Assessment of Potential Shell Creek Impacts Resulting from Changes in City of Punta Gorda Facility Withdrawals

Submitted To:

Peace River/Manasota Regional Water Supply Authority
&
City of Punta Gorda Utilities Department

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Executive Summary

The Peace River/Manasota Regional Water Supply Authority (Authority) and the City of Punta Gorda (City) have submitted a conjunctive water use permit application to the Southwest Florida Water Management District (SWFWMD) which includes a request to increase in the permitted maximum monthly Shell Creek Reservoir water withdrawals from 8 to 10 million gallons per day (mgd) to accommodate a projected “gap” between water supply demands and permitted withdrawals. The District has requested information to evaluate and address whether the biological communities of the Shell Creek/lower Peace River estuarine system may be adversely impacted as a result of the proposed “gap” increased permitted freshwater withdrawals. This document has been prepared to provide data and analysis requested by the District.

Available Data Used in the Study

The Shell Creek Hydrobiological Monitoring Program (HBMP) began in 1991 and incorporates a series sampling sites providing comprehensive seasonal and long-term water quality data in both tidal Shell Creek and the freshwater reaches upstream above the dam. In addition to the HBMP data, information from a number of other sources was utilized in conjunction with the “Gap” analyses.

- U.S. Geological Survey (USGG) historical flow gage information from both the lower Peace River and Shell Creek watersheds
- Historic rainfall data from the District, including National Oceanographic and Atmospheric Administration (NOAA) national network sites at Arcadia and Punta Gorda
- Historical water quality data from both the USGS and the City of Punta Gorda Utilities monitoring programs

Analyses In Support of GAP Permit Application

A number of technical analyses and summaries of existing available information were undertaken in conjunction with evaluating potential impacts of the proposed “Gap” increase in withdrawals from the Shell Creek Reservoir.

1. Characterization of Historical Shell Creek Flow Regime. Daily USGS flow data for the period 1966-2004 were used to develop a comprehensive overview of both annual and seasonal variability in Shell Creek freshwater flows.

- Time series and Cumulative Distribution Function (CDF) plots indicate freshwater flows over the Hendrickson Dam vary seasonally and annually. Flows during the drier and cooler historic AMO period (1966-1994) were lower when compared with a wetter and warmer recent AMO period (1995-2004). Higher flows occurred primarily in wet-season months (June 16 through September 15).

- The USGS Seasonal Kendall Tau method was used to test for significant long-term changes in flows. Results are consistent with other studies which also indicate that long-term increases in base flows in Shell Creek during winter/spring flows are a result of agricultural groundwater augmentation.

- Analyses of variance (ANOVA) results indicate no significant differences in flows between the previously described AMO periods.

2. Influences of Withdrawals on Flow Characteristics. The initial proposed approach to assessing the influence withdrawal increases was to develop a baseline "un-impacted" flow hydrograph by reintroducing withdrawals back into measured 1972-2004 Shell Creek flows. However, further analysis indicated that withdrawal rates over the period of record have increased and, more importantly, there is often no direct relationship between decreasing withdrawals and increasing flows over the dam, since withdrawals under no-flow conditions don't direct influence on flows.

Consequently, an alternative was proposed that consisted of adjusting the historic withdrawals to the maximum current withdrawal capacity (8 mgd), followed by a series of 2 mgd incremental increases in withdrawals. Data for the period 1972-2004 were used to compare potential maximum differences in flows that could result from increasing the current maximum withdrawal to the proposed withdrawal (10 mgd), as well as 12, 14 and 16 mgd withdrawals. Conversely, very conservative estimates of the relative magnitude of potential differences between the current maximum withdrawal capacity and the baseline "no withdrawal" scenario might be approximated by comparing the predicted differences between 8 and 16 mgd, and then subtracting that estimate from the current maximum capacity. These estimates would be extremely conservative since withdrawals do not directly affect daily flows once water stops flowing over the dam.

Based on this analysis, the greatest changes in flows were predicted during the lowest monthly flows, and changes decreased in magnitude as flows increased. Differences between the current maximum capacity and alternative withdrawals indicate that the proposed "Gap" permit increase from 8 to 10 mgd would result in relatively small changes in the range, minimum, maximum, and other statistics associated with flows. While changes in flows due to withdrawals are most conspicuous during the spring dry season, withdrawals could potentially reduce flows significantly on a percentage basis during any month as a result of the wide seasonal variability.

3. Influences of Flow on Salinity, Dissolved Oxygen, and Chlorophyll *a*. Data from selected Shell Creek HBMP sites along tidal Shell Creek monitoring transect were used to determine relationships between flow and these three water quality parameters.

- **Salinity**. Under no-flow conditions, surface salinities near the dam can reach nearly 15 psu (practical salinity units). As flows increase, salinities can decrease to zero, although the effect of flow on salinity decreases downstream, and the flow at which no further changes in salinities occur increases downstream. Variability increases in the salinity flow relationship moving downstream along the transect as a result of the combined effects tidal volume and Peace River flows. Unusually high tides or extended periods of southerly winds, may move higher salinity water upstream increasing salinities beyond those predicted using typical salinity/flow relationships.

- **Dissolved Oxygen**. Seasonal DO values were analyzed to examine the influence of flow and temperature on observed DO concentrations. Results indicated that bottom DO values are generally lower than surface DO values, regardless of flow, although differences become less distinct under very high flows. Also, DO levels at the dam are low at low flows, regardless of season, but differences are less apparent downstream. A pattern of declining DO values with high flows occurs during the summer, and may be a result of related to higher water temperatures, which increase respiration rates and decrease the ability of water to physically hold oxygen.

- **Chlorophyll *a*.** Data analyses indicate that chlorophyll *a* levels decline with decreasing flows. This is probably due to the combined influences of increases in water color and a decrease in residence time (wash-out).

- **Univariate and Cumulative Frequency (CDF) Analyses.** These analyses were performed to evaluate spatial and temporal differences in salinity, dissolved oxygen and chlorophyll *a* along the Shell Creek monitoring transect. Results indicate spatial gradients in surface and bottom salinity levels, but not DO or chlorophyll *a*. Temporal differences are apparent from surface and bottom salinity data in the tidal portion of Shell Creek.

4. Potential Influences on Salinity of Facility Freshwater Withdrawals. Modeling and analyses, including CDF plots, were used to measure the magnitude and duration of potential salinity changes in the tidal reach of Shell Creek downstream of the Hendrickson Dam due to the proposed increase in withdrawals from the existing 8 mgd to the proposed 10 mgd. Potential increases in surface and bottom salinities along Shell Creek due to a proposed increase in withdrawals from 8 to 10 mgd would be very small when compared to both the short and longer term seasonal variations occurring naturally in this reach of the creek.

5. Comparisons of Flows with and without Proposed Withdrawals. The USGS has successfully used log-Pearson Type III distributions for assessing low-flow frequency changes. The primary objective of these analyses is the assessment of potential changes in flow-duration and lowest mean-discharges for various consecutive-day periods under various water management alternatives. The results of these analyses indicated only small differences between the current maximum 8 mgd withdrawal and the proposed "Gap" increase to 10 mgd.

6. Characterization of Major Freshwater Ions. Relevant long-term monitoring data were gathered, reviewed, standardized and combined from a number of sources to characterize current and historical trends in water quality characteristics and major ion constituents of the two major upstream freshwater sources (Shell and Prairie Creeks), as well as within the City of Punta Gorda's reservoir. While most of the analyses indicate no significant trends in water quality, some changes are likely associated with increases in groundwater use and "tail water" agricultural discharges to natural surface waters. For example, there has been an increase in chloride levels over time at Prairie Creek near Fort Ogden and Shell Creek at CR 764. Data for Prairie Creek at CR 764 indicate increases in specific conductance, hardness, total dissolved solids, and chlorides. Shell Creek Reservoir data indicate increases in specific conductance, hardness, chloride, sulfate and silica levels over time. Increases in surface DO levels also suggest that the reservoir may be more eutrophic due to increased agricultural development in the upstream watersheds.

Within the reservoir, concentrations of most parameters, including specific conductance, hardness, DO, pH, total dissolved solids, total Kjeldahl nitrogen (TKN), total phosphorus, orthophosphorus, total organic carbon, and alkalinity increased with increasing flows, while color, sulfate, and chloride decreased.

7. Riparian Vegetation. The spatial distribution of riparian vegetation along estuarine Shell Creek below the Hendrickson Dam was evaluated and compared with previous GIS vegetation patterns information developed by Florida Marine Research Institute (FMRI) for the District from field verified 1994 aerials. Vegetation along the creek transitions downstream from a larger mix of low-salinity and freshwater species, to fewer species tolerant of a larger range in salinities, to species such as mangroves and needle rush, which are tolerant of salinities much greater than that of sea water.

Within a given salinity regime, other factors become more important in affecting marsh species distributions. For example, under freshwater conditions, species competition influences distributions. Under higher salinity conditions, elevation becomes more important, as does proximity to wave energy. For instance, leather fern was more frequent on the steep side (outside) of the channel bends, while bulrushes typically occurred on the inside of the channel bends, where the change in elevation is more gradual. In these cases, elevation data (or distance from channel) may be important if vegetation distributions are to be predicted.

Mapping data from 1994 (FMRI 1998) and this 2006 “Gap” report indicate a spatial shift to a larger number of freshwater species, specifically giant cutgrass, upstream of the Myrtle Slough confluence. In addition, the distribution of at least one species, bulrush, appears to have increased along the river channel since 1994. Salinity data indicate lower salinities during 2002 – 2004, compared with 1991 – 2001, and changes in salinity could cause a slow shift to larger numbers of more typically freshwater species. Bulrushes are tolerant of a wide range of salinities and may easily expand into gaps where other species are absent.

However, the resolution of the digital orthophoto quadrangle (DOQQs) used may limit the ability make this comparison and, as noted by the authors of the FMRI report, better resolution photographs would have been helpful in making more accurate observations. Finally, although not addressed in this study, the impact of recent hurricanes cannot be disregarded when considering possible spatial and temporal changes in vegetation along Shell Creek.

8. Evaluation of Information of Flow Influences on Biological Community Structure. Biological information gathered as part of the Peace River HBMP and the District minimum flow studies were evaluated and summarized in order to provide a general overview of the relationships between historical seasonal and long-term variations in Shell Creek flow and the structure and composition of biological communities in the Shell Creek/lower Peace River estuarine system. The information, graphics and conclusions contained in previous studies conducted for the District were reviewed and summarized as part of this report with regard to evaluating the salinity tolerances of key groups of estuarine species and assess potential responses to predicted levels of salinity increase potentially resulting from proposed "Gap" withdrawals.

Contents

Technical Support for Conjunctive "Gap" Application by the City of Punta Gorda and Peace River/Manasota Regional Water Supply Authority

1.0 Overview

The overall primary goal and combined objectives of the individual technical analyses presented and summarized in this document are to provide District staff with sufficient information to ensure that the biological communities of the Shell Creek/lower Peace River estuarine system are not significantly adversely impacted as a result of proposed "Gap" increased permitted freshwater withdrawals. The City of Punta Gorda's water treatment facility has (and continues) to withdraw water for public supply from the Shell Creek Reservoir under permit by the Southwest Florida Water Management District (SWFWMD). Table 1.1 provides a historical summary of these District permits and their associated permitted levels of withdrawals. Under the proposed "Gap" permit modification, the maximum peak monthly Facility withdrawal would be increased to 10.0 mgd (15.47 cfs).

Table 1.1
Shell Creek Permit History

Water Use Permit Number	Time Period	Average Permitted Withdrawal (mgd)	Maximum Peak Monthly Permitted Withdrawal (mgd)
200871.01	11/03/76 to 11/03/82	NA	NA
200871.02	04/06/83 to 04/06/89	3.9	7.4
200871.03	11/28/89 to 11/28/95	4.22	8.1
200871.04	08/26/97 to 07/07/99	5.38	6.9
200871.05	07/07/99 to 12/20/02	5.38	6.9
200871.06	12/20/02 to 8/26/07	5.38	6.9

2.0 Shell Creek Hydrobiological Monitoring Program (HBMP) Data and Sampling Design

Since its implementation in 1991, the Shell Creek HBMP design incorporates a series of nineteen sampling sites (see **Map 2.1** and **2.2**), that provide a comprehensive network of information regarding seasonal and long-term variability in water quality in Shell Creek and the Peace River:

- Upstream of the Hendrickson Dam
- Within the tidal portion of Shell Creek
- Within the Peace River both upstream and downstream of its confluence with Shell Creek

The HBMP includes monthly measurements of physical, chemical and biological water quality characteristics using the design summarized in Table 2.1 and **Map 2.2**.

Table 2.1
Sampling Design

Parameter	Sampling Location																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Physical *In Situ* Profiles																			
Water Chemistry (surface)																			
Secchi Disk																			
Extinction Coefficient																			

- *In situ* physical water column profile characteristics are measured at each of the nineteen sampling sites at 0.5 meter intervals from just below the surface (0.15 meters) to just above the bottom.

- Subsurface water quality samples are collected and analyzed for a suite of parameters at sampling locations 1 through 9 (Table 2.2).

- The penetration of light into the water column is inferred by the measurements of Secchi Disk depths at sampling locations 1 and 2.

- More accurate determinations of the penetration of light into the water column are determined at sampling locations 3 through 9 from calculated extinction coefficients based on *in situ* profiles of photosynthetically active radiation (PAR).

Table 2.2
Water Chemistry Parameters and Methods

Parameter	*Method*	Detection Limit
Color	EPA 110.2	1.0 Co_Pt Units
Chloride	EPA 325.2	0.4 mg/l
Turbidity	EPA 180.1	0.1 mg/l
Total Suspended Solids	EPA 160.2	0.8 mg/L
Alkalinity	EPA 310.1	0.1 mg/l
NO2+NO3 Nitrogen	EPA 353.2	0.002 mg/l
NH3+NH4 Nitrogen	EPA 350.1	0.002 mg/l
Total Kjeldahl Nitrogen (TKN)	EPA 351.2	0.1 mg/l
Ortho-Phosphorus	EPA 365.2	0.002 mg/l
Total Phosphorus	EPA 365.4	0.002 mg/l

Table 2.2
Water Chemistry Parameters and Methods

Parameter	*Method*	Detection Limit
Silica	EPA 370.1	0.05 mg/l
Chlorophyll *a*	Flurometeric SM 10200H.3 Spectrophotometric Sm10200.H2	0.25 ug/l 2.0 ug/l

The Shell Creek HBMP permit condition specifies that the monthly measurement of ambient physical, chemical and biological water quality characteristics be made within two calendar days of the "fixed" station sampling element of the Peace River HBMP. This coordination provides the District monthly comparable measurements of water quality characteristics throughout the lower Peace River and Shell Creek areas of the Charlotte Harbor estuary.

3.0 Additional Existing Data Sources

The Shell Creek HBMP has historically also utilized data available from a number of additional long-term data sources (listed below).

3.1 Gaged Freshwater Inflows. An extensive network of U.S. Geological Survey (UGSG) flow gages with long-term records from the lower Peace River and Shell Creek watersheds (see Table 3.1). Historic and current data are available at the Tampa USGS Office Web Site (http://fl.water.usgs.gov/Tampa/index.html).

Table 3.1
USGS Gages in Peace River/Shell Creek Watersheds

Location	Gage Number	Record
Peace River at Arcadia	02296750	1931 - Present
Horse Creek near Arcadia	02297310	1950 - Present
Joshua Creek at Nocatee	02297100	1950 - Present
Prairie Creek near Ft. Ogden	02298123	1963 - Present
Shell Creek near Punta Gorda	02298202	1965 - Present

3.2 Rainfall. SWFWMD receives daily area rainfall data from four long-term gages within the general area (see Table 3.2). The Arcadia and Punta Gorda sites are part of the National Oceanographic and Atmospheric Administration's (NOAA) national network, while the other two are maintained in conjunction with the two consumptive water use permits. Historic and current rainfall data from throughout the Southwest Florida Water Management District (SWFWMD) are available at the SWFWMD Web Site (http://www.swfwmd.state.fl.us/).

Table 3.2
Existing Network of Long-Term Rainfall Gages

Name	District Gage Number	Period of Record
Arcadia	148	1907 - Present
Peace River Water Facility	331	1980 - Present
Shell Creek Water Facility	211	1986 - Present
Punta Gorda	255	1914 - Present

3.3 Continuous Tide and Conductivity Recorders. A primary goal of both the Shell Creek and Peace River/Manasota Regional Water Supply Authority HBMP programs has been the development of information detailing spatial and temporal relationships between small scale changes in freshwater inflows and corresponding salinity patterns in the Shell Creek/lower Peace River/Charlotte Harbor. In order to obtain greater temporal frequency, in 1996 the USGS installed an automated water level gage approximately 15.5 kilometers upstream of the mouth of the Peace River at Harbour Heights. This gage is located immediately adjacent to Shell Creek HBMP Sampling Site 8 (which is identical to the Peace River HBMP fixed Station 14). This gaging station measures tide stage and both near surface and bottom conductivity at 15-minute intervals. In 1997, as part of the District's anticipated establishment of minimum flows for the lower Peace River and Shell Creek, the USGS placed a similar continuous recorder in Shell Creek.

