operation.

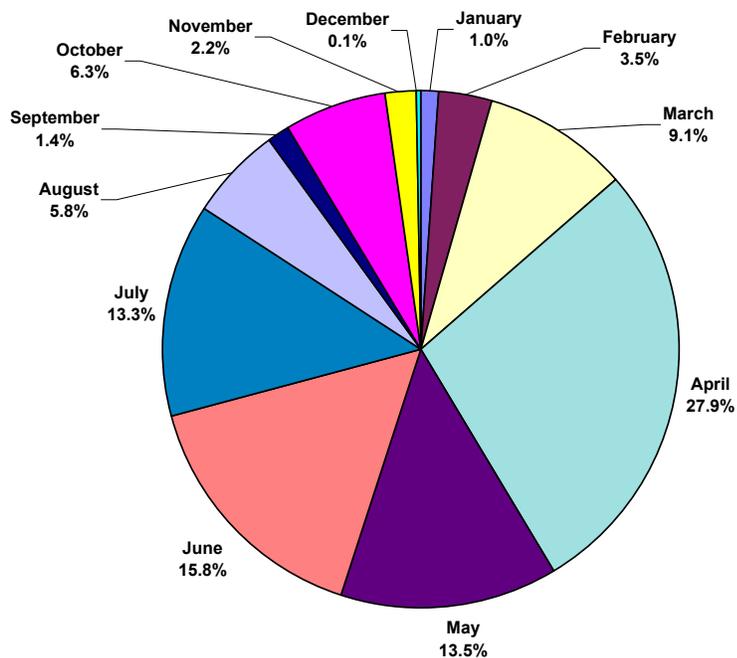
Figure 120. Relative Monthly Precipitation Totals for CY 1997–2010

CY 2010 Summary



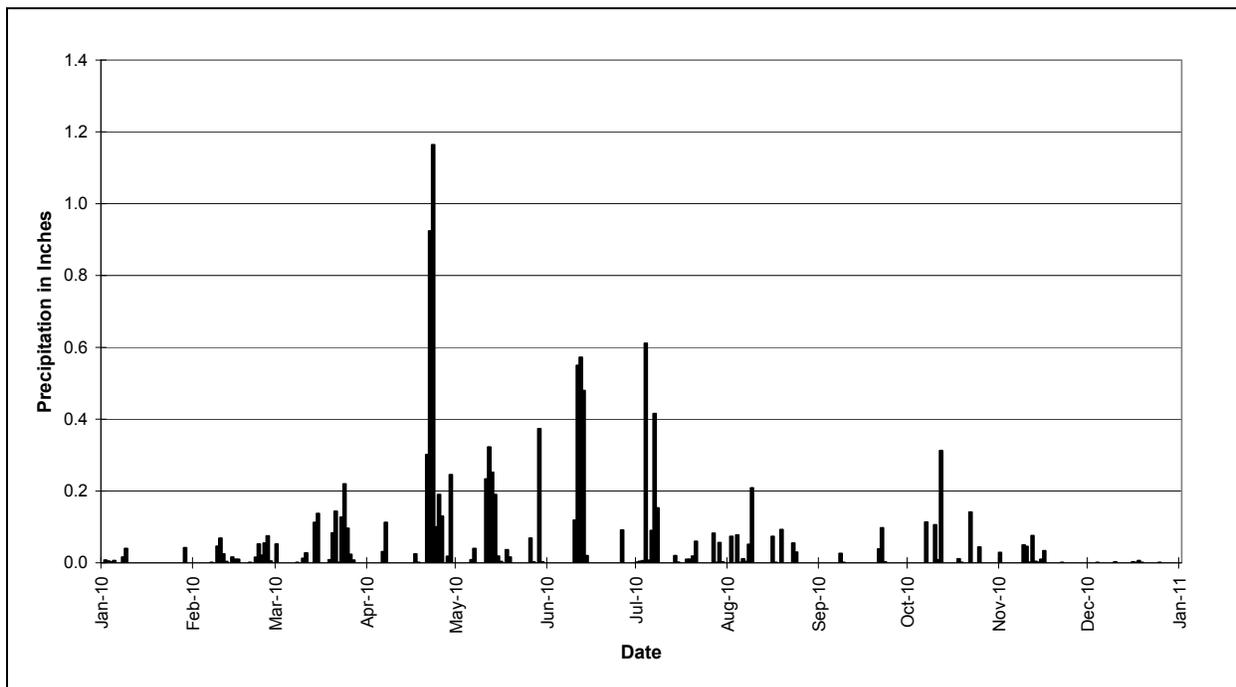
Note: Arithmetic average of gages in operation.