Table 3.3
Existing Continuous Water Level and Conductivity USGS Gages In The Shell Creek/Lower Peace River Estuary

Name	USGS Gage Number	Record
Peace River at Harbour Heights	02297460	1996 - Present
Shell Creek	02298208	1997 - Present

3.4 City of Punta Gorda Water Quality Data. Additional historic water quality data are also available from both the USGS and the City of Punta Gorda (Table 3.4). These data, combined with additional information from the three HBMP sites located upstream of the Hendrickson Dam and more recent District ambient monitoring information, were used to assess long-term changes in water quality in the freshwater reaches of the Shell/Prairie system.

Table 3.4 USGS and City of Punta Gorda Water Quality Information	
Station ID	**Station Name/Description**
USGS Long-term Water Quality Monitoring Sites	
2298123	Prairie Creek Near Fort Ogden (SR 31)
2298202	Shell Creek Near Punta Gorda (Reservoir – HBMP #3)
City of Punta Gorda Water Quality Data	
PC 764	Prairie Creek at SR 764 (HBMP #1)
SC 764	Shell Creek at SR 764 (HBMP #2)
Res	Shell Creek Reservoir
Intake	Intake to Treatment Facility

3.5 Lower Peace River Data. Although the Shell Creek HBMP was established in 1991, relevant data sources developed in conjunction with the "older" Peace River/Manasota Regional Water Supply Authority Facility's HBMP monitoring program are available that include information dating back to 1975.

4.0 Technical Analyses In Support of "Gap" Permit Application

Based on discussions and subsequent SWFWMD staff recommendations, a series of technical methods including graphical and statistical analyses were used to summarize and address potential impacts of proposed additional "Gap" withdrawals from the Shell Creek reservoir. Relevant historical data and information collected through 2004 were included in the analyses, which were used to quantify the magnitude of potential impacts relative to historical conditions in support of the Conjunctive Water Use Permit Application. The analytical approaches and conclusions to four different potential areas of impacts are described below.

4.1 Characterization of Historical Shell Creek Flow Regime. Daily USGS flow data for the period 1966-2004 were used to develop a comprehensive overview of both annual and seasonal variability in Shell Creek freshwater flows.

Time Series and CDF Plots. A series of summary graphics were developed and are presented in "Appendix A - Flow Characterization". These graphics provide a comprehensive overview of both long-term and seasonal patterns with regard to temporal changes in Shell Creek flows. Graphical analyses are listed below.

- Time series plots of Mean, Minimum, Q95, Q90, Q75, Median (Q50), Q25, Q10, Q05 and Maximum monthly Shell Creek gaged flows for the 1966-2004 period are presented in **Figures 4.1.1** through **4.1.10**. These graphics indicate that, while freshwater flows over the Hendrickson Dam have varied widely both seasonally and yearly, flows have been similar with the exception of a possible increase over the past 10-15 years.

- Moving average 3, 15, 30 and 60 day Shell Creek flows were calculated for each day over the gaged period of record. Time series plots of minimum monthly values for each of these four different lagged flow terms were created (**Figures 4.1.11** through **4.1.14**). Graphical analyses of monthly minimum flows again indicated that Shell Creek flows over the dam have been relatively stable over the period of record with possibly a slight increase in the lowest flows over the past decade.

- Cumulative distribution function (CDF) plots for: 1) the overall period of record (1966-2004); 2) the dry Atlantic Multi-decadal Oscillation (AMO) period (1966-1994); and 3) the recent wet-AMO period (1995-2004) are provided in **Figures 4.1.15** through **4.1.17**. These graphics indicate that flows during the past decade correspond with a warmer (wetter) than average AMO, when compared with the previous cooler (dry) twenty-nine year AMO period. This graphic shows that the apparent increase in flows has occurred primarily in the four summer wet-season months (June 16 through September 15th).

- CDF plots for the same three periods for each of the twelve months are presented in **Figures 4.1.18** through **4.1.29**. These CDF plots of differences in the distributions among flows during the AMO periods support the previous observation that much of the observed change in Shell Creek flows has occurred due to wetter summer wet-seasons.

- Finally, box and whisker plots of annual average hydrographs of: 1) monthly; 2) mean monthly; and 3) median monthly Shell Creek flows for each of the three time periods are presented in **Figure 4.1.30** through **4.1.38**. Plots again indicate the differences between the drier historic cooler AMO period (1966-1994) and the wetter recent warmer AMO period (1995-2004) during the typical summer wet-season periods.

Statistical Tests for Trends. The USGS Seasonal Kendall Tau method was used to test for long-term changes in flows. Results are summarized in Table 4.1.1.

- Daily values were used for Kendall Tau Trend Tests of the Mean, Maximum, Q5, Q10, Q25, Q50 (Median), Q75, Q90, Q95 and Minimum monthly flows.

- Similar trend tests were applied to for monthly minimum 3, 15, 30 and 60 day moving average flows.

The results of the statistical analyses indicate that there have been long-term increases in baseflow in Shell Creek. These findings are not unexpected, given previous and ongoing studies that have concluded that Prairie Creek and Shell Creek flows are and continue to be augmented during the typical dry winter/spring periods by discharges associated with increased agricultural groundwater use.

Table 4.1.1
Statistical Summary of Results of Seasonal Kendal Trend Analyses Based on Monthly Maximum Values (1966-2004)

Monthly Flow Metric	Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic	Trend
Shell Creek near Punta Gorda (USGS Gage 2298202)					
Monthly Mean	0.076	0.019	0.201	0.998	
Monthly Maximum	0.035	0.281	0.545	1.000	
Monthly Q5	0.047	0.143	0.406	1.246	
Monthly Q10	0.047	0.142	0.402	1.060	
Monthly Q25	0.066	0.040	0.225	1.069	
Monthly Q50 (Median)	0.072	0.026	0.226	0.840	
Monthly Q75	0.076	0.018	0.205	0.540	
Monthly Q90	**0.114**	**0.000**	**0.067**	**0.674**	▲
Monthly Q95	**0.123**	**0.000**	**0.053**	**0.667**	▲
Monthly Minimum	**0.126**	**0.000**	**0.050**	**0.667**	▲
Monthly 3-day Minimum	**0.150**	**0.000**	**0.013**	**1.042**	▲
Monthly 15-day Minimum	0.080	0.015	0.212	0.541	
Monthly 30-day Minimum	0.090	0.001	0.150	0.729	
Monthly 60-day Minimum	0.090	0.007	0.184	0.988	

Note: Direction of arrow denotes significant increasing or decreasing trend. Red arrows are significant at p=0.05 level, while blue show trends significant at p=0.10, and blanks indicate no significant trends in flows.

Analyses of Variance (ANOVA). The Waller-Duncan K-ratio t Test; the Ryan-Einot-Gabriel-Welsch Multiple Range Test; and the Bonferroni (Dunn) t Test were used to make statistical comparisons among mean monthly flows between the dry (1966-1994) and wet (1995-2004) AMO periods (Table 4.1.2). These three statistical tests were used to provide overall comparisons, since each statistically accounts and corrects for unequal cell sizes in a slightly different manner. Results indicate that although monthly mean and median Shell Creek flows over the past ten years have, on average, been higher during the summer wet-season than during the previous 1966-1994 cooler, drier AMO period, comparisons were not significant at the 0.05 level (5%).

Table 4.1.2
Comparisons of Overall and Monthly Mean Shell Creek Flows Between the Historical Dry and Recent Wet AMO Periods

Comparisons	Monthly Mean		Monthly Median	
	Dry AMO 1966-1994	Wet AMO 1995-2004	Dry AMO 1966-1994	Wet AMO 1995-2004
Overall	330	418	275	323
January	155	211	147	188
February	175	205	147	192
March	271	169	196	121
April	126	79	96	62
May	93	87	67	71
June	455	561	330	221
July	590	795	514	649
August	662	853	595	703
September	742	1003	658	809
October	414	550	303	440
November	165	228	138	142
December	122	277	111	272

- Comparisons of mean and median values between time periods followed by different letters are significantly different at the p=0.05 level (5%).

4.2 Influences of Withdrawals on Flow Characteristics. The Initial approach, discussed with SWFWMD staff, was to develop a baseline "un-impacted" flow hydrograph by adding actual City of Punta Gorda withdrawals back into the gaged 1972-2004 historic Shell Creek flows (the period for which accurate flow records exist). Then the relative magnitude and variation in the flows due to historic withdrawals and expected under proposed withdrawal schedules, could be calculated. This approach has been successful in assessing the potential impacts of freshwater withdrawals by the Peace River Facility on the downstream segments of the lower Peace River estuary.

However, flaws in this approach became apparent when analyzing the proposed "Gap" withdrawal increases from current permitted levels taken from above the Hendrickson Dam. Not only have withdrawal rates increased significantly over the period of record, but even more importantly, in-stream flow did not increase proportionally with decreasing withdrawals. In fact, during no-flow conditions, withdrawals have no influence on flow whatsoever.

The alternative approach agreed to by District staff consisted of first adjusting the historic withdrawals to the maximum current capacity of the Facility (8 mgd). Next, a series of alternative flows were developed using increasing two mgd increments. A series of analyses were then conducted using the historic 1972-2004 flow record to compare potential maximum differences in Shell Creek flows anticipated due to increasing the current maximum capacity to the proposed 10 mgd, as well as other possible further increments of 12, 14 and 16 mgd.

Conversely, very conservative estimates of the magnitude of potential differences between the current maximum capacity and the baseline "no withdrawal" condition might be approximated by comparing the predicted differences between 8 and 16 mgd withdrawals, and then subtracting that value from the current maximum capacity. However, those estimates would be extremely conservative since withdrawals do not directly influence daily flows once water stops flowing over the structure. Results of these analyses are below.

- Line plots were developed of monthly (Jan-Dec) flows depicting potential maximum differences between the current 8 mgd maximum capacity and proposed 10 mgd, as well as potential 12, 14 and 16 mgd withdrawals. Individual graphics are presented in **Figure 4.2.1** through **Figure 4.2.10** (**Appendix B** – "Influences of Withdrawals on Flows") showing predicted monthly differences for Mean, Minimum, Q95, Q90, Q75, Median, Q25, Q10, Q5 and Maximum flows over the 1972-2004 historic period of record. As expected, the largest predicted changes would be expected during the lowest monthly percentiles and become progressively less apparent as flows increase. These graphical analyses also clearly indicate the lack of changes at the lowest monthly percentiles when flows are zero.

- A similar series of line plots are also presented contrasting differences in total annual flow percentiles potentially resulting from the five withdrawal alternatives. Figures 4.2.11 through 4.2.20 depict differences in annual Mean, Minimum, Q95, Q90, Q75, Median, Q25, Q10, Q5 and Maximum flows over the 1972-2004 period. Again differences are greatest for the lowest percentiles and rapidly become less apparent when comparing differences under higher flow conditions.

- Box and whisker plots (by month) of differences between the current maximum Facility capacity and alternative withdrawal increases are presented in **Figures 4.2.21** through **4.2.36** for 3-day, 15-day, 30-day and 60-day moving averages over the 1972-2004 period.

Table 4.2.1
Box and Whisker Plots of Moving Average Flows for Alternative Withdrawals

Average Period	8-10 mgd	8-12 mgd	8-14 mgd	8-16 mgd
3-day	Figure 4.2.21	Figure 4.2.22	Figure 4.2.23	Figure 4.2.24
15-day	Figure 4.2.25	Figure 4.2.26	Figure 4.2.27	Figure 4.2.28
30-day	Figure 4.2.29	Figure 4.2.30	Figure 4.2.31	Figure 4.2.32
60-day	Figure 4.2.33	Figure 4.2.34	Figure 4.2.35	Figure 4.2.36

These graphics indicate that the proposed "Gap" increase from 8 to 10 mgd would result in relatively small downward shifts in the monthly statistical distributions of each of the average lagged flow terms.

- **Figures 4.2.37** through **4.2.40** show box and whisker plots (by month) of expected percent change in flow between the current maximum capacity and alternative potential increases. During periods of very low flows over the structure any withdrawals can result in marked changes when viewed on a percentage basis. While changes due to facility withdrawals are most apparent during the spring dry-season due to the wide degree of inter-annual seasonal variability, withdrawals could potentially reduce flows appreciably on a percentage basis during any month. CDF plots of percent change in flows between the Facility's current capacity and alternative maximum increases are shown in **Figure 4.2.41**.

4.3 Influences of Flow on Salinity, Dissolved Oxygen, and Chlorophyll *a*. A series of graphics showing the influences of Shell Creek flow on selected key water quality parameters in the tidal reaches downstream of the dam are graphically presented using 1991-2004 fixed station HBMP data. The results of these analyses are described below.

Salinity. Graphical analyses are presented (see **Appendix C** – "Influences of Flow on Selected Parameters") in Figures 4.3.1 through 4.3.36 (Table 4.3.1) of the relationships between flow and both sub-surface and near bottom salinity at nine selected HBMP fixed locations along the Shell Creek monitoring transect and one Peace River background location (Stations 11, 4 through 9, and 16 and 17, as shown in **Maps 2.1** and **2.2**.) A review of these figures indicates a number of interesting patterns:

- Under no-flow conditions, surface salinities near the dam can reach nearly 15 psu (practical salinity units) during extended drought conditions such as occurred between 1999-2002.

- Both subsurface surface and near bottom salinities decrease rapidly with increasing flow and reach and remain zero at and beyond some rate of freshwater inflow.

- The rate of the decline in salinity with increasing flow is less, and the flow needed to result in zero salinity increases as you move downstream along the HBMP monitoring transect.

- The variation in the relationship between salinity and flow (the observed spread of data points) also increases moving downstream along the monitoring transect. This result reflects greater variability due to increased stream volume and the greater influences of both tidal and lower Peace River flow variations.

- There are a number of higher salinities observations that do not seem to fix the normal salinity/flow relationships. These high salinity values probably result from unusually high tides, or very strong, extended periods of southerly winds that push higher salinity water upstream into the lower Peace River/Shell Creek estuarine system.

Table 4.3.1
Salinity Flow Relationships

Station	River Kilometer	Same Day Flow		Seven Day Average Flow	
		Surface Salinity	Bottom Salinity	Surface Salinity	Bottom Salinity
11	9.9	Figure 4.3.1	Figure 4.3.2	Figure 4.3.19	Figure 4.3.20
4	8.74	Figure 4.3.3	Figure 4.3.4	Figure 4.3.21	Figure 4.3.22
5	6.72	Figure 4.3.5	Figure 4.3.6	Figure 4.3.23	Figure 4.3.24
6	4.61	Figure 4.3.7	Figure 4.3.8	Figure 4.3.25	Figure 4.3.26
7	2.35	Figure 4.3.9	Figure 4.3.10	Figure 4.3.27	Figure 4.3.28
16	1.26	Figure 4.3.11	Figure 4.3.12	Figure 4.3.29	Figure 4.3.30
17	0.43	Figure 4.3.13	Figure 4.3.14	Figure 4.3.31	Figure 4.3.32
9	-0.37	Figure 4.3.15	Figure 4.3.16	Figure 4.3.33	Figure 4.3.34
8	Lower Peace River	Figure 4.3.17	Figure 4.3.18	Figure 4.3.35	Figure 4.3.36

Dissolved Oxygen (D.O.). Graphical analyses are also presented in **Figures 4.3.37** through **4.3.72** (Table 4.3.2) of the relationships between flow and both sub-surface and near bottom D.O. at eight selected HBMP locations and one lower Peace River background site along the monitoring transect. The data were seasonally divided into two groups: 1) December through February; and 2) April through September, to show the relative magnitude and interactions of flow and temperature on D.O. concentrations. The resulting figures indicate a number of distinct patterns:

- As expected, bottom dissolved oxygen levels are generally lower than corresponding surface levels along the Shell Creek transect regardless of flow.
- This difference between surface and bottom D.O. levels becomes less distinct under very high flow conditions, regardless of season.
- Upstream, near the dam, very low bottom D.O. levels occur under low flow conditions, regardless of season.
- These low bottom D.O. levels under low flows become increasing less apparent moving downstream.
- Both surface and bottom D.O. levels generally decline with increasing flow during the summer. However, this pattern of declining D.O. levels during periods of increasing flow is not similarly apparent during cooler (December-February) months. These seasonal differences between D.O. levels and flow are an indication that higher flows during the summer are also related to higher water temperatures. Higher water temperatures

increase respiration rates and decrease the ability of water to physically hold oxygen, both of which result in lower D.O. levels.

Table 4.3.2
Dissolved Oxygen Flow Relationships

Station	River Kilometer	Same Day Flow		Seven Day Average Flow	
		Surface D.O.	Bottom D.O.	Surface D.O.	Bottom D.O.
11	9.9	Figure 4.3.37	Figure 4.3.38	Figure 4.3.55	Figure 4.3.56
4	8.74	Figure 4.3.39	Figure 4.3.40	Figure 4.3.57	Figure 4.3.58
5	6.72	Figure 4.3.41	Figure 4.3.42	Figure 4.3.59	Figure 4.3.60
6	4.61	Figure 4.3.43	Figure 4.3.44	Figure 4.3.61	Figure 4.3.62
7	2.35	Figure 4.3.45	Figure 4.3.46	Figure 4.3.63	Figure 4.3.64
16	1.26	Figure 4.3.47	Figure 4.3.48	Figure 4.3.65	Figure 4.3.66
17	0.43	Figure 4.3.49	Figure 4.3.50	Figure 4.3.67	Figure 4.3.68
9	-0.37	Figure 4.3.51	Figure 4.3.52	Figure 4.3.69	Figure 4.3.70
8	Lower Peace River	Figure 4.3.53	Figure 4.3.54	Figure 4.3.71	Figure 4.3.72

- **Chlorophyll *a*.** Relationships of sub-surface chlorophyll *a* levels with same day and lagged flows are presented in **Figures 4.3.73** through **4.3.84** (Table 4.3.3) for the five HBMP fixed water chemistry transect sampling sites and one lower Peace River background location. Seasonal differences in the relationships between chlorophyll *a* and flow are apparent and the data indicate that chlorophyll *a* levels generally decline with flow. This is probably due to the combined influences of increases in water color and decreases in residence time (wash-out). Similar relationships between chlorophyll *a* and flow have also been observed from lower Peace River HBMP data.