Figure 121. Monthly Precipitation for CY 2010



Note: Arithmetic average of gages in operation.

Figure 122. Relative Monthly Precipitation Volumes for CY 2010



Note: Arithmetic average of gages in operation.

Figure 123. Daily Precipitation Totals for CY 2010

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 2010; these data are included in Appendix A. Prior to 2010, groundwater elevations were also monitored at selected wells using dedicated instrumentation. While this effort continued into 2010, failure of the dedicated equipment led to the collection of essentially no useful data. This topic is summarized 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 2010 is included as Figure 124, and the map for the fourth quarter of CY 2010 is included as Figure 125. 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.

Potentiometric surface maps for 2010 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 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 dry well.

Groundwater flow paths in 2010 are consistent with conditions in 2009, as estimated from the potentiometric surface maps (Figure 124 and Figure 125). In addition, unsaturated areas in 2010 are similar to several of those depicted in 2009. 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. Conversely, well 45608 remained artesian during second quarter CY 2010, as indicated on the potentiometric surface map and corresponding hydrograph. A discussion of the hydrographs is presented below and provides more detail on selected wells.

Consistent with conditions reported in 2008 and 2009 (DOE 2009d, 2010d), water levels in 2010 were no longer affected by Site closure activities. The last year in which groundwater levels clearly showed aftereffects of those activities was 2007 (DOE 2008c). Prior to closure, other influences—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 have a meaningful effect on groundwater levels. Instead, as with conditions reported since 2008, changes in water levels in 2010 were seasonally controlled, dependent on climatic factors (predominantly precipitation and evapotranspiration). Although there are exceptions, overall, the monitoring network indicates that water levels in 2010 were slightly higher in the second quarter than the fourth quarter. This is the usual pattern and is attributed to the fairly wet spring. March and April received a total of 4.3 inches of precipitation, much of it in late March.

Precipitation in 2010 was recorded at eight locations across the Site. The estimated “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 2010 was 11.64 inches. This value is about 4 percent less than the historical (1997–2009) average estimated total annual precipitation, which is 12.13 inches. Figure 118 summarizes precipitation totals for recent CYs and displays the total precipitation for 2010. (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 can provide fundamental indicators of the groundwater regime and are critical to a meaningful evaluation of groundwater quantity, quality, and flow. 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 (DOE 2007c, 2008c, 2009d, 2010d), 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. To date, this has not yet occurred at any well

location. Water level data used for these hydrographs include 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.

As noted in previous years, it took some time for water levels to stabilize following Site closure activities. The hydrographs confirm statements made above: this stabilization period has been completed. The monitoring network in general indicates that water levels in 2010 display seasonal variations with a strong correlation to precipitation events. For example, seasonal influences can be observed in the hydrographs of wells 80105, 80205, and 11104 monitoring the OLF. Some behavior appears to be in response to mechanisms other than seasonality (for example, see the hydrographs for wells 88104, B206989, and 23296), but in each case can be explained by considering local conditions, as discussed below.

Hydrographs that display seasonal patterns may be rapidly influenced by precipitation events. Seasonal influences are most notable in the spring months after heavy precipitation events; a total of approximately 3.24 inches of precipitation was observed at Rocky Flats during the month of April. The effect of this precipitation is evident in several hydrographs, but it is perhaps most apparent in those representing monitoring wells 70193, 70393, and 70693, each of which is located upgradient of the PLF.

In 2010, precipitation was recorded using data from eight tipping buckets across the Site. The total amount of precipitation recorded in 2010 was 11.64 inches. (Note that tipping buckets do not provide an accurate measure of snowfall; therefore, this value typically under-represents the actual amount of precipitation received.) The relationship between groundwater and precipitation can be complex because groundwater elevations tend to respond slowly to precipitation events. There was a total of 5.87 inches of precipitation observed throughout the months of March through May, which is represented by most hydrographs with a delayed response (see Section 3.1.3.4 for additional discussion of precipitation).

Table 37. Total Monthly Precipitation Data for 2010

Month	Precipitation (inches)
January	0.12
February	0.41
March	1.06
April	3.24
May	1.57
June	1.83
July	1.55
August	0.68
September	0.17
October	0.74
November	0.25
December	0.02
Total Annual	11.64

Note: Values are averaged from eight tipping bucket rain gauges across the Site. This total does not include snowfall totals.

Seasonal variations are apparent in almost all of the wells, with a few exceptions. Unsaturated areas were generally unchanged from those observed in 2009. For example, well 95299, which is located adjacent to and downgradient of the ETPTS groundwater intercept trench, was dry. This well has been observed to contain water only once since 2000 (in late 2006). This area is typically dry due to the dewatering effects of that trench. Conversely, well 90299, which is also usually dry, was recharged following the spring precipitation and provided samples in both the second and fourth quarters of 2010.

Well 45608, located on the constructed hillside south of former B991, ceased its artesian behavior in the spring of 2010. Beginning in May 2010, water levels were consistently measured below the top of well casing. The artesian flow previously observed has been 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. Cessation of artesian flow appears correlated to the kink developing in this well, and therefore the change in flow conditions may be more a function of well or hillside condition than regional groundwater conditions.

The hydrographs for wells 23296, 88104, and B206989 all reflect rising water levels. Well 23296, located downgradient of the groundwater intercept trench feeding the ETPTS and adjacent to South Walnut Creek at the base of the former Pond B-2 dam, exhibited water levels that were above historical levels. These rising water levels date back to October 2008, which coincides with the Dam Breach project that started in September of that year. The rising water levels exhibited by the hydrograph for well 23296 are attributed to resumption of stream flows through South Walnut Creek, rather than routing this water around the ponds via the bypass pipeline as had been the practice in prior years. The water level in this well shows a spring-2010 increase that appears related to precipitation. (Note that due to the rising water levels following breaching of the adjacent dams, the casing of this well was extended in May.)

Well 88104 is located south of the buried remains of former B881. The corresponding hydrograph illustrates that the water level in this well has been rising, with a couple of interruptions, since 2005. This is attributed to groundwater in the pediment to the north being

intercepted by the footprint of former B883 and B881, which were connected by a tunnel. The preferential pathways likely represented by these features would act to route this groundwater to the south, toward the remnants of B881 and its immediate surroundings, such as the area monitored by well 88104. This groundwater has a surface expression as a seep that appears in the vicinity of the southern edge of the former building. The seep drains into and supports a marshy area where 88104 is located. As is evident from the discussion provided in Section 3.1.5.3, analytical data for samples collected from well 88104 do not suggest adverse impacts to surface water from the increased quantities of groundwater observed on the hydrograph for this well.

Well B206989 is located at the foot of the PLF dam and monitors the weathered bedrock. The hydrograph for this well also shows rising water levels that date back—again, with interruptions—to about 2009. This is attributed to a combination of effects: First, the Landfill Pond operates in flow-through, and has since shortly after site closure. This would act to keep the valley in which well B206989 is located more saturated than was the case prior to flow-through operation. Second, both 2009 and 2010 were characterized by wet springs, which would have recharged the groundwater monitored by this well. Finally, the groundwater sampling method employed at this well was changed in May 2010, as it was at all of the poorer-producing wells at the site. Previously, the well would dewater during sampling, and samples would be collected from the ensuing recharge, typically on a subsequent date. Since May 2010, samples are collected from the water initially present within the well casing, without first purging the well (which had typically caused it to dewater). By not repeatedly dewatering the well, the scarce formation water in this area is not repeatedly depleted, and water levels in this very poor producing well have been recovering to what is expected to be a more ambient elevation. This does not mean that the well will produce more water; rather, the ambient water level will be more reflective of undisturbed conditions within the adjacent weathered bedrock of the UHSU.

Wells 33502, 33604, 33703, and 33905 monitor the buried drainage that hosts the vinyl chloride (VC) plume upgradient of FC-2. Hydrographs for these wells, similar to other observations in 2010, show strong seasonal patterns, with sharp spring peaks and winter troughs in water levels. The casing of well 33703 is strongly kinked, preventing the measurement of water level after May 2010. This well is scheduled to be replaced in early 2011.