Table 4.3.3
Chlorophyll *a* Flow Relationships

Station	River Kilometer	Same Day Flow	Ten Day Average Flow
		Surface Chlorophyll *a*	Surface Chlorophyll *a*
4	8.74	Figure 4.3.73	Figure 4.3.79
5	6.72	Figure 4.3.74	Figure 4.3.80
6	4.61	Figure 4.3.75	Figure 4.3.81
7	2.35	Figure 4.3.76	Figure 4.3.82
9	-0.37	Figure 4.3.77	Figure 4.3.83
8	NA	Figure 4.3.78	Figure 4.3.84

Univariate and Cumulative Distribution Functions (CDF). Additional graphical analyzes were prepared to further clarify the spatial and temporal differences in salinity, dissolved oxygen and chlorophyll *a* that occur along the Shell Creek monitoring transect. Six HBMP sampling sites (numbers 11, 4, 5, 6, 7 and 9) spaced relatively equally along the monitoring transect were selected to show differences in salinity and dissolved oxygen. Only five of these sites were used in the analyses of chlorophyll *a* levels, since it is not measured at site #11.

- **Figures 4.3.85** through **4.3.87** are univariate plots of the statistical distributions of each of these three water quality parameters to indicate spatial differences along the tidal Shell Creek reach. These plots show that while there are distinct spatial gradients along the monitoring transect in surface and bottom salinity levels, but not in dissolve oxygen or chlorophyll *a* concentrations.

- CDF plots presented in **Figures 4.3.88** through **4.3.92** depict differences in the distributions of these parameters among the water quality monitoring locations. Again, these figures show the spatial differences in salinity, but not in either dissolved oxygen or chlorophyll *a*.

- Finally, temporal differences in surface and bottom salinities are apparent in **Figures 4.3.93** and **4.3.94** between the extended drought conditions that characterized the 1999-2001 time period and the following three wetter years, 2002-2004. The magnitude of the differences depicted clearly indicates the high degree of natural variability in salinity that can occur in the tidal reach of lower Shell Creek.

4.4 Potential Influences of Freshwater Withdrawals on Shell Creek Salinity. The primary objectives of the presented modeling and analyses were to characterize the magnitude and duration of potential salinity changes downstream of the Hendrickson Dam that may occur due to the proposed increase of maximum withdrawals from 8 to 10 mgd. Based on these results inferences could then be drawn with regard to possible environmental impacts that might be expected due to this and potential additional increased freshwater withdrawals.

In general, estuarine organisms typically occurring in the upper estuarine reaches of tidal systems such as Shell Creek can persist and flourish despite the physiological stresses associated with short term and seasonal changes in salinity levels. Black needlerush (*Juncus roemerianus*), for example, occurs in areas where salinities often range seasonally between 0 and 30 psu. While the physiological hardiness of this species may be an extreme example, many estuarine fishes and benthic invertebrates are similarly tolerant of wide salinity ranges over short time scales.

However, despite such tolerances to wide ranges of salinity fluctuations, the observed distribution and abundance of most estuarine plants and animals still often tend to be segregated along measurable salinity gradients. Such tendencies have been interpreted as indicating that many estuarine species often have narrower "optimal" salinity ranges with respect to environmental physiology and competitive interactions. While black needlerush can tolerate extreme salinities ranges, the actual spatial distribution of this species is generally limited to those portions of the estuary where long-term average salinities only range between 5 and 15 psu (practical salinity units).

Since 1976, the ongoing Peace River HBMP has been conducted within the lower Peace River/upper Charlotte Harbor estuarine system, first by General Development Utilities and then the Peace River/Manasota Regional Water Supply Authority. Many of the elements of this HBMP are designed to assess the variability and response of the lower river/upper harbor estuarine system's abiotic and biotic characteristics to natural seasonal salinity gradient fluctuations in response to changes in freshwater inflows. An understanding of responses to natural variability in freshwater patterns has provided an understanding of the potential magnitude of the potential effects that might be associated with freshwater withdrawals from the lower Peace River. Long-term historical information and methodology developed in conjunction with the Peace River HBMP is directly applicable to evaluating potential impacts associated with increased freshwater withdrawals from Shell Creek.

In conjunction with the 2001 Shell Creek HBMP Summary Report, a series of conductivity/flow models were developed using the 1991-2000 fixed station *in situ* water column profile data to estimate the potential salinity impacts of the City's permitted 6.9 mgd withdrawals. The summary results of these models (and the other graphics related to this section) are presented in **Appendix D** – "Potential Salinity Impacts". **Figures 4.4.1** through **4.4.6** depict the predicted subsurface surface and near bottom salinity impacts of 6.9 mgd withdrawals by river kilometer under conditions of Shell Creek flows of 25, 50, 100, 200, 400 and 800 cfs. The results of the 2001 Shell Creek HBMP Summary Report indicated that at flows of 25 cfs, the maximum salinity impacts along the tidal Shell Creek reach would be between 1.0 and 1.2 psu (practical salinity untis).

Two factors associated with the results of this previous salinity modeling effort should be clarified. First the models used a number of conservative assumptions and thus the actual impacts probably would be somewhat less. Importantly, the model fit at low flows (less than 25 cfs) was very poor and thus no estimates were made of potential salinity impacts at very low flows.

In conjunction with the current "Gap" analyses of assessing the potential impacts of increasing maximum Shell Creek withdrawals, an updated, more comprehensive series of statistical models were developed using the 1991-2004 fixed station, *in situ* HBMP monitoring data. The following describes the methodology and assumptions that were applied in developing these updated statistical models.

- The graphical salinity/flow analyses presented in Section 4.3 were used to evaluate the range of flow data to be used in the development of both the sub-surface and near-bottom salinity models. The modeled flows were limited to the normal ranges of gaged freshwater inflows at each depth over which measured salinities were typically greater than zero.

- Same day flow, as well as a series of preceding average flow terms (3, 5, 10, 20, 30 and 60-day averages) were tested in developing each of the statistical models to establish background conditions and the "resident memory" associated with the characteristic of the longer-term salinity gradient within the creek system. In addition, long-term lags (30 and 60 day averages) of total gaged lower Peace River flow (Peace River at Arcadia +

Horse Creek near Arcadia + Joshua Creek at Nocatee + Shell Creek near Punta Gorda) were also tested for potential inclusion in the final models.

- Based on a series of preliminary statistical analyses, the data from the eleven fixed HBMP salinity monitoring locations along the Shell Creek transect (Table 4.4.1) were subdivided for further modeling into three segments (A-C) based on relative differences in flows after which each reach of the creek was then characterized by freshwater conditions. Thus, salinities were assumed to be zero in segment A when flows were greater than 120 cfs, and observations with higher flow values were excluded from the modeling. (However, when the resulting models were subsequently applied in assessing the potential impacts of the proposed withdrawal schedule, the complete daily record of all gaged flows was used, which included both high and low flow events.)

Table 4.4.1
Approximate Shell Creek Flow when Salinity approaches Zero (psu)

Station #	River Kilometer	Subsurface	Near Bottom	Segment Group
# 11	9.90	80 cfs	100 cfs	A
# 4	8.74	90 cfs	120 cfs	A
# 12	8.09	120 cfs	150 cfs	B
# 13	7.40	130 cfs	160 cfs	B
# 5	6.72	140 cfs	200 cfs	B
# 14	5.73	150 cfs	200 cfs	B
# 6	4.61	300 cfs	300 cfs	C
# 15	3.66	400 cfs	400 cfs	C
# 7	2.35	400 cfs	400 cfs	C
# 16	1.26	450 cfs	450 cfs	C
# 17	0.43	450 cfs	450 cfs	C

Statistical Models of Salinity Flow Relationships. A series of summary statistics and modeling procedures were then used to determine potential "best-fit" relationships between freshwater inflows and sub-surface and near bottom salinities within each of the three designated creek segments.

- Simple linear regressions
- Correlation matrices
- The SAS RSREG procedure
- Stepwise regression
- Multi-linear regression using log transformed terms

Tabular results for the Stepwise and GLM procedures are included in **Appendix E** - "Statistical Models".

- As an initial step, potential interactions among variables were tested using a combination of both simple regressions and correlation matrices. Next the SAS RSREG and Stepwise General Linear Model procedures were applied in the development of each statistical model to screen the potential significance of a number of possible applied linear, non-linear (squared and cubic), and interactive terms. Flow terms were then log transformed to account for the curvilinear response of salinity to increasing freshwater flow. Conversely, non-transformed variables were used in modeling those independent terms with more linear relationships.

- Using an iterative process, surface and bottom salinity models were developed using the fewest number of independent variables that were both significant at the 0.05 level and added appreciably (at least two percent) to the overall explained error of the model. Only a single long-term preceding average flow term was used in the models to eliminate increasing the model fit simply due to autocorrelation. In developing the statistical models, enhancement of the explained error (R-square) was considered secondary to increasing the establishment of enhancement of the relationships between predicted and observed salinities (model fit).

Independent models using the same general form were developed for surface and bottom salinities within each of the three defined Shell Creek segments (Table 4.4.1) using the following generalized formula:

$$Log(Salinity) = \beta_{\alpha} + (\beta_1 x\ Log(Flow_1)) + (\beta_2 \times Log(Flow_2)) + (\beta_3 x(RiverKilometer))$$

where:
β_{α} = specific intercept
β_1 = “short-terms” flow slopes (linear and/or non-linear)
β_2 = “long-terms” flow slopes (linear and/or non-linear)
β_3 = river kilometer specific slope

$Flow_1$ = daily or short term lagged flow
$Flow_2$ = lagged flow (30 day surface and 60 day bottom)

- The relationships between the paired predicted modeled salinities and the actual observed salinities (relative fit), as well as the distribution of modeled residual errors with salinity are graphically presented in **Figure 4.4.7** through **4.4.18**. Overall, the graphical plots of predicted versus observed salinities indicate that the developed statistical models accurately predict salinity flow relationships (Table 4.4.2), accounting for approximately seventy percent of the observed variation in observed salinity within each transect segment.

Table 4.4.2
Results of Regression Analyses by Group and Depth

Group / Depth	Intercept	River Kilometer	Log 3-Day Average Shell Creek Flow	Log 30-Day Average Lower River USGS Gaged Flow	RSquare
Segment A, Center = 9.32RK (8.74 to 9.90 River Kilometers)					
Surface	16.1	-0.461	-0.544	-1.336	0.77
Bottom	26.7	-0.779	-0.406	-2.487	0.72
Segment B, Cener = 6.91 RK (5.73 to 8.09 River Kilometers)					
Surface	21.2	-0.706	-0.454	-1.929	0.76
Bottom	22.3	-0.217	-0.408	-2.537	0.71
Segment C, Center = 2.52 RK (0.43 to 4.61 River Kilometers)					
Surface	22.3	-0.217	-0.408	-2.537	0.71
Bottom	36.8	-1.462	-0.169	-3.973	0.67

However, a review of the presented information indicates that there are a number of observations within each of the three defined creek segments when the models noticeably under predict unusual higher salinities during periods of relatively higher flows. These instances of unusually high salinities when compared to the corresponding rates of freshwater inflow probably reflect instances of seasonally very high tides or unusually strong sustained south winds pushing higher salinity water up into the lower Peace River and Shell Creek.

Predicted Changes in Salinity Due to Shell Creek Facility Withdrawals. Subsurface and near bottom salinity/flow models developed for each of the three transect segments were then used to answer the following two basic questions.

1. What would the maximum spatial and temporal increases in salinities be at the surface and near the bottom in each creek segment if freshwater withdrawals were increased from 8 to 10 mgd?

2. What would the similar predicted maximum increases in salinities be if withdrawals at some future point were further increased to 12, 14 or 16 mgd?

To answer these questions, the same procedures were applied as previously described above (see Section 4.2) with regard to analyzing changes in flow. First historic withdrawals were adjusted to the maximum current capacity of the Facility (8 mgd). Next a series of alternative flows were developed using increasing 2 mgd increments. A series of analyses were then conducted using the historic 1972-2004 flow record in order to compare potential maximum differences in Shell Creek flows that might result due to increasing the Facility's current maximum capacity to both the current proposed increase to 10 mgd, as well as other possible further increments of 12, 14 and 16 mgd. Using this method, very conservative estimates of the relative magnitude of potential differences between the current maximum Facility capacity and the baseline “no withdrawal” scenario might be approximated by comparing the size of the predicted differences between 8 and 16 mgd, and then subtracting that estimate from the current maximum capacity. However, again it should be emphasized that utilizing such estimates would be extremely conservative since withdrawals do not directly influence daily flows once water stops flowing over the structure.

Cumulative distribution function plots of the results were then developed to provide overviews of the statistical distributions of the predicted salinity differences between maximum possible withdrawals under the Shell Creek Facility’s current maximum capacity of 8 mgd, the proposed “Gap” increase to 10 mgd, and potential future alternative expansions. The resulting graphical CDF plots are presented in **Figures 4.4.19** through **4.4.24**.

Salinity Cumulative Distributions. Plotting Cumulative Distribution Functions (CDF) is often a useful graphical method of evaluating the statistical frequency distributions of data sets containing large series of observations. In simple terms, the cumulative distribution function (CDF) is the probability that a measured variable (in this case a predicted change in salinity) has a value less than or equal to x, and can be expressed by the following equation.

$$F(x) = \Pr(X < x) = \alpha$$

The expression for variables with continuous distributions can be calculated using the following formula.

$$F(x) = \int_{\infty}^{x} f(u)du$$

Were F(x) is the estimated accumulated probability of the integrated change in the continuous variable (salinity).

Figures 4.4.19 through **4.4.24** indicated that the proposed “Gap” increase from 8 to 10 mgd would potentially result in only very small increases in surface and bottom salinities along the Shell Creek tidal reach. The magnitude of these changes would be so small that actual observations of the changes would probably be very difficult to detect. It should be noted that these increases would be in addition to the current changes from the “no withdrawal” condition (**Figures 4.4.1** through **4.4.6**). The relative magnitude of these changes in salinity are relatively small when compared to both the short and longer term seasonal variations occurring naturally in this reach of Shell Creek.

5.0 Comparisons of Flows with and without Maximum Withdrawals

The U.S. Geological Survey (USGS) has used log-Pearson Type III distributions for assessing low-flow frequency changes for a number of its long-term continuous stream flow gaging sites in Southwest Florida. The primary objectives of these analyses has been to assess potential changes in flow-duration and lowest mean-discharges for various consecutive-day periods as a method of forecasting and determining potential impacts related to water management alternatives. Statistical Analysis System (SAS) code was provided by District staff that replicates this USGS methodology. This SAS code was modified using the 1966-2004 flows derived from the USGS Shell Creek gage, and the results of these analyses are presented in Table 5.1 below and in **Figures 5.1** through **5.4**, and in **Tables 5.2** through **5.5** (**Appendix F** – "Low Frequency Analyses"). It should be noted that in this instance the "Without Withdrawals" scenario was developed simply by adding withdrawals back into the actual flows. As previously discussed, such a method for an in-stream structure overestimates flows during low flow periods, since in many instances adding withdrawals back will actually not result in any further increases in measured creek flows. Therefore, in this instance the most reliable comparisons would probably be among the three withdrawal alternatives.

Table 5.1
Lowest Average Flow (cfs) for Indicated Recurrence Intervals (years)

Consecutive Days	Years				
	2	3	5	10	25
Without Withdrawals					
1	10.0	6.2	4.0	2.5	1.6
3	11.3	7.1	4.6	2.9	1.9
10	14.8	9.3	6.0	3.5	2.4
30	24.4	15.8	10.5	6.7	4.3
60	38.4	25.9	17.7	11.8	7.8
90	53.2	38.4	28.0	19.9	14.1
120	70.9	51.7	38.1	27.6	19.0
With Withdrawals					
1	0.7	0.1	0.0	0.0	0.0
3	1.0	0.2	0.0	0.0	0.0
10	2.0	0.4	0.1	0.0	0.0
30	8.8	2.5	0.7	0.2	0.0
60	25.9	12.5	6.0	2.7	1.1
90	44.3	28.4	18.3	11.4	7.0
120	65.0	44.3	30.6	20.7	14.0
8 mgd Maximum Withdrawals					
1	0.1	0.0	0.0	0.0	0.0
3	0.1	0.0	0.0	0.0	0.0
10	0.5	0.1	0.0	0.0	0.0
30	2.0	0.4	0.1	0.0	0.0
60	5.6	1.3	0.3	0.1	0.0
90	11.0	2.7	0.6	0.1	0.0
120	16.3	3.8	0.9	0.2	0.0
10 mgd Maximum Withdrawals					
1	0.1	0.0	0.0	0.0	0.0
3	0.1	0.0	0.0	0.0	0.0
10	0.3	0.1	0.0	0.0	0.0
30	1.6	0.3	0.1	0.0	0.0
60	4.8	1.1	0.2	0.1	0.0
90	10.0	2.4	0.6	0.1	0.0
120	15.2	3.5	0.8	0.2	0.0

6.0 Characterization of Water Quality and Major Freshwater Ions Relative to Flow

This section provides overviews of both the current status and historical trends in the water quality characteristics and major ion constituents of the two major upstream freshwater sources (Shell and Prairie Creeks) to the City of Punta Gorda's reservoir. Additional analyses are also presented indicating the relationship between water quality within the reservoir and flow over the dam. Relevant long-term monitoring data were gathered, reviewed, standardized and combined from a number of sources.

- Historical water quality data were available from two long-term USGS monitoring sites within the watershed. The first was from USGS site #2298123 described as Prairie Creek near Fort Ogden, which is located at the SR 31 Bridge. The second USGS site was # 2298202 where samples are collected within the reservoir near the dam. The USGS data contains historical water quality data from both of these sites dating back to the mid 1960s.

- Long-term water quality data were also obtained from the City of Punta for the Prairie Creek at SR 31 and the reservoir, as well as monitoring sites for both Prairie Creek and Shell Creek at the bridges on Washington Loop Road (CR 764).

- Shell Creek HBMP water quality monitoring data (1991-2004) were also included for Sites #1 and #2, which respectively correspond to the City's Prairie Creek and Shell Creek at the bridges on Washington Loop Road (CR 764); as well as HBMP Site #3 where samples are collected in the reservoir at the dam.

- Recent data were also obtained from the District's ongoing ambient watershed water quality monitoring program that included data for samples taken from the Shell Creek Reservoir.

The relative spatial distributions of these four sampling locations are depicted in **Map 6.1** (see **Appendix G**– "Water Quality".

6.1 Time Series Plots. Plots of available historical water quality information from these four sampling locations are listed in Table 6.1 and contained in Appendix G. Different colors are used in these time-series plots to indicate the source of the available information.

- Blue – USGS data
- Black – District data
- Yellow – HBMP data
- White – City of Punta Gorda data

Table 6.1
Summary of Time-Series Plots

Parameter	Sampling Location/Monitoring Program			
	Prairie Creek at SR 31 USGS # 2298123	Prairie Creek at CR 764 HBMP #1	Shell Creek at CR 764 HBMP #2 City of Punta Gorda	Reservoir USGS #2298202 HBMP #3 City of Punta Gorda
Color	Figure 6.1	Figure 6.19	Figure 6.35	Figure 6.51
Turbidity	Figure 6.2	Figure 6.20	Figure 6.36	Figure 6.52
Specific Conductance	Figure 6.3	Figure 6.21	Figure 6.37	Figure 6.53
Hardness	Figure 6.4	Figure 6.22	Figure 6.38	Figure 6.54
Dissolved Oxygen	Figure 6.5	Figure 6.23	Figure 6.39	Figure 6.55
pH	Figure 6.6	Figure 6.24	Figure 6.40	Figure 6.56
Total Dissolved Solids	Figure 6.7	Figure 6.25	Figure 6.41	Figure 6.57
Alkalinity	Figure 6.8	Figure 6.26	Figure 6.42	Figure 6.58
Nitrite Nitrogen	Figure 6.9			Figure 6.59
Nitrite + Nitrate Nitrogen	Figure 6.10	Figure 6.27	Figure 6.43	Figure 6.60
Ammonia/Ammonium	Figure 6.11	Figure 6.28	Figure 6.44	Figure 6.61
Total Kjeldahl Nitrogen	Figure 6.12	Figure 6.29		Figure 6.62
Total Phosphorus	Figure 6.13	Figure 6.30	Figure 6.45	Figure 6.63
Orthophosphorus	Figure 6.14	Figure 6.31	Figure 6.46	Figure 6.64
Total Organic Carbon		Figure 6.32	Figure 6.47	Figure 6.65
Silica	Figure 6.15	Figure 6.33	Figure 6.48	Figure 6.66
Chloride	Figure 6.16	Figure 6.34	Figure 6.49	Figure 6.67
Fluoride	Figure 6.17			
Sulfate	Figure 6.18		Figure 6.50	Figure 6.68

While most of the long-term patterns depicted in these graphical analyses simple indicate non-trending seasonal and annual variability, there are a number of water quality characteristics for which the data suggest there have been systematic, progressive changes over time. For the most part, these changes can be shown to be directly associated with increases in groundwater use and "tail water" agricultural discharges to natural surface waters.

Prairie Creek at SR 31 near Fort Ogden (USGS # 2298123). Long-term data indicate a marked increase in chloride levels over time. Smaller increases have also occurred in levels of sulfate, specific conductance and total dissolved solids. At the same time, there have been small corresponding declines in both pH and alkalinity.

Prairie Creek at CR 764 (HBMP #1). The data show increasing changes in a number of water quality characteristics, including: specific conductance; hardness; total dissolved solids; and chlorides. All of these parameters showed distinct spikes in levels associated with the recent 1999-2001 drought, which resulted in marked increases in groundwater usages. The apparent increases in both nitrite+nitrate nitrogen and silica levels are also probably directly related to increases in agricultural activities in the watershed.

Shell Creek at CR 764 (HBMP #2 and City of Punta Gorda). Somewhat surprisingly, the data suggest that there have been declines in chloride levels in this part of the watershed, even though specific conductance and sulfate levels showed distinct spikes during the 1999-2001 drought. Again, silica levels show recent marked increases.

Shell Creek Reservoir (USGS #2298202, HBMP #3 and City of Punta Gorda). The data from this site provides an opportunity for comparisons among the four data sources. In those instances were samples were collected during similar periods, the information from the four data sources seems to be reasonably comparable. Not surprisingly, given the observed patterns shown to have occurred upstream in both Prairie and Shell Creeks, specific conductance, hardness, chloride, sulfate and silica levels in the Shell Creek reservoir have all increased over time. Nitrite+nitrate nitrogen have also increased, and the observed increase in surface dissolved oxygen levels suggest that the reservoir may becoming slightly more eutrophic with increased agricultural development in the upstream Prairie and Shell Creek watersheds.

6.2 Reservoir Concentrations versus Flow. The series of plots described in Table 6.2 and presented in Appendix G, depict the overall general relationships observed between gaged Shell Creek flows at the Hendrickson Dam and reservoir water quality characteristics. The general relationships between each of the parameters and flow are also summarized. In those instances (such as turbidity) where there is a sharp initial increase with flow followed by no further change the term "threshold" has been applied to describe the relationship.

Table 6.2
Plots of Reservoir Concentrations Versus Gaged Shell Creek Flow

Parameter	Graphic	Relationship With Flow
Color	Figure 6.69	Increasing
Turbidity	Figure 6.70	Threshold
Specific Conductance	Figure 6.71	Decreasing
Hardness	Figure 6.72	Decreasing
Dissolved Oxygen	Figure 6.73	Decreasing
pH	Figure 6.74	Decreasing
Total Dissolved Solids	Figure 6.75	Decreasing
Alkalinity	Figure 6.76	Decreasing
Nitrite Nitrogen	Figure 6.77	No Pattern (detection limits)
Nitrite + Nitrate Nitrogen	Figure 6.78	Threshold
Ammonia/Ammonium	Figure 6.79	No Pattern
Total Kjeldahl Nitrogen	Figure 6.80	Increasing
Total Phosphorus	Figure 6.81	Increasing
Orthophosphorus	Figure 6.82	Increasing

Table 6.2
Plots of Reservoir Concentrations Versus Gaged Shell Creek Flow

Parameter	Graphic	Relationship With Flow
Total Organic Carbon	Figure 6.83	Increasing
Silica	Figure 6.84	Threshold
Chloride	Figure 6.85	Decreasing
Sulfate	Figure 6.86	Decreasing

7.0 Riparian Vegetation

The spatial distribution of riparian vegetation along estuarine Shell Creek below the Hendrickson Dam was evaluated and compared with previous GIS vegetation patterns developed by Florida Marine Research Institute (FMRI) for the District from field verified 1994 aerials.

- Spatial vegetation patterns were compared to observed seasonal variations in the Shell Creek salinity structure from 1991-1994 HBMP data.

- Field observations were made to evaluate dominant plant species and major breaks in current vegetation patterns with regard to major riparian communities along Shell Creek between the Hendrickson Dam and the Peace River.

7.1 Purpose and Methods. The objectives of this task were to compare existing vegetation distributions along Shell Creek with vegetation mapped by FMRI (1998) and to identify dominant vegetation communities and/or taxa along the creek below the Hendrickson Dam. Six individual E-size maps of 2004 digital orthophoto quadrangles (DOQQs) were used for vegetation mapping. Maps were verified and/or modified to reflect vegetation observed along Shell Creek on 6 April, 2006. Information from these maps was integrated into the 2004 DOQQs and compared to 1995 DOQQs to examine vegetation distributions and document possible changes in vegetation distributions since 1998. The primary vegetation components and corresponding distributions along Shell Creek were also documented. Distances along Shell Creek were based on the HBMP center line (kilometers upstream from the mouth of Shell Creek where it meets the Peace River). Distances and vegetation distributions are mapped in **Figure 7-1**. Maps of the six individual river reaches used in the study are provided in **Figures 7-2** through **7-7** (See **Appendix H** – "Tidal Shell Creek Vegetation Maps").

7.2 Results and Discussion. No substantial differences in overall vegetation distributions were identified in between-year comparisons of vegetation. Those differences that were found are most likely due to the scale at which vegetation was mapped during the previous FMRI survey. Relatively conspicuous breaks in vegetation were identified during the 2006 field visit, although these breaks were not discernible from the DOQQs.

Between-year Comparisons. The map resolution in the FMRI study was inadequate to make accurate between-year vegetation comparisons of vegetation along Shell Creek. Thus, the vegetation differences observed between comparisons of the 1994 and 2006 surveys probably simply reflect the results of the scale at which mapping was done and the Land Use Cover and Forms Classification System (FLUCFCS) codes assigned. Consequently, what may appear to be a greater abundance of bulrushes (*Scirpus validus*) or giant cutgrass (*Zizaniopsis miliaceae*) probably are the result of greater mapping detail during the 2006 "Gap" field mapping.

A comparison of salinities between the drier years from 1999 - 2001 and wetter years during 2002 – 2004 indicates lower (near zero) salinities at, and just below, the dam during the wetter years (see **Figures 4.3.93** and **4.3.94**). Mean and median salinities as far as three km downstream of the dam were less than 1.0 psu during wet years. In contrast, mean salinities during previous dry years were > 2 psu just below the dam, and were approximately 4 psu approximately 3 km downstream of the dam. These low salinities could easily allow the expansion of freshwater species such as giant cutgrass, swamp lily (*Crinum americanum*), and pickerel weed (*Pontederia cordata),* all of which occur at salinities < 0.5 psu and were observed during the 2006 mapping event.

Small areas formerly designated as FLUCFCS 615 (*Streams and Lake Swamps*) during the 1994 survey appear now as freshwater marsh. This cover class was observed only in the freshwater marshes upstream of Myrtle Slough.

The diversity of freshwater species just downstream of the dam is relatively low when compared with typical freshwater marshes. It is important to note that several species, including bulrushes, sawgrass (*Cladium jamaicense*), jointweed (*Polygonum* spp.), and others, are tolerant of a wide range of salinities. Bulrushes occur under freshwater conditions, but not in monospecific stands as they do in oligohaline marshes (Latham *et al*. 1994). Increasing salinities will kill intolerant species, and may result in an eventual shift to a larger number of salt tolerant species, including leather fern (*Acrostichum* spp.), other *Scirpus* species, and needle rush (*Juncus roemerianus*).

A return to freshwater species following decreasing salinities is generally slower when compared with a shift to species with greater salinity tolerances. This is because many salt tolerant species grow better in fresh water and are only excluded from fresh water by competitive interactions. That is, salt tolerant species are not necessarily displaced by changes in salinity, rather, they must be displaced by interactions with freshwater species.

FLUCFCS Category Differences. The most apparent differences in vegetation mapping between the 1998 FMRI report and 2006 "Gap" mapping were observed in areas formerly designated as *Stream and Lake Swamps* (615), which generally refers to bottomland hardwoods. Mapping units with this designation most frequently coincided with an extensive amount of Brazilian pepper (*Schinus terebinthifolius*), cabbage palm (*Sabal palmetto*), and other woody species such as willow (*Salix caroliniana*), salt bush (*Baccharis halimifolia*). Consequently, many instances of 615 were changed to the *Exotic Wetland Hardwoods* (619) category and were not likely due to actual changes in vegetation.

Another difference between the 1998 and 2006 mapping was the minimal extent of bulrushes in the 1998 mapping. The extent of this species along the edges of the channel between the old railroad bridge (approximately RK 4.3) and the upstream freshwater marsh was conspicuous, and the category was added along the edges of the channel.

The *Wet Prairie* (643) category was also assigned to portions of Shell Creek in the FMRI (1998) report. This class is distinguished from marshes by the presence of more grasses (i.e. fewer broad leaved herbaceous species) and less water. Areas with the *Wet Prairie* category were not mapped in the 1998 FMRI report to have extended more than three km below the dam. During the 2006 observations, this 643 category appeared to be dominated by cattails (predominantly *Typha angustifolia*) and scattered cabbage palm. Although the 6412 might better describe the cattails, during the 2006 visit, it was arbitrarily designated "*Typha* with scattered cabbage palm" to include the cabbage palms.

Vegetation Distributions. The "Gap" vegetation study noted several conspicuous changes in vegetation communities along Shell Creek, beginning with a relatively large number of freshwater species and species tolerant of low-salinities just below the dam. Just downstream of the dam at the confluence with Myrtle Slough, Shell Creek the vegetation was characterized by the distributions of several species with greater salt tolerance. Farther downstream near the mouth of Shell Creek, the marshes were characterized by those few plant species with greater salinity tolerances. Plant communities observed along Shell Creek below the dam are briefly summarized below.

- **Freshwater species**. There was a conspicuous change from freshwater and oligohaline species on Shell Creek upstream of Myrtle Slough (within approximately 1.0 km of the dam) to species tolerant of higher salinities downstream of Myrtle Slough. Species upstream of Myrtle Slough included species tolerant of low salinities such as bulrushes, sawgrass, cattails, leather fern, cabbage palm, and Brazilian pepper. However, species diversity was greater when compared with downstream vegetation classes due to the presence of salt intolerant species such as pickerel weed, swamp lily, morning glory (*Ipomea* spp.), and giant cutgrass. These freshwater species were not observed downstream of the reach in Shell Creek just below the upstream confluence of Myrtle Slough.

- **Leather fern and bulrushes**. In addition to upstream–downstream gradients, elevation changes along the channel were readily apparent. Below the freshwater marshes, the outside curves of the channel were steep and sometimes undercut by the current, resulting in a steep-sided marsh. In contrast, the inside of the channels were much more gradual. Leather ferns dominated the steep sides, while bulrushes and cattails dominated the less abrupt or gradual shoreline.

- **Bulrushes**. Below Myrtle Slough, monospecific stands of bulrushes along the creek edges were conspicuous, often with cattails and leather fern behind them, and needle rush and/or Brazilian pepper farther landward. However, the bulrush stands became small and subsequently were limited to small isolated clumps among the dominant needle rush in the vicinity of the railroad bridge (approximately 6 km downstream of the dam).

- **Cabbage palm, bulrushes, and leather fern**. These occurred along nearly the entire length of Shell Creek and overlapped with all other species. Like bulrushes, leather fern became much less conspicuous downstream of the railroad bridge and cabbage palms occurred farther inland below the railroad bridge when compared with reaches upstream of the bridge.

- **Needle rush and mangroves.** The dominant vegetation class from the confluence of Shell Creek and the Peace River, upstream to the railroad bridge, was characterized by needle rush and mangroves. These communities remained conspicuous until just upstream U.S. Highway 17 on Shell Creek (approximately 2.4 km below the dam), at which point they were no longer visible from the channel.

7.3 Conclusions. Mapping from the previous study (FMRI 1998) and this report indicated several relatively distinct vegetation communities along Shell Creek, although the overlap among species is conspicuous. Vegetation along the creek transitions from a larger mix of low-salinity and freshwater species along the upper reaches, to fewer species tolerant of a larger range in salinities in the middle reaches, to species such as mangroves and needle rush that are tolerant of salinities greater than that of sea water in the lower reach near the Peace River.

Within a given salinity regime, other factors become more important in affecting marsh species distributions. For example, under freshwater conditions, species competition influences distributions. Under higher salinity conditions physical factors such as elevation become more important, as does proximity to wave energy. For example, leather fern was more frequent on the steep side (outside) of the channel bends, while bulrushes typically occurred on the inside of the channel bends, where the change in elevation is more gradual. In these cases, elevation data (or distance from channel) may be important if vegetation distributions are to be predicted.

Mapping data from 1994 (FMRI 1998) and this 2006 "Gap" report indicate a spatial shift to a larger number of freshwater species, specifically giant cutgrass, upstream of Myrtle Slough. In addition, the distribution of at least one species, bulrush, appears to have increased along the river channel since 1994. Salinity data indicate lower salinities during 2002 – 2004, compared with 1991 – 2001, and changes in salinity could cause a slow shift to larger numbers of more typically freshwater species. Bulrushes are tolerant of a wide range of salinities and may easily expand into gaps where other species are absent.