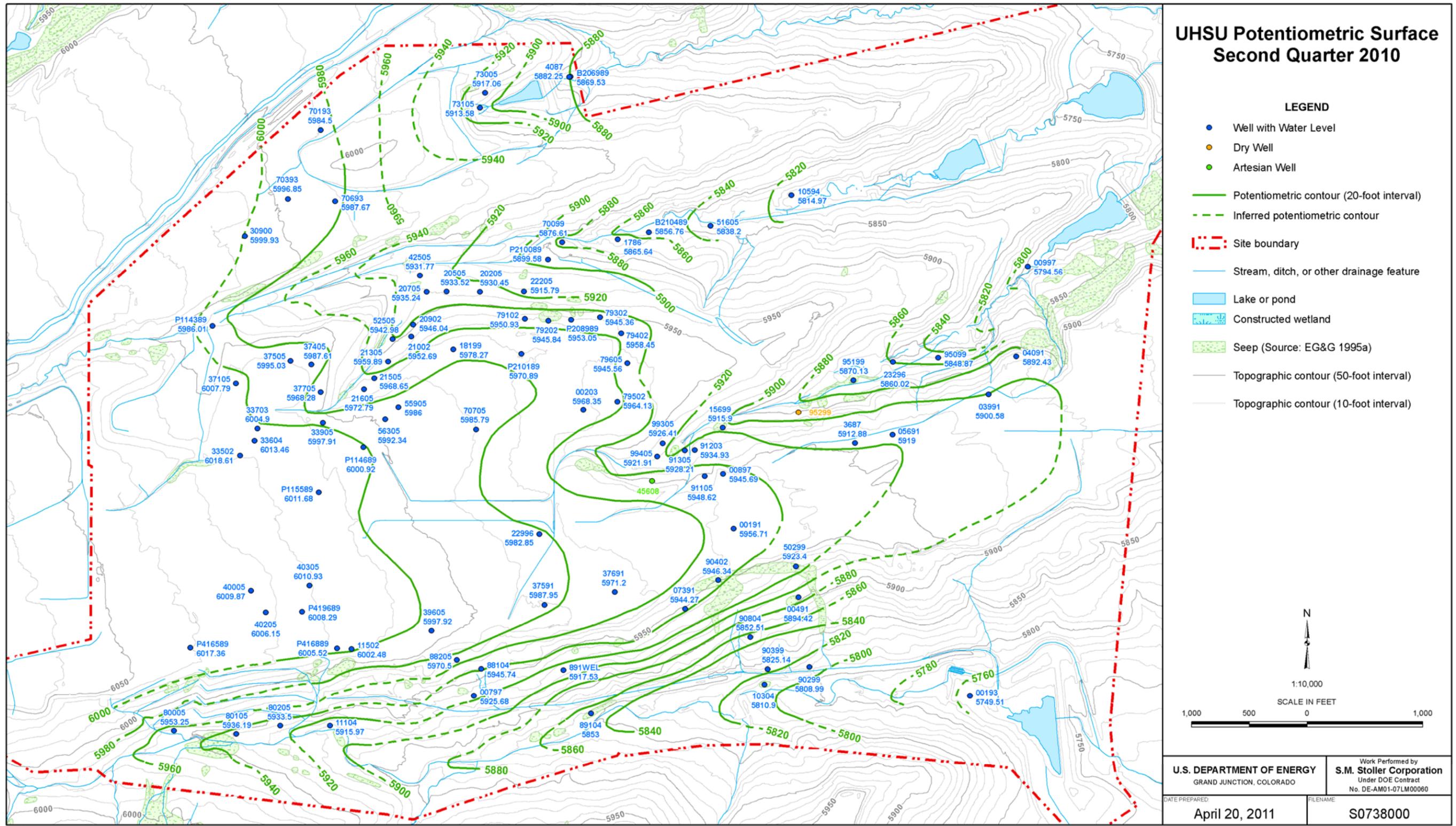


Figure 124. UHSU Potentiometric Contours: Second Quarter CY 2009

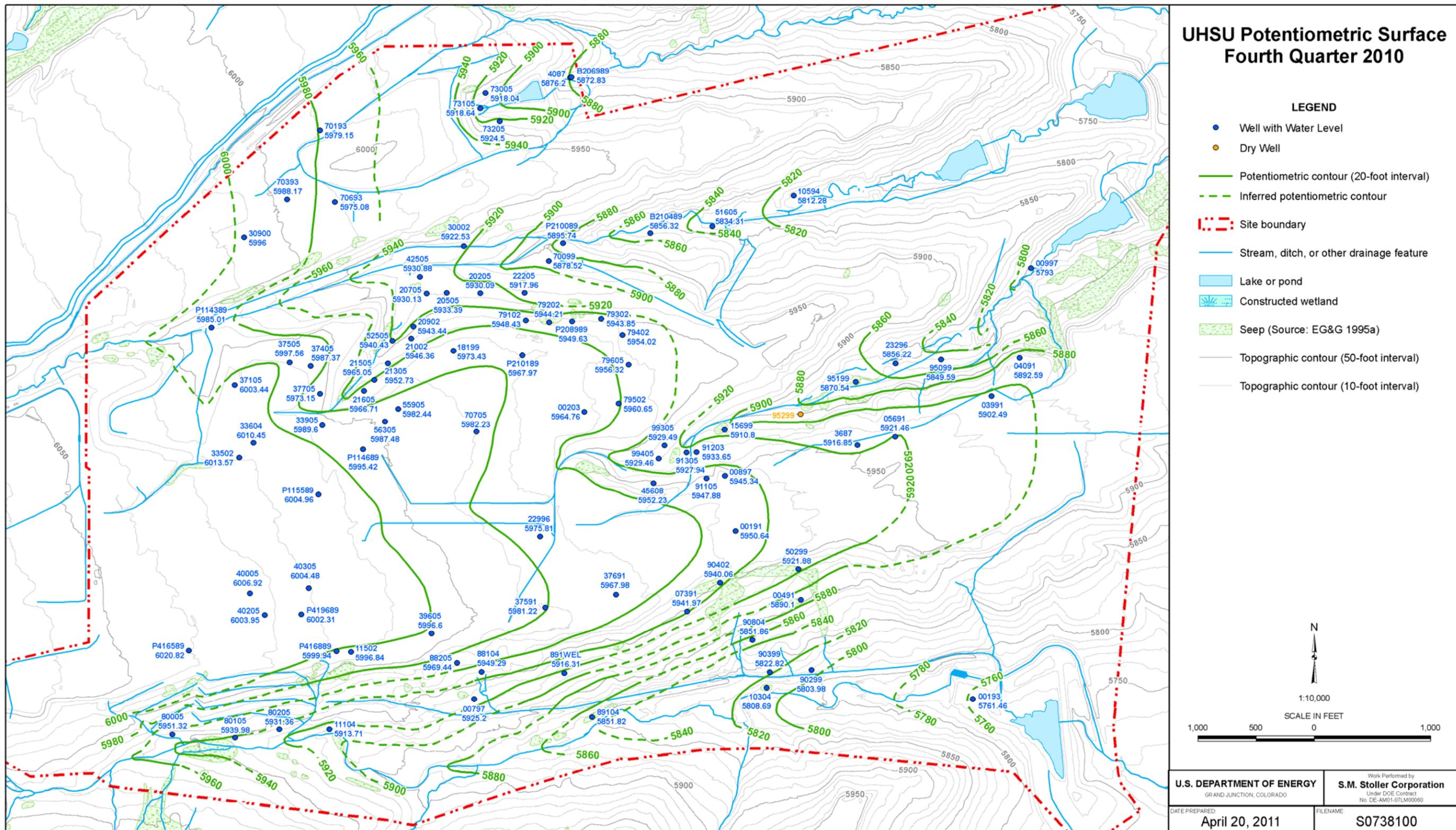


Figure 125. UHSU Potentiometric Contours: Fourth Quarter CY 2009

Groundwater Flow Velocities

Groundwater flow directions and velocities in 2010 are generally consistent with those reported in 2009. 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).

Well pairs selected for use in this report are the same as those selected in 2009.

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 RFCAs 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 2010. (Note that because of an equipment malfunction, the groundwater elevation for well 30002 was not obtained during routine, second quarter water-level measurements. The water level measured during second quarter sampling in June was used instead.) Results of the hydraulic gradient calculation typically differ slightly when data are used from different quarters, but the differences are typically not large, with several exceptions. The hydraulic gradients calculated for well pair 40305-39605 for second and fourth quarters are 0.012 and 0.007, respectively. This relatively large variation is a result of the combination of fairly consistent water elevations in well 39605 during 2010, and more widely varying elevations in well 40305. The steeper gradient observed in second quarter is the result of the significantly higher water level seen in well 40305. The water elevation measured is one of the highest levels seen in this well since 2000. The water level in 40305 was more than 6 feet lower when it was measured in the fourth quarter, resulting in a lower gradient. Similarly, the gradients calculated for well pairs 79102-22205 (0.149 and 0.129) and 79502-99305 (0.071 and 0.059) indicated steeper gradients during second quarter than fourth. In both cases, elevation changes in the downgradient wells are reduced relative to those in the upgradient wells.