However, the resolution of the DOQQs used may limit the ability make this comparison and, as noted by the authors of the FMRI report, better resolution photographs would have been helpful in making more accurate observations.

Exotic wetland hardwoods (619) was not used as a FLUCFCS category in the 1998 report. The distribution of Brazilian pepper along Shell Creek is extensive and should be included in any mapping effort, although a particular FLUCFCS category is arbitrary and the resolution of DOQQs may limit an accurate interpretation of this category as well.

Finally, the impact of recent hurricanes cannot be disregarded when considering possible spatial and temporal changes in vegetation along Shell Creek. The 2006 "Gap" field observations indicated that mangroves and Brazilian pepper, as well as herbaceous species, were sheared back or killed by the force of hurricane Charlie in August 2004. Different species recover at different rates and are further affected by competition with surrounding species. Although noted, the degree of the influences of recent hurricanes on vegetation along Shell Creek was not evaluated in this study.

8.0 Evaluation of Information of Flow Influences on Biological Community Structure

Biological information gathered as part of the Peace River HBMP and the District minimum flow studies were evaluated and summarized in order to provide a general overview of the relationships between historical seasonal and long-term variations in Shell Creek flow and the structure and composition of biological communities in the Shell Creek/lower Peace River estuarine system. The information, graphics and conclusions contained in previous studies conducted for the District were reviewed and are summarized below with regard to evaluating the salinity tolerances of key groups of estuarine species and assess potential responses to predicted levels of salinity increase potentially resulting from proposed “Gap” withdrawals.

8.1 ***Distribution of Macrobenthic Invertebrates in Shell Creek as Related to Salinity and Sediment Structure* (Culter, 2005).** District information developed by Mote Marine Laboratory as part of Shell Creek minimum flows studies was reviewed and summarized with regard to observed seasonal salinity variations in response to changes in freshwater inflows.

Study Design. Within Shell Creek, thirty locations were sampled between the Punta Gorda reservoir and the Peace River, with ten additional sites located within side channels. Both intertidal and subtidal samples were taken with two techniques at each site – sweep nets and a 3 inch diameter core. This resulted in 40 sites sampled, with two depths per site, with two techniques per depth. For cores, this resulted in 80 total samples collected, and the same number of samples collected for sweep nets. However, only one-half of these collected samples were actually processed. The justification for processing only half the samples is not stated in the report, but it might be assumed to be a result of constraints on time and/or budgets. Samples were sieved through a 0.5 mm screen and retained organisms were preserved in the field with 10 percent buffered formalin. In the laboratory, fauna were sorted, identified and enumerated to the “lowest practical taxonomic level”, and then quantified by station, river kilometer, and tidal stratum. Diversity, abundance and other community metrics were then calculated.

In the field, non-organismic material retained on the 0.5 mm screen was separated from the organisms themselves. This sediment material was then dried to a constant weight and then combusted at a temperature of 525^0C to determine “coarse organic matter” which was defined as the decrease in weight after combustion. Sediment grain size analysis was determined for wet sediment samples via a Coulter LS particle analyzer.

All samples were collected in May 2003. Field parameters (temperature, salinity, pH, dissolved oxygen) were also collected along a gradient from the base of the reservoir to the Peace River at both surface and bottom depths during May 7 and May 8 of 2003.

General Impressions. Benthic communities have previously been used to characterize the health of various estuarine systems in Tampa Bay (Leverone *et al*. 1991, Karlen *et al*. 1997) and the Chesapeake Bay (Dauer 1993, Dauer and Alden 1995). As an indication of the value of benthic sampling, a classic assessment of the "recovery" of Tampa Bay following a massive red tide event focused on changes in benthic communities over time (Dauer and Simon 1976a and 1976b).

As such, it is well established in the literature that benthic communities can serve as time-integrating indicators of estuarine health, and that even a one-time sampling effort can be useful for determining the overall status of benthic communities. However, the influence of antecedent conditions (drought, flood, red tide, etc.) needs to be considered, to allow for the appropriate caveats when interpreting results from single sampling efforts. This is an important consideration, as the information contained within this report is from a single sampling effort in May of 2003, over the course of what appears to be two days (May 7 and May 8).

Overall, the author has explained with sufficient detail the techniques used, although a number of additional relevant comments could increase the value of this paper. A few typographical and/or grammatical errors occur in the report, but they do not adversely affect the ability of a reader to understand the concept being discussed.

The discussion section of this report is quite thorough using existing literature to compare and contrast results from this report to results from other benthic studies in the Peace River, as well as the scientific literature as a whole.

Conclusions of the Report. The majority of sediments within Shell Creek are coarse to fine sands, with no evidence of clay layers previously reported for portions of the lower Peace River (i.e. Lettuce Lake and Deep Creek). This reference to clay being found in these two locations in the Peace River is not properly cited – this information would be very useful to readers. This would seem to suggest that impacts of previously documented "slime spills" associated with breaches from upstream clay settling areas did not extend into Shell Creek.

The sediment type referred to as "coarse organic matter" varied from 30 to 99 percent of sample dry weights, but no clear pattern was found when comparing distance from the reservoir versus organic content (see **Figures 6 and 7**, in **Appendix I**).

For the macroinfauna, more than 10,000 organisms were counted, representing 76 separate taxa. Crustaceans and mollusks were roughly equivalent (43 and 41 percent of all species) and they dominated the benthic samples. Polychaetes (segmented worms), which are dominant organisms in estuarine benthic communities, accounted for just over 2 percent of the taxa identified, while Chironomids (insect larvae) comprised 9 % of the taxa. Overall, the predominance of chironomids over polycheates is one of many indications that species with higher salinity requirements are at a disadvantage in Shell Creek, when compared to species with lower salinity requirements. However, a great number of euryhaline estuarine organisms (e.g. amphipods and mysid shrimp) were encountered as well. The overall pattern of distribution of benthic communities led the author to conclude (p. 18) "It is probable that relatively small increases in flow would force the euryhaline species out of Shell Creek, which would then be dominated by the insect larvae." If this conclusion could be further supported, it would suggest that a "tipping point" of sorts might exist for flows in Shell Creek, where a small decrease in flows at the wrong flow regime might prevent the conversion of the benthos from one dominated by euryhaline estuarine organisms to one dominated by freshwater-associated insect larvae. Should this reduction in flows occur due to human intervention, then organisms that depend upon insect larvae as a food source might be adversely impacted.

This issue is potentially important when considering the impacts of relatively small flow reductions. While the author does not have enough data to completely address this issue, it would be useful if the author could outline a process through which such a scenario could be tested.

Potential Issues with Report with Regard to Application to the "Gap". The experimental design, sampling techniques, spatial and temporal intensity of data gathering, statistical analysis, and conclusions from the author are all reasonable and appropriate. The report is well written, although further information, outlined below, would increase its value.

One-time sampling efforts would not be considered acceptable for characterizing the health of a water body if such efforts focused on water quality. However, benthic sampling is a very useful assessment technique because benthic communities integrate water quality changes over a period of time. Consequently, there does not appear to be a fatal flaw in assessing the health of Shell Creek's benthos based on a one-time sampling effort, although prior results from various benthic sampling efforts in Tampa Bay (Dauer and Simon, 1976a and 1976b, Leverone *et al*. 1991, Karlen et al. 1997) all included a time series component. That is, conclusions of these prior reports were based on multi-year sampling efforts. While the present report only includes results from a single season, its conclusions are not necessarily invalid, but appropriate caveats should be included.

The authors state (p. 17) that the macroinfauna study was conducted "…in May 2003, a spring dry season." However, field data (collected on May 7 and 8, 2003) show the highest salinity to be 6.2 psu. In a report on the fish and invertebrate composition of the Peace River and Shell Creek, Peebles (2002) reported salinities in excess of 15 psu within Shell Creek. Also in that report, Peebles (2002) states "For Shell Creek…an earlier survey (PBS&J 2001) reported salinities > 25 psu within the creek." Therefore, the conditions under which Shell Creek was sampled for macroinfauna represent a condition under which the ambient water quality reflected much greater rates of freshwater inflow (i.e. lower salinities) than those previously found by Peebles (2002) and others.

While it is probable that such conditions are typically found during the "wet season", they do not seem to be supportive of a sampling effort designed to characterize benthic communities during a typical "dry season." A key to resolving this issue would be to design and fund a long-term macroinfaunal sampling project. To enact such a program, the author should include an appendix that gives the latitude and longitude of sample locations, as well as greater details on the depths at which samples and cores were taken.

Finally, the author should better explain the rationale for only processing one-half of the collected samples, and include information on the randomization techniques used for determining which samples would be processed, and which would be set aside.

8.2 ***An Assessment of the Effects of Freshwater Inflows on Fish and Invertebrate Habitat Use in the Peace River and Shell Creek Tributaries* (Peebles, 2002).** District minimum flows studies were also reviewed and summarized with regard to the observed variations in the spatial distribution and structure of these biological communities in the estuarine portion of Shell Creek due to seasonal flow related salinity changes.

Study Design. Three gear types were used to sample organisms in the lower Peace River and Shell Creek: 1) a plankton net for nighttime (at flood tides]); 2) a bag seine during the day at variable tides, and 3) an otter trawl during the day at variable tides. The plankton net was used to capture both plankton and "hyperbenthic" organisms. The bag seine was used to capture organisms more strongly associated with shoreline features, while the otter trawl was used to capture organisms associated with open waters and/or channels. Samples were collected monthly from April 1997 or May 1997 (plankton nets) until April 1999.

The lower Peace River was divided into seven "collection zones" from just below Horse Creek to Charlotte Harbor, while Shell Creek was divided into four collection zones from the base of the dam to the Peace River. For each zone two plankton net tows, two bag seine hauls and one otter trawl sampling effort were conducted each month. Field parameters such as temperature, salinity, dissolved oxygen and pH were collected from main channel areas during the plankton tows.

Ancillary data on streamflow in both the Peace River and Shell Creek were obtained, for use in determining if relationships could be established between flows and patterns of distribution and/or abundance of sampled organisms.

General Impressions. Overall, the author has conducted a very thorough investigation of the relationships between flow and faunal abundance in Shell Creek and the lower Peace River. The spatial and temporal intensity of this work is quite high. For example, a study on juvenile and adult fish populations in Tampa Bay conducted by staff from the Florida Fish and Wildlife Conservation Commission (Matheson et al. 2005) used seine sampling alone, in five strata for the entire bay. Also, samples were originally not collected at all locations on a monthly basis. The paper by Matheson et al. (2005) summarizes a data collection effort developed by the Commission to implement the State of Florida's Fisheries-Independent Monitoring Program for the largest open-water estuary in Florida.

The data collection summarized by Peebles in this report thus involves sampling using a greater number of gear types, with a greater number of samples distributed within a greater number of strata, within a much smaller geographic zone than that conducted to meet requirements of the State of Florida for its Fisheries Independent Monitoring Program. However, Matheson et al. (2005) were able to compare data collected over multiple years (1989 to 2002), compared to the approximately 2 year data collection effort in this report.

In addition, the discussion section of this report is very thorough in its use of existing literature to compare and contrast results from this report to the scientific literature as a whole.

Conclusions of the Report. A major issue is that the sampling period in this report occurred during the 1997 to 1998 El Niño event. This event caused dramatic reductions in salinity during the winter of 1997 to early spring of 1998. In the Peace River, salinities during this El Niño were actually lower than salinities recorded during the wet seasons of 1997 and 1998, which were both included in the study period (**Figure 3.2.1**, **Appendix J**). In Shell Creek, salinity values averaged less than 6 psu from May 1997 to March 1999 (**Figure 3.2.2**, **Appendix J**). For all data combined, the mean salinity for the Peace River was 7 psu, while the mean salinity for Shell Creek was ca. 1 psu.

For a variety of species of various life stages, the center of abundance (i.e. the location where they were most common), moved downstream with increased flows (**Figure 3.7.1**, **Appendix J**). These results are similar to conclusion from Matheson et al. (2005; and see references within) that organisms in tidal rivers tend to move downstream during periods of high flow, and upstream during lower flow periods. When examining the relationships between the abundance of organisms and flows, there tended to be a positive relationship between the natural log of abundance and the natural log of inflows for juvenile sand seatrout, naked gobies, and mysid shrimp (**Figure 3.8.1**, **Appendix J).**

In summary, most organisms were more abundant during periods of elevated freshwater inflow, and their centers of abundance tended to track the downstream movement of reference isohalines in response to these increased inflows. These conclusions are consistent with a broader body of literature from Tampa Bay (Matheson *et al*. 2005), the Little Manatee River (Rast et al. 1991) and San Francisco Bay (Jassby et al. 1995).

Potential Issues with Report with Regard to Application to the "Gap". The experimental design, sampling techniques, spatial and temporal intensity of data gathering, statistical analysis, and conclusions from the author are all reasonable and appropriate. The report is well written, and it includes many relevant examples from the broader scientific body of work assessing the influence of freshwater inflows on fish and invertebrate populations.

The only major issue associated with this report is the inability to extrapolate the results to other time periods (both past and future) and also the issue of the relevance of salinity and/or flow relationships that may be compromised due to the inclusion of a strong El Niño event. While El Niño's could be viewed as being similar to typical "wet seasons" in that they are both characterized as being high inflow time periods, there are major differences between the two phenomena. Potential issues are summarized in the following table.

Table 8.2.1
Differences with "Gap" Application

Criteria	Seasonal Differences	
	Typical Summer "Wet Season"	Typical Winter/Spring El Niño Event
Water Temperature	24 to 32 degrees Celsius	< 21 degrees Celsius
Prevalence of hypoxia	Abundant with high flows	Potentially absent
Likely predominance of larval forms	Summer spawners	Fall to winter spawners

The inclusion of a strong El Niño event in the sampling period has the potential to confound the salinity and flow effects on fish distributions. For those graphs in which data are plotted as the abundance of organisms vs. freshwater inflows (e.g., Figs. 3.7.1, 3.8.1, 3.8.2, etc. in Peebles report) the first "dry season" had greater freshwater inflows than either of the two sampled "wet seasons". And while the salinities in the lower Peace River were lower during the 1997 to 1998 El Niño than during the 1997 or 1998 "wet seasons" (Fig. 3.2.1), temperatures were considerably higher during the two wet seasons. In addition, dissolved oxygen levels during the El Niño event were higher than those during the 1998 wet season, and considerably higher than the 1997 wet season (Figures 3.2.1 in Peebles report). In a recent paper by Turner *et al*. (2006) concluded that hypoxia in the open waters of Charlotte Harbor required both sufficient freshwater inflow to create a inflow-driven formation of a halocline, and also water temperatures generally had to be in excess of 30^{o} Celsius.

For Shell Creek, the report states that "Salinities >17 psu were never observed, whereas an earlier survey (PBS&J 2001) reported salinities > 25 psu within the creek." (See Section 4 above for further discussions of seasonal and annual variability of salinity within the estuarine reaches of Shell Creek). Consequently, the report, as written, is probably an appropriate tool for developing relationships between rates of freshwater inflow and the abundance and spatial distribution of fish and invertebrates during high inflow time periods, with the caveat that the highest inflows occurred during a very strong El Niño event.

The ability to report on relationships between rates of freshwater inflow and abundance and spatial distribution of fish and invertebrates during low inflow time periods is compromised by the overall paucity of low inflows during the sampling effort.

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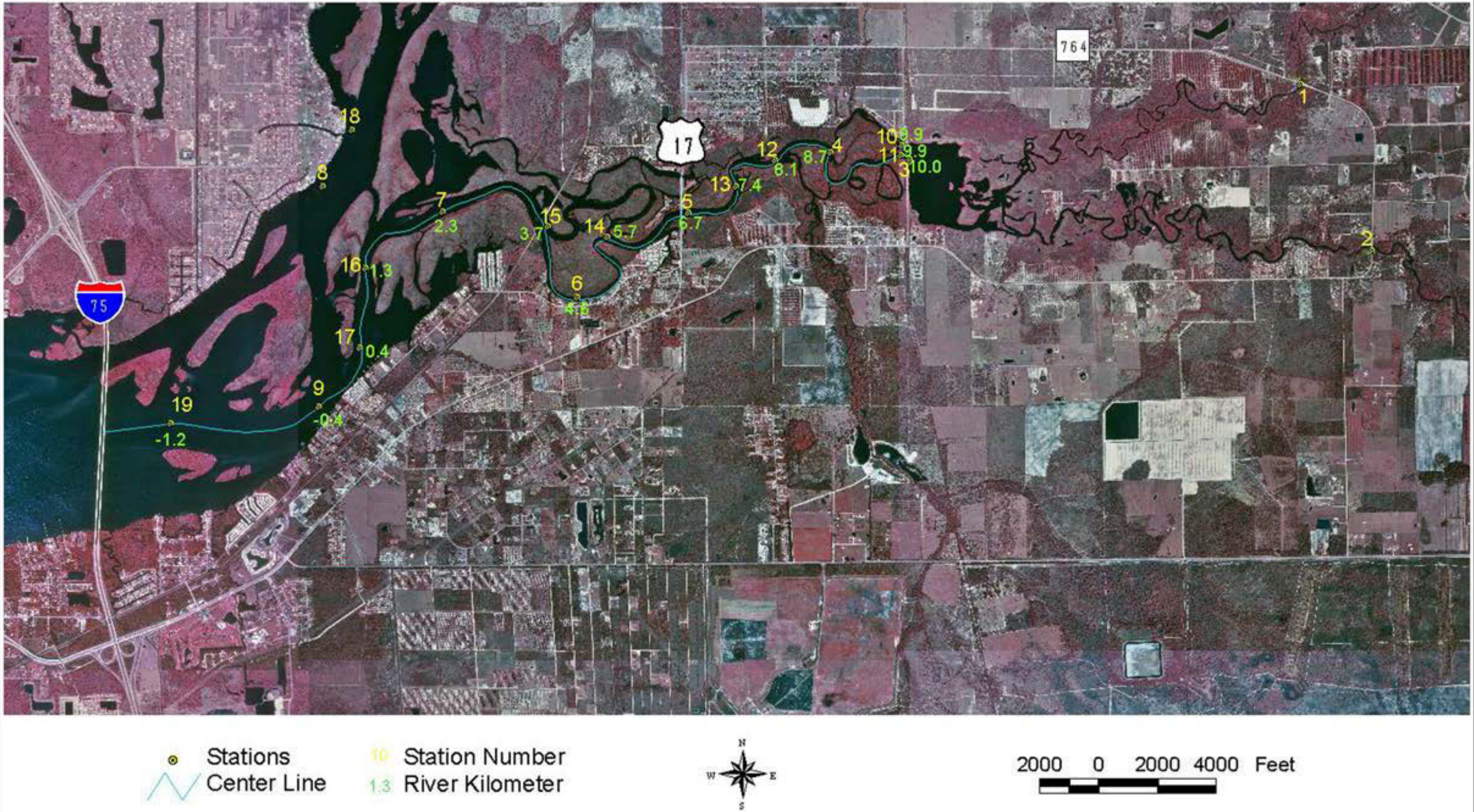
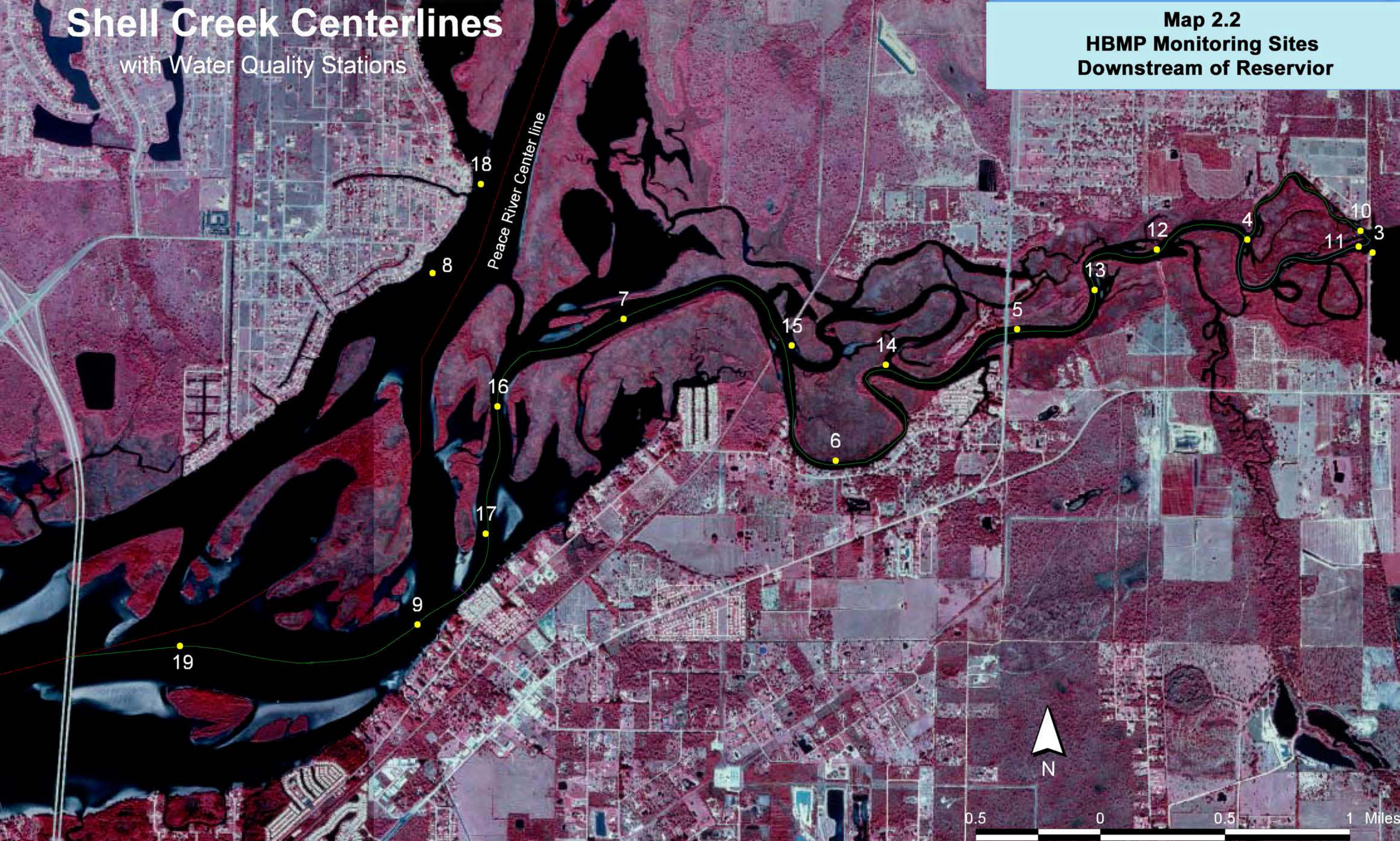
Maps

Section 2.0

Map 2.1
HBMP Monitoring Sites and River Kilometers




Shell Creek Centerlines
with Water Quality Stations
Map 2.2
HBMP Monitoring Sites
Downstream of Reservior
Peace River Center line
18
8
7
16
17
9
19
15
14
6
5
13
12
4
10
3
11
N
0.5
0
0.5
1
Miles

Appendix A

Flow Characterization

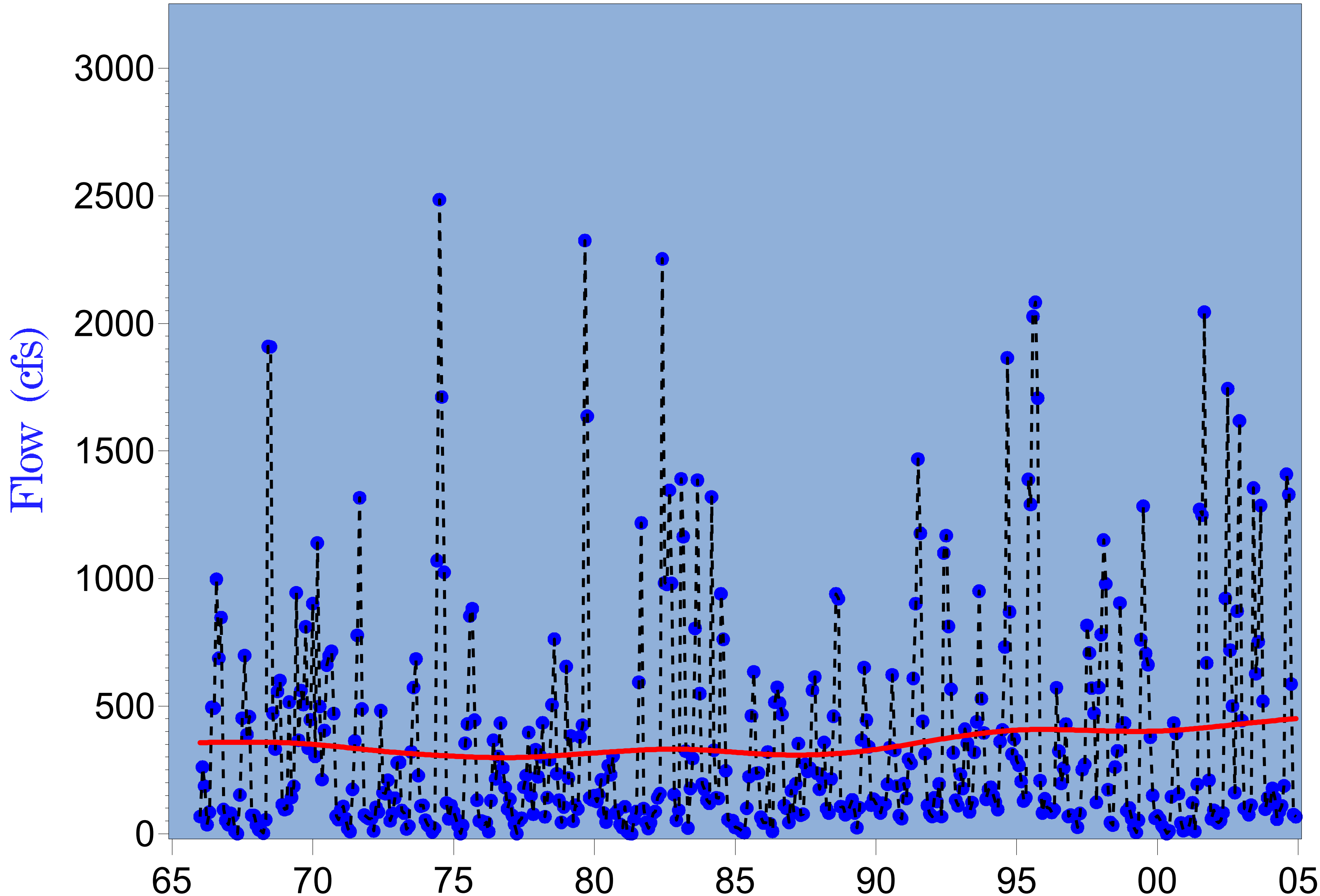


Figure 4.1.1 Monthly mean long-term flow at Shell Creek gage (1966-2004)

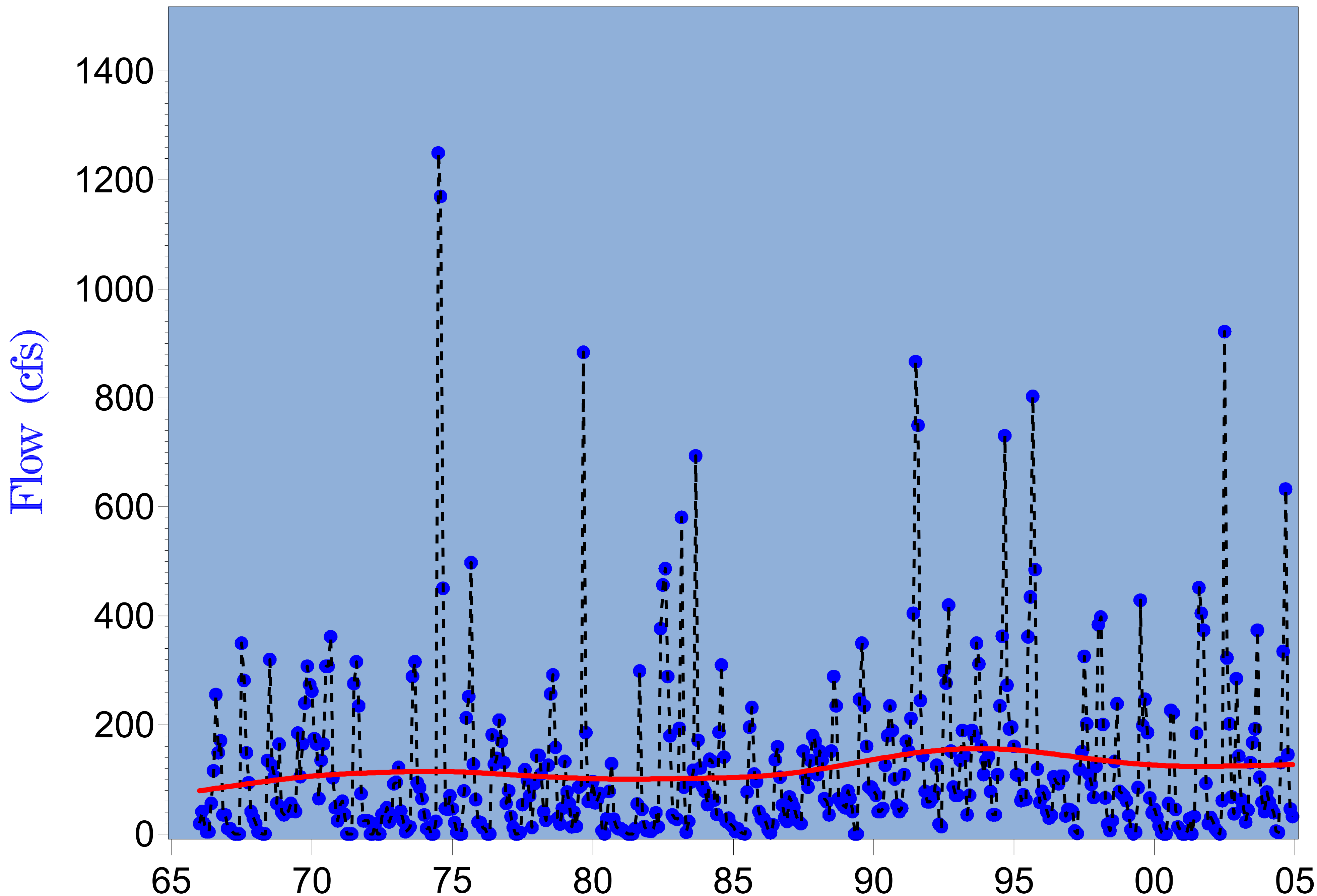


Figure 4.1.2 Monthly minimum long-term flow at Shell Creek gage (1966-2004)

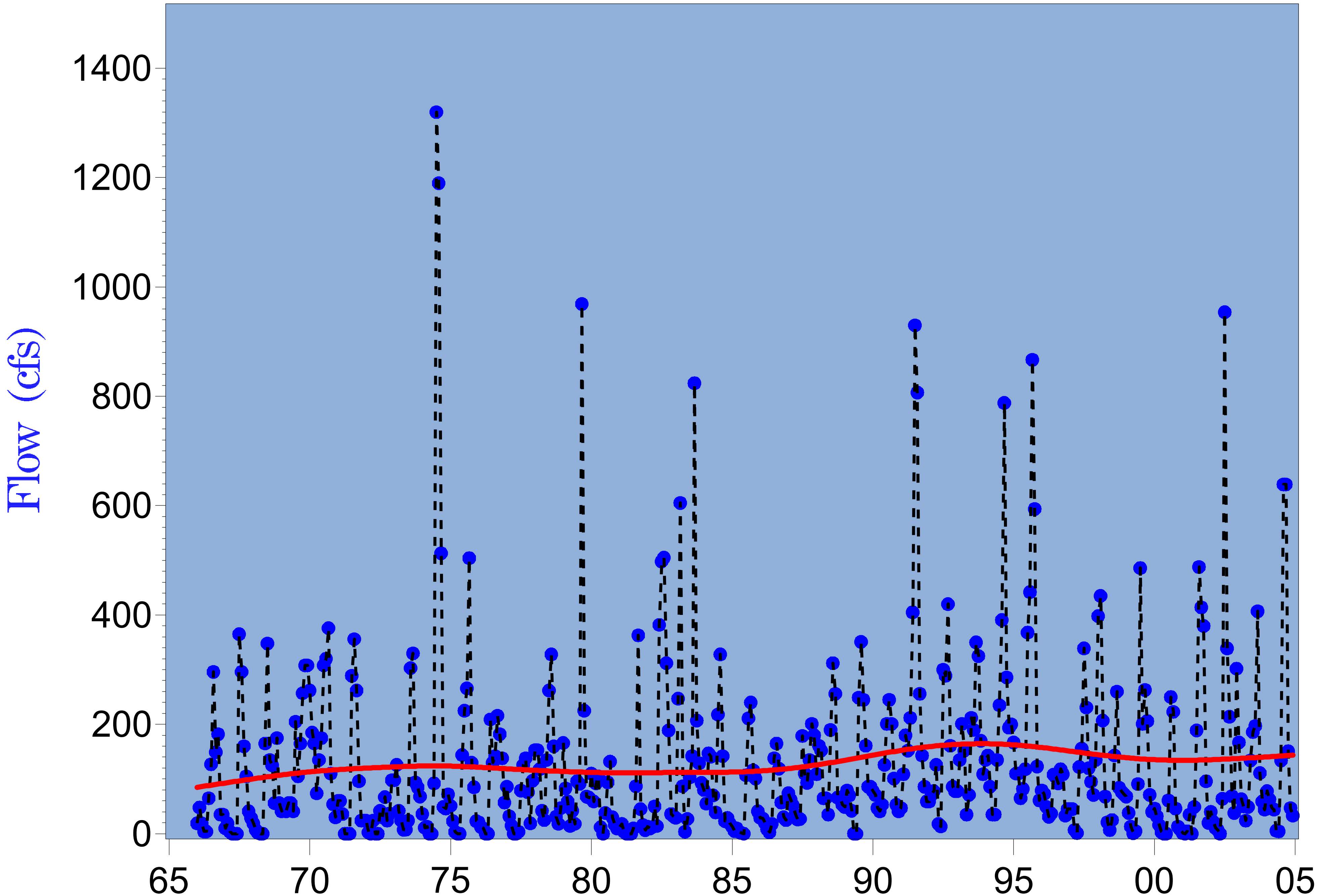


Figure 4.1.3 Monthly Q95 long-term flow at Shell Creek gage (1966-2004)