The opposite pattern is illustrated by some well pairs. Gradients calculated for well pair 40005-P419689 are 0.003 and 0.010 for second and fourth quarters, respectively. The same general explanation applies as above, but in this case the difference in water levels between wells in the fourth quarter is higher: the water level in the downgradient well, P419689, falls much more than

it does in the upgradient well (40005), resulting in a steeper gradient in the fourth quarter. For well pair 70393-70693, hydraulic gradients for second and fourth quarters are 0.022 and 0.032, respectively. While both wells show sharp declines in water level from second to fourth quarters, the variation during fourth quarter is more significant; thus, the steeper gradient during this time period.

Calculated seepage velocities are only useful as estimates. Table 38 presents the flow velocities calculated using the 2010 data for selected well pairs. These velocities are most often used to estimate the travel time of conservative (nonreactive) constituents. Reactive constituents 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, the hydraulic conductivity, 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 value 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 (i.e., reworked) alluvium has the internal structure 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 will 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.

An example well pair illustrates some of the related difficulties. Well 18199 is located between former B776 and B771. It screens mainly sandstone of the Arapahoe Formation (the “No. 1 Sandstone”; EG&G 1995a) and Rocky Flats Alluvium. 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. For this reason, well 20505 was selected as the downgradient well in this well pair. This well is screened in 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 2010, 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.

Table 38. Calculated Flow Velocities for 2010

Well Pair	Area	2010 Quarter	Geological Unit	WL Elevation, Well 1	WL Elevation, Well 2	dh (ft)	dl (ft)	dh/dl (hydraulic gradient)	Calculated K (cm/s) ^a	v (ft/yr)	Time to Traverse Transect (yr)
P115589-P114689	North IA	2	Qrf	6011.68	6000.92	10.76	550.14	0.020	4.18E-04	84.59	6.50
		4	Qrf	6004.96	5995.42	9.54	550.14	0.017	4.18E-04	75.00	7.34
P114689-21605	North IA/B559	2	Qrf/Qrf/KaKlclst	6000.92	5972.79	28.13	503.78	0.056	3.14E-04	181.24	2.78
		4	Qrf/Qrf/KaKlclst	5995.42	5966.71	28.71	503.78	0.057	3.14E-04	185.15	2.72
56305-21505	B559	2	Qrf/KaKlclst	5992.34	5968.65	23.69	319.61	0.074	2.09E-04	160.62	1.99
		4	Qrf/KaKlclst	5987.48	5965.05	22.43	319.61	0.070	2.09E-04	151.76	2.11
18199-20505	B771	2	Qrf/KaNo.1ss/ Qrf/KaKlclst	5978.27	5933.52	44.75	500.43	0.089	4.06E-04	375.84	1.33
		4	KaNo.1ss/Qrf/ KaKlclst	5973.43	5933.39	40.04	500.43	0.080	4.99E-04	412.86	1.21
P416589-80105	OLF	2	Qrf/Qrf/KaKlclst	6017.36	5936.19	81.17	846.63	0.096	3.14E-04	311.20	2.72
		4	Qrf/Qrf/KaKlclst	6020.82	5939.98	80.84	846.63	0.095	3.14E-04	310.21	2.73
40305-39605	South IA	2	Qrf/KaKlsl/ KaKlclst	6010.93	5997.92	13.01	1126.39	0.012	1.12E-04	13.40	84.05
		4	Qrf/KaKlsl/ KaKlclst	6004.48	5996.6	7.88	1126.39	0.007	1.12E-04	8.11	138.94
40005-P419689	South IA	2	Qrf/KaKlclst/ Qrf/KaNo.1ss	6009.87	6008.29	1.58	478.87	0.003	4.06E-04	13.87	34.53
		4	Qrf/KaKlclst/ Qrf/KaNo.1ss	6006.92	6002.31	4.61	478.87	0.010	4.06E-04	40.46	11.84
P419689-11502	South IA	2	Qrf/KaNo.1ss/ KaKlclst	6008.29	6002.48	5.81	535.27	0.011	3.02E-04	33.91	15.79
		4	Qrf/KaNo.1ss/ KaKlclst	6002.31	5996.84	5.47	535.27	0.010	3.02E-04	31.93	16.76
40305-22996	South IA/ 800 Area	2	Qrf/KaKlclst/Qrf	6010.93	5982.85	28.08	2037.05	0.014	3.14E-04	44.74	45.53
		4	Qrf/KaKlclst/ KaKlclst	6004.48	5975.81	28.67	2037.05	0.014	1.05E-04	15.31	133.02
88205-00797	881 Hillside	2	Qrf/KaKlclst/Qrf	5970.5	5925.68	44.82	343.12	0.131	3.14E-04	424.37	0.81
		4	Qrf/KaKlclst/Qrf	5969.44	5925.2	44.24	343.12	0.129	3.14E-04	418.88	0.82
00191-00491	903 Pad-Lip	2	Qrf/Qrf/KaKlclst	5956.71	5894.42	62.29	816.98	0.076	3.14E-04	247.48	3.30
		4	Qrf/KaKlclst	5950.64	5890.1	60.54	816.98	0.074	2.09E-04	160.58	5.09
07391-10304	Ryan's Pit/ Woman Ck.	2	Qrf/KaKlclst/ Qc/KaKlclst	5944.27	5810.9	133.37	948.74	0.141	1.28E-04	186.56	5.09
		4	Qrf/KaKlclst/ Qc/KaKlclst	5941.97	5808.69	133.28	948.74	0.140	1.28E-04	186.05	5.10