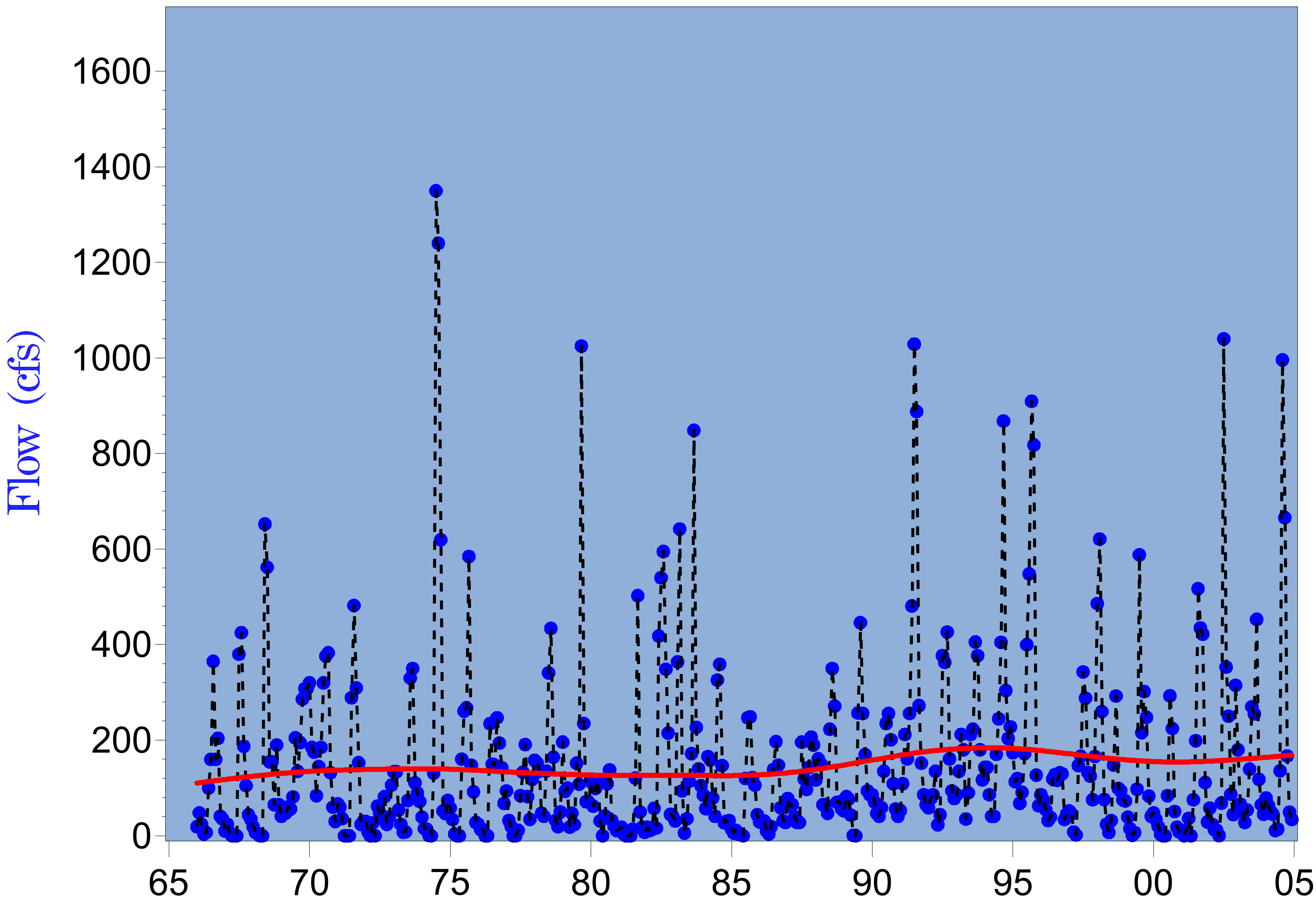


Figure 4.1.4 Monthly Q90 long-term flow at Shell Creek gage (1966-2004)

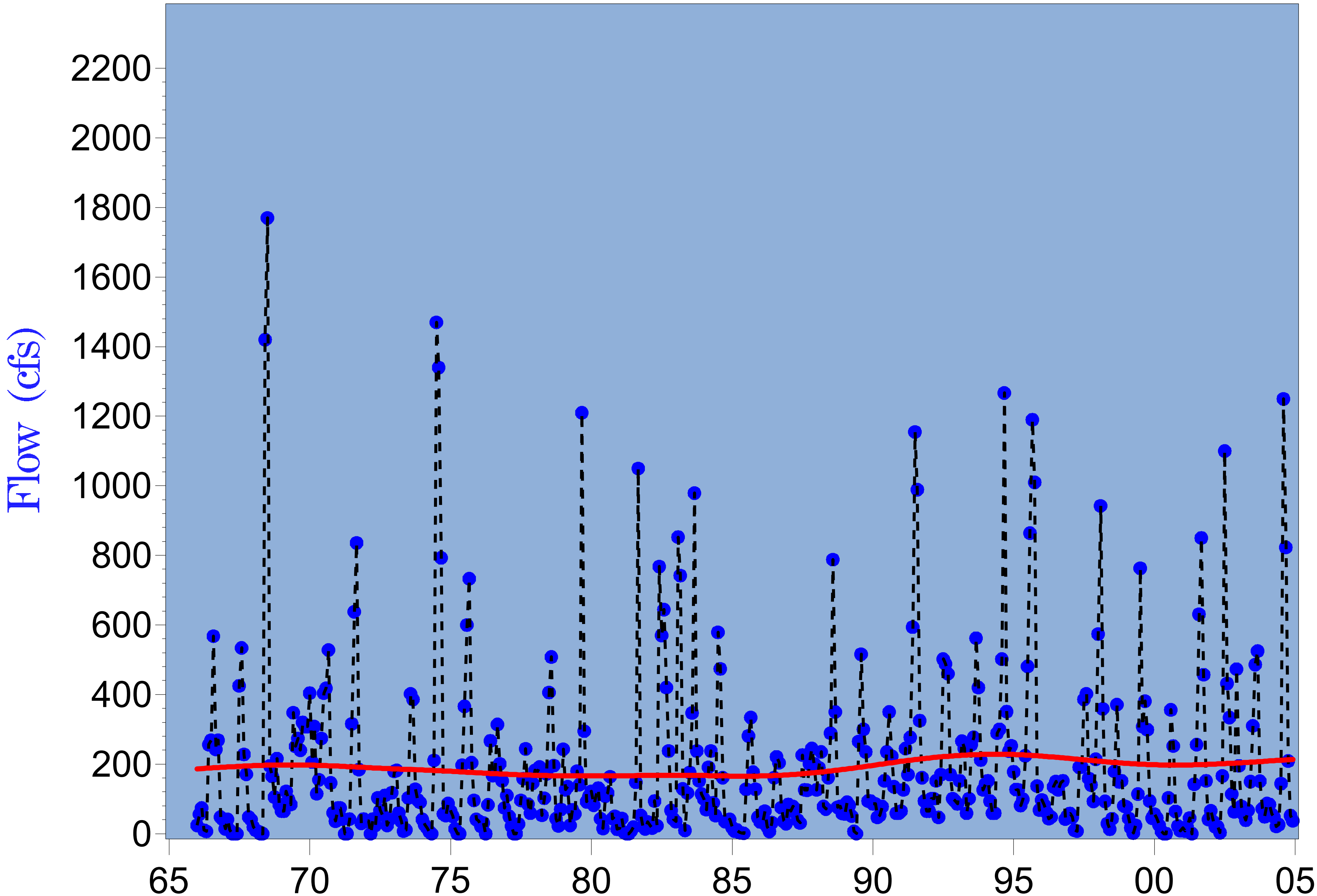


Figure 4.1.5 Monthly Q75 long-term flow at Shell Creek gage (1966-2004)

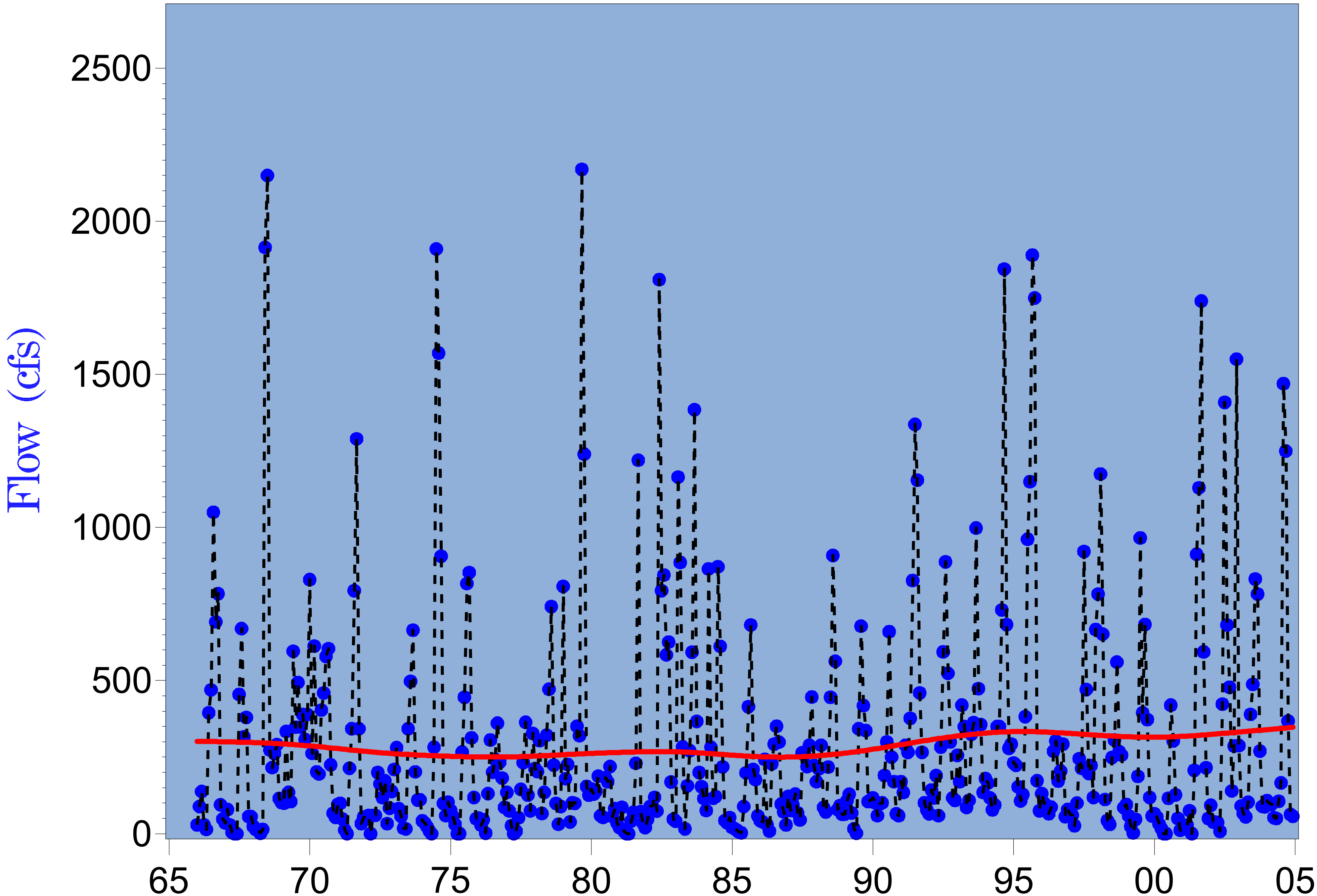


Figure 4.1.6 Monthly Q50 (median) long-term flow at Shell Creek gage (1966-2004)

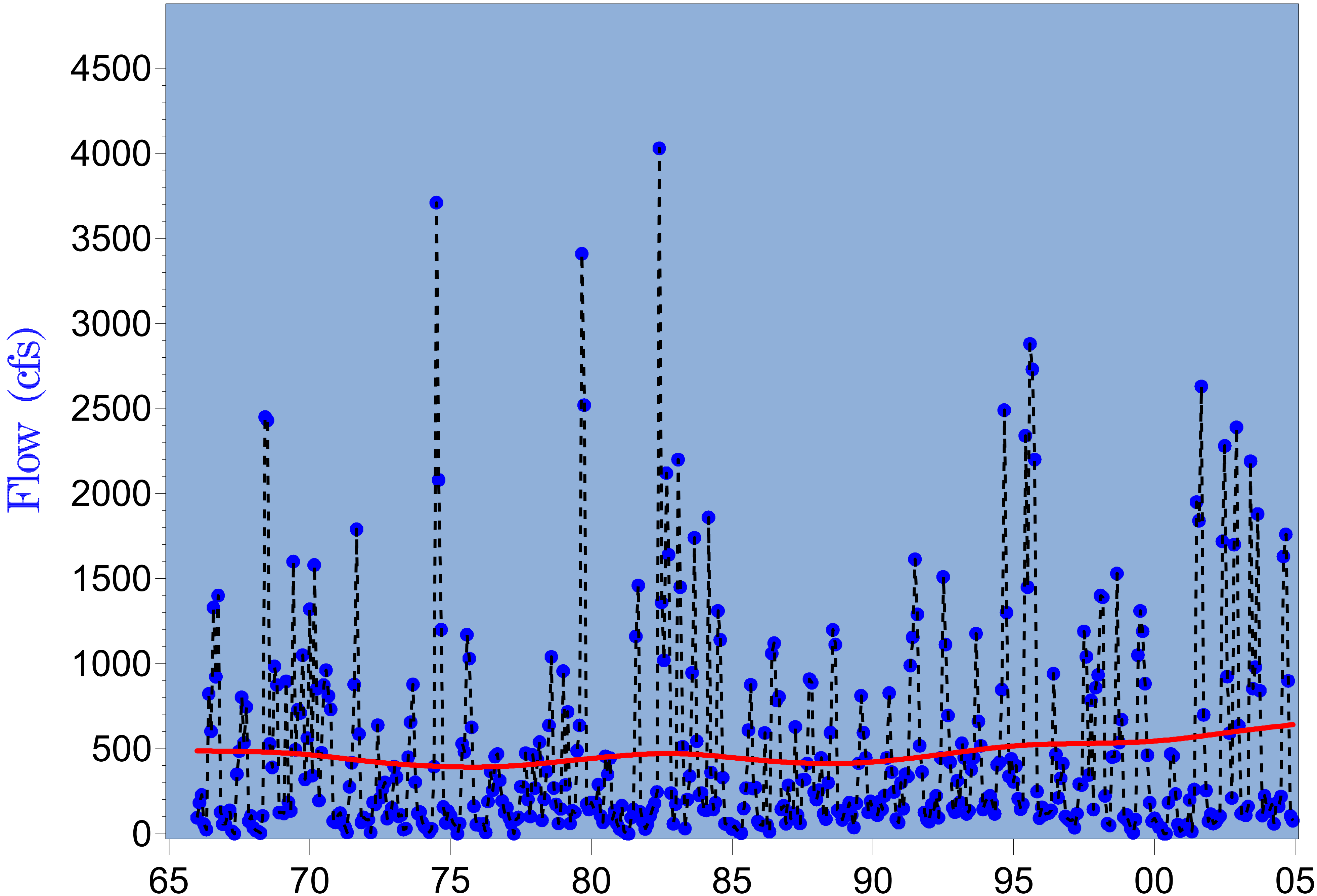


Figure 4.1.7 Monthly Q25 long-term flow at Shell Creek gage (1966-2004)

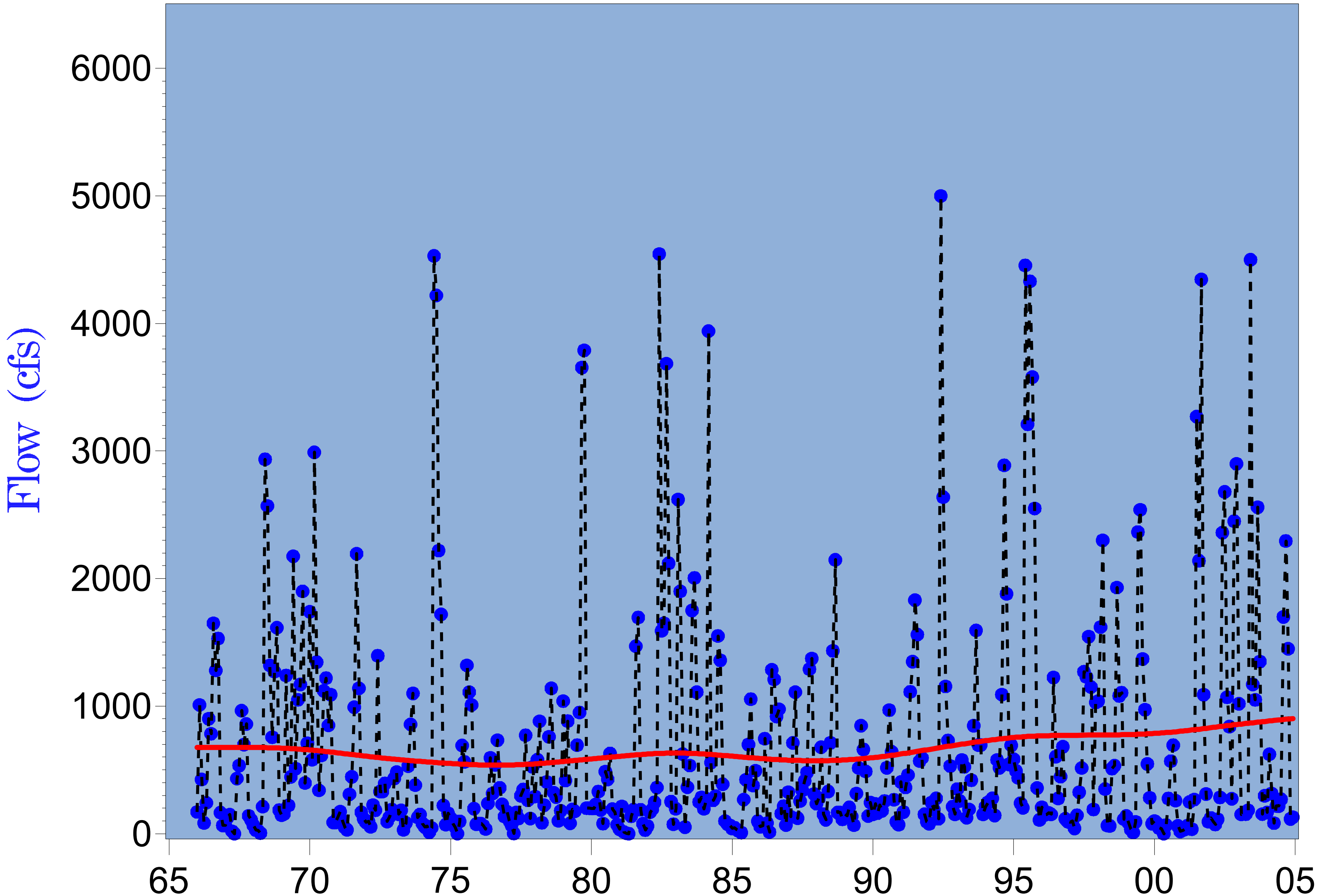


Figure 4.1.8 Monthly Q10 long-term flow at Shell Creek gage (1966-2004)