Table 38 (continued). Calculated Flow Velocities for 2010

Well Pair	Area	2010 Quarter	Geological Unit	WL Elevation, Well 1	WL Elevation, Well 2	dh (ft)	dl (ft)	dh/dl (hydraulic gradient)	Calculated K (cm/s) ^a	v (ft/yr)	Time to Traverse Transect (yr)
91105-91203	Oil Burn Pit #2	2	Qrf/KaKlsIt/Qrf/KaKlclst	5948.62	5934.93	13.69	242.17	0.057	2.16E-04	126.58	1.91
		4	Qrf/KaKlsIt/KaKlclst	5947.88	5933.65	14.23	242.17	0.059	1.12E-04	68.18	3.55
P210189-79102	SEPs	2	Qrf/KaKlsIt/KaKlclst	5970.89	5950.93	19.96	301.98	0.066	1.12E-04	76.69	3.94
		4	Qrf/KaKlsIt/KaKlclst	5967.97	5948.43	19.54	301.98	0.065	1.12E-04	74.98	4.03
79102-22205	North of SEPs	2	KaKlclst/KaKlsIt	5950.93	5915.79	35.14	235.62	0.149	1.48E-05	22.90	10.29
		4	KaKlclst/KaKlsIt	5948.43	5917.96	30.47	235.62	0.129	1.48E-05	19.80	11.90
79502-99305	SEPs/B991	2	Qrf/KaKlclst/Qrf/KaKlclst	5964.13	5926.41	37.72	532.37	0.071	2.09E-04	153.54	3.47
		4	KaKlclst/Qrf/KaKlclst	5960.65	5929.49	31.16	532.37	0.059	1.05E-04	63.68	8.36
70393-70693	PU&D/PLF	2	Qrf	5996.85	5987.67	9.18	410.48	0.022	4.18E-04	96.72	4.24
		4	Qrf	5988.17	5975.08	13.09	410.48	0.032	4.18E-04	137.92	2.98
30900-30002 ^b	PU&D/North Walnut Creek	2	Qrf/KaNo.1ss/KaKlclst	5999.93	5927.74	72.19	1890.74	0.038	3.02E-04	119.28	15.85
		4	Qrf/KaNo.1ss/KaKlclst	5996	5922.53	73.47	1890.74	0.039	3.02E-04	121.42	15.57

^a cm/s = centimeters per second

^b Well 30002 water level elevation for second quarter 2010 was measured in June, rather than April as was that in well 30900. Refer to text for additional information.

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 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.

Table 38 presents the results of the calculation of seepage velocities. Refer to Figure 124 and Figure 125 for the locations of the wells. Estimated seepage velocities in 2010 range from a low of 8.11 feet per year (ft/yr) within the bedrock from well 40305 to well 39605 in the southern IA, to a high of 424.37 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 10 months (from well 88205 to well 00797) to over 139 years (from well 40305 to well 39605 in the southern IA). However, once again 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 seasonal recharge patterns, as discussed above. For example, the gradients mentioned above between wells 40005 and P419689 (0.003 and 0.010 for second and fourth quarters, respectively) lead to corresponding calculated velocities of 13.87 ft/yr and 40.46 ft/yr—travel times of over 34 years and about 12 years. As illustrated, these estimates are very sensitive to measured water levels.

In general, the velocities calculated for 2010 are comparable to those calculated prior to Site closure (e.g., K-H 2004b) and are also similar to those presented in 2009 (DOE 2010d). For a more detailed discussion of flow between well pairs by area, refer to the 2006 and 2007 annual reports (DOE 2007c, 2008c).

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 related to differences in gradient, as explained above; when water levels are very similar in both members of a well pair, the low gradient results in a slow travel time, and when levels are very different, the gradient is steeper. The well pairs discussed above in terms of gradients illustrate this scenario, as do other well pairs. Wells that may be of more interest due to contaminants in the groundwater monitored by them include well pair 00191–00491. The former well is near the 903 Pad Plume source area, and the latter is on the hillside southeast of the 903 Pad. The second-quarter travel time calculated for this well pair is 3.3 years, while the fourth-quarter travel time is estimated at slightly more than 5 years. (In 2009, both quarters yielded estimated travel times closer to 5 years.) Similarly, well pair 91105–91205 (Oil Burn Pit #2 source area and downgradient well, respectively) varies from slightly under 2 years to over 3.5 years; in 2009, both quarters yielded estimates exceeding 3.5 years. In this case, the second-quarter conditions leading to the estimate of shorter travel time may have been a factor in the increased contaminant concentrations reported at well 91203 in the fourth quarter of 2010. Refer to Section 3.1.5.3 and the text on groundwater plumes for additional discussion of conditions in these areas.

Velocities and travel times were estimated for the Ryan's Pit Plume area, where the source area is monitored by Evaluation well 07391, and the pathway to surface water is monitored by AOC well 10304. The travel times estimated in 2010 (just over 5 years in both second and fourth

quarters) are equivalent to those estimated in 2009 (DOE 2010d). Both of these wells were sampled in 2010. Data from AOC well 10304 did include a second-quarter detection of TCE that was well below the corresponding RFLMA Table 1 value (DOE 2007a), with an estimated (J-qualified) concentration of 0.68 µg/L. This is the second detection of TCE reported for this well, the first being from a sample collected in fourth-quarter 2007. TCE was not detected in the subsequent sample collected from this well in the fourth quarter of 2010. Given the consistent estimates of travel time, this TCE detection does not appear indicative of a change in flow conditions. See Section 3.1.5.3 for additional discussion of the 903 Pad/Ryan's Pit Plume.

Overall, groundwater flow paths and flow velocities in 2010 show little change from previous years.

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 2010 potentiometric surface maps are from the 1995 Hydrogeologic Characterization Report (EG&G 1995a). Although this depiction of seeps has been the best available map of the seeps for the Site for several years, 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. Thus, efforts to map existing seeps in the COU began in 2010. Although not a rigorous investigation, the project is designed to qualitatively establish the presence of seeps and document their general location.

One observation made during 2010 is that seeps often occur where former building foundations, footer drains, and other features remain that have created preferential pathways for groundwater to reach the surface. This observation supports the design of the monitoring network, which considered the anticipated post-closure groundwater flow directions.

Figure 126 presents the locations where seeps and wet areas were observed during CY 2010. Note that many of the wet areas observed were dry later in the year, including most seeps on the OLF and those identified near the former Building 771 area.

New seeps and wet areas have developed at several locations throughout the COU where wetlands are developing naturally. The *Rocky Flats, Colorado, Site Wetland Mitigation Monitoring and Management Plan* (DOE 2006b) provides guidance for monitoring mitigation wetlands and reporting. The 2010 results are presented in the *Rocky Flats, Colorado, Site, 2010 Annual Wetland Mitigation Monitoring Report* (DOE 2011c).

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, 2010 (CY 1997–2010) for the locations operational in