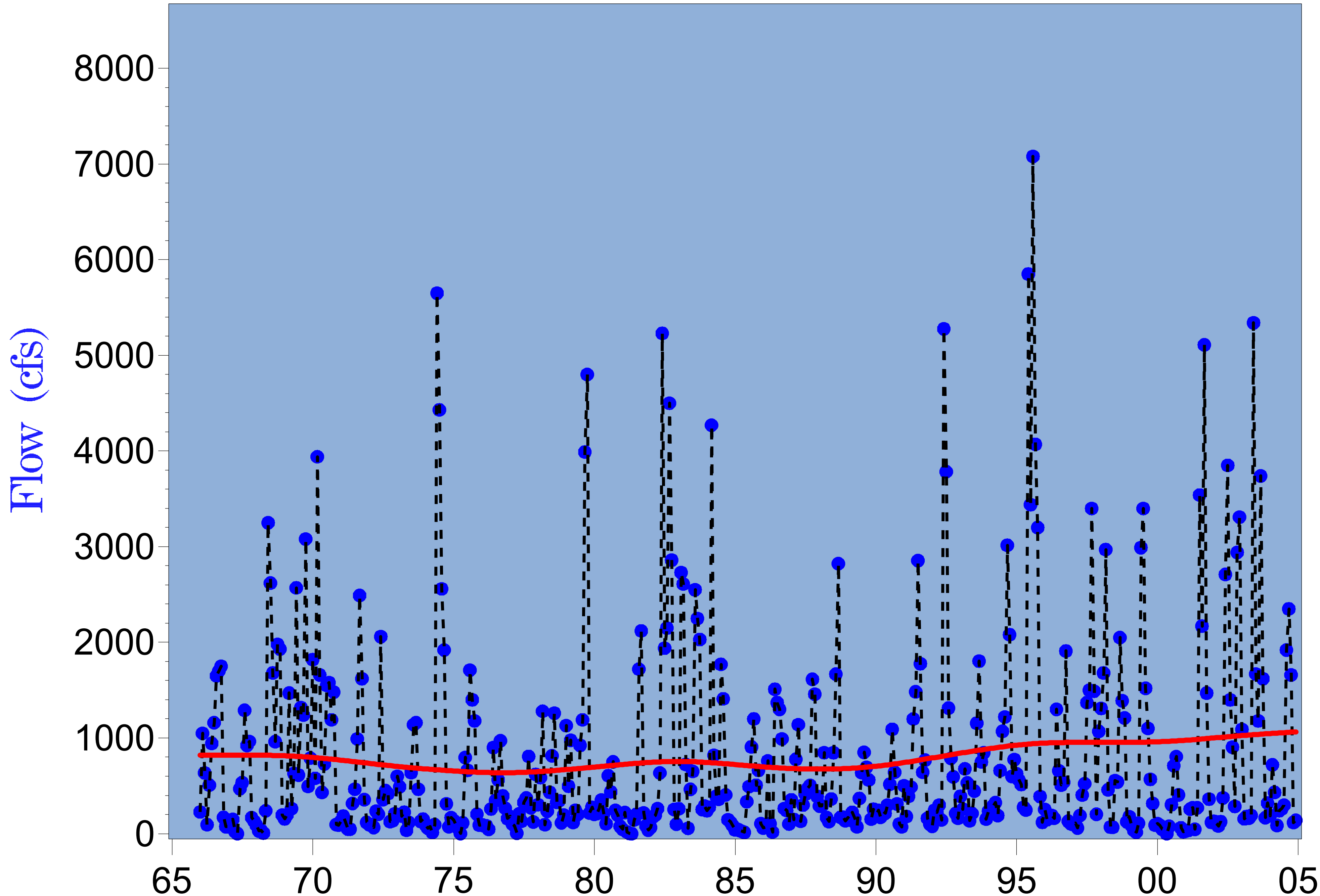


Figure 4.1.9 Monthly Q5 long-term flow at Shell Creek gage (1966-2004)

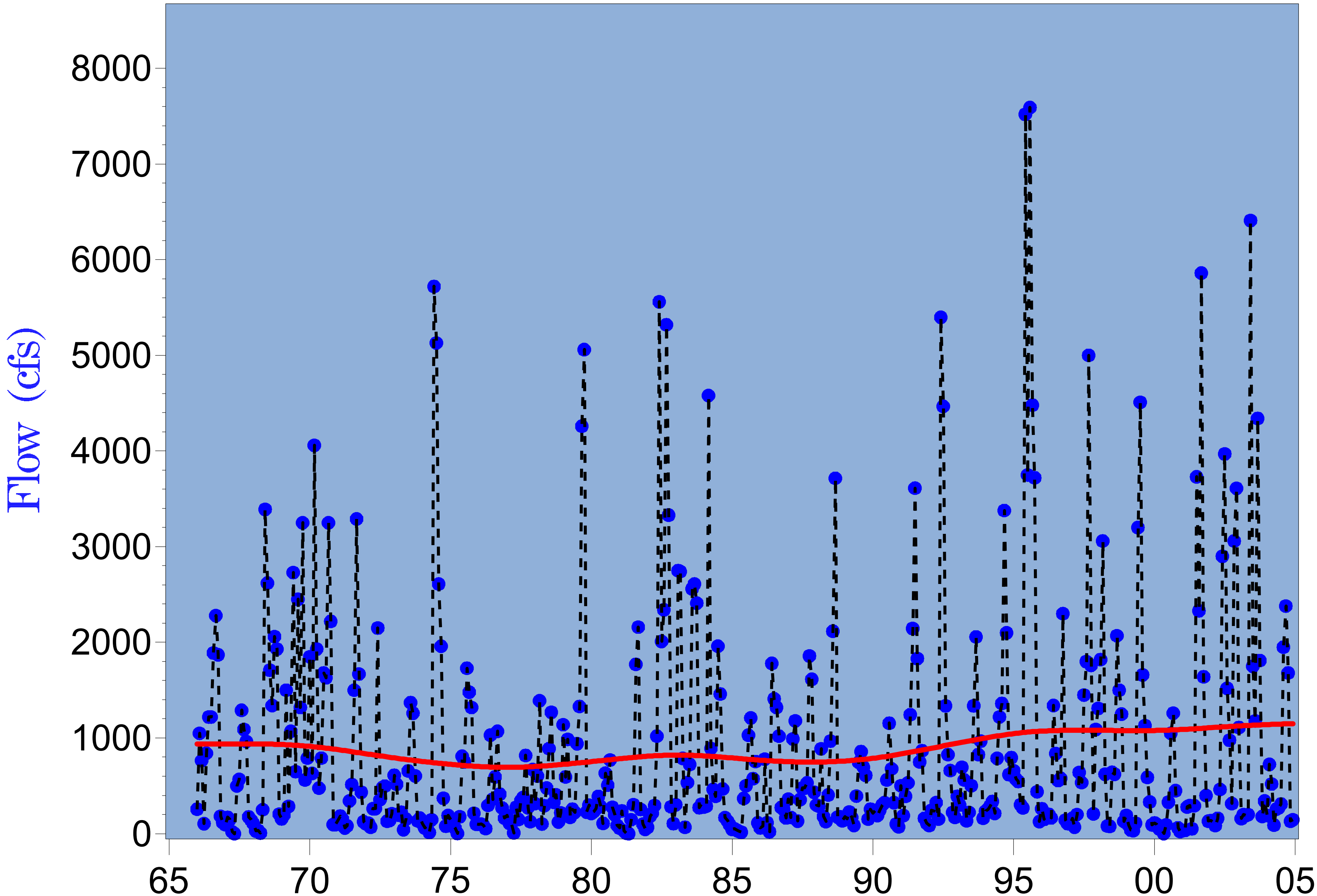


Figure 4.1.10 Monthly maximum long-term flow at Shell Creek gage (1966-2004)

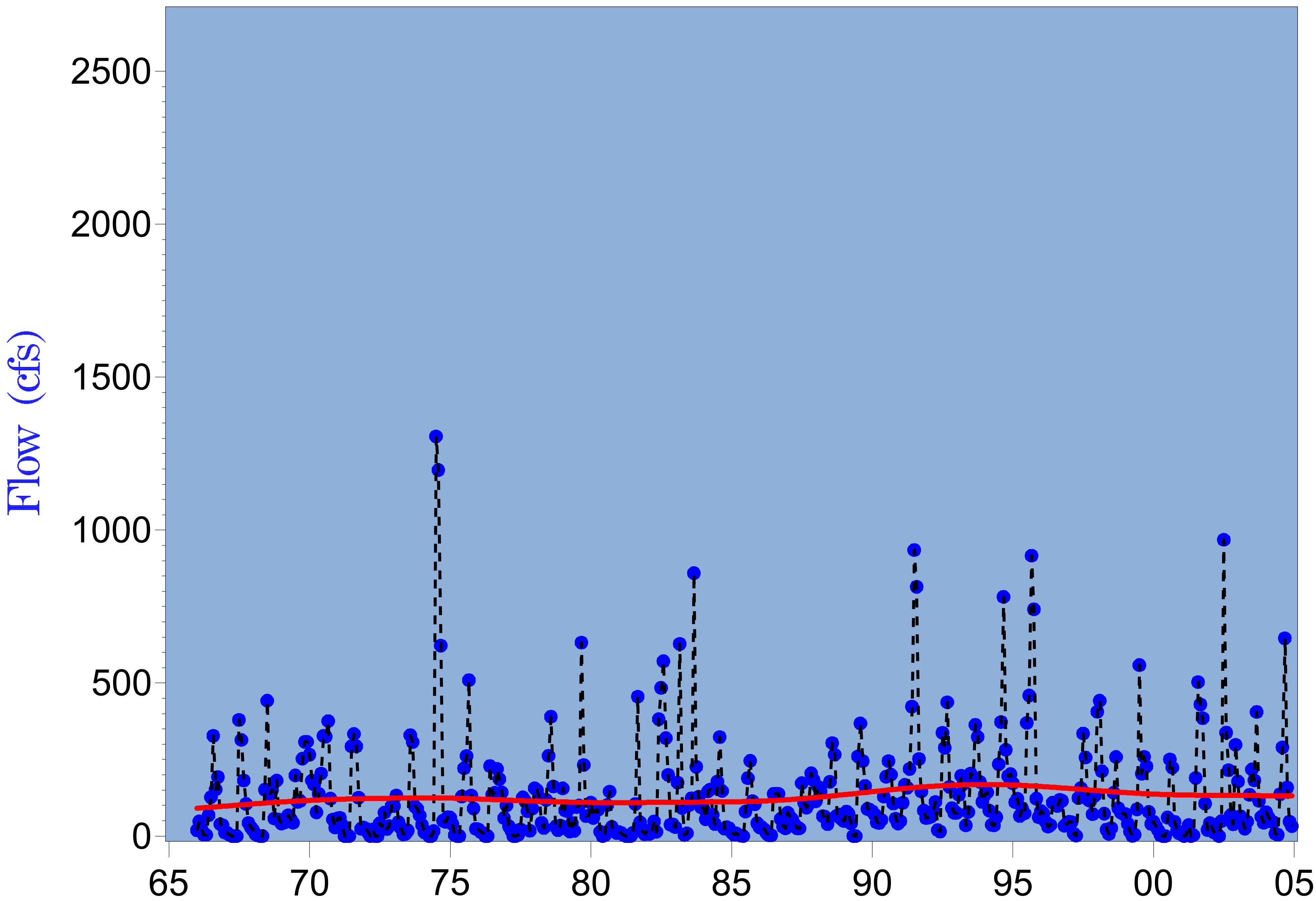


Figure 4.1.11 Monthly minimum 3-day averaged lagged flow at Shell Creek gage (1966-2004)

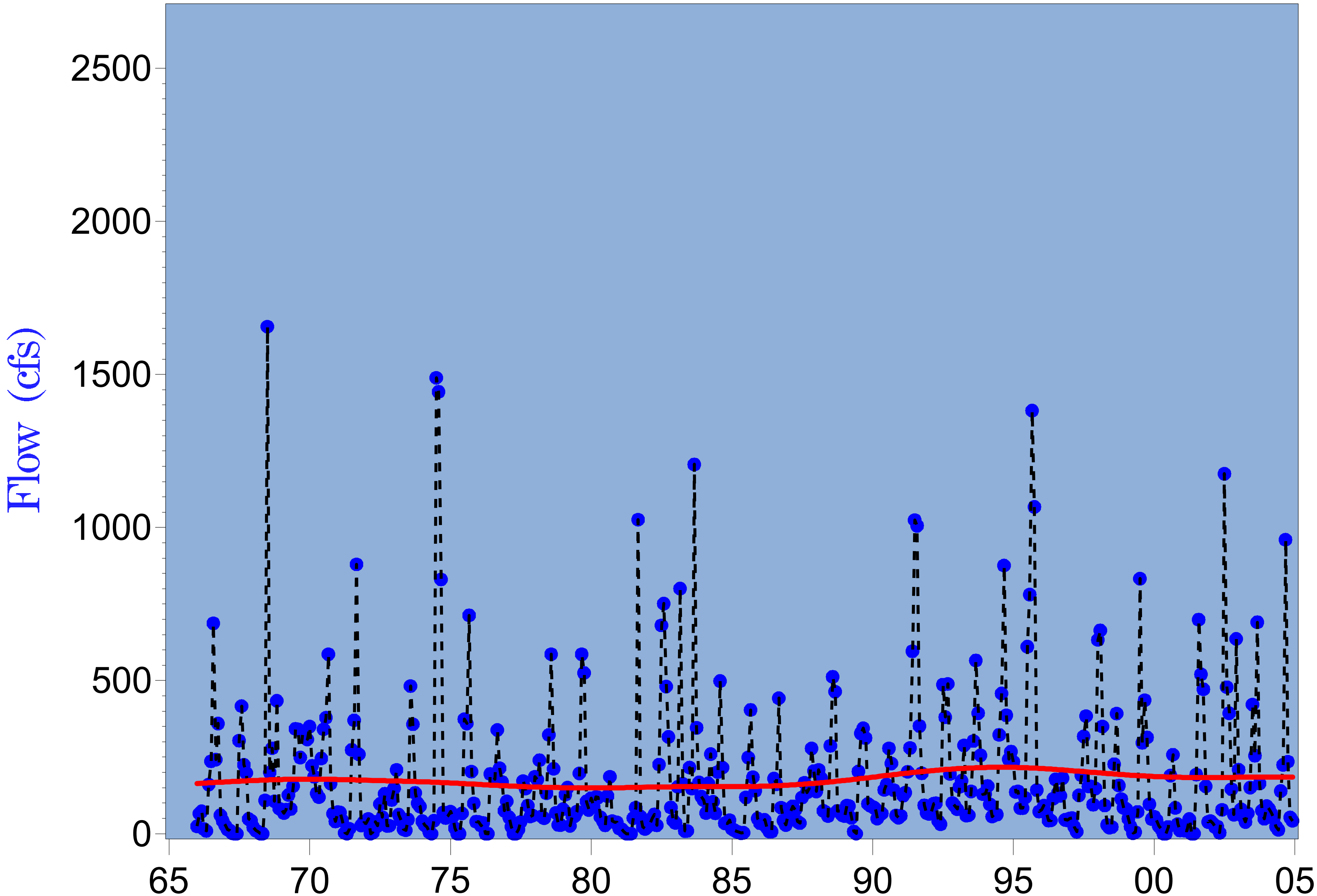


Figure 4.1.12 Monthly minimum 15-day averaged lagged flow at Shell Creek gage (1966-2004)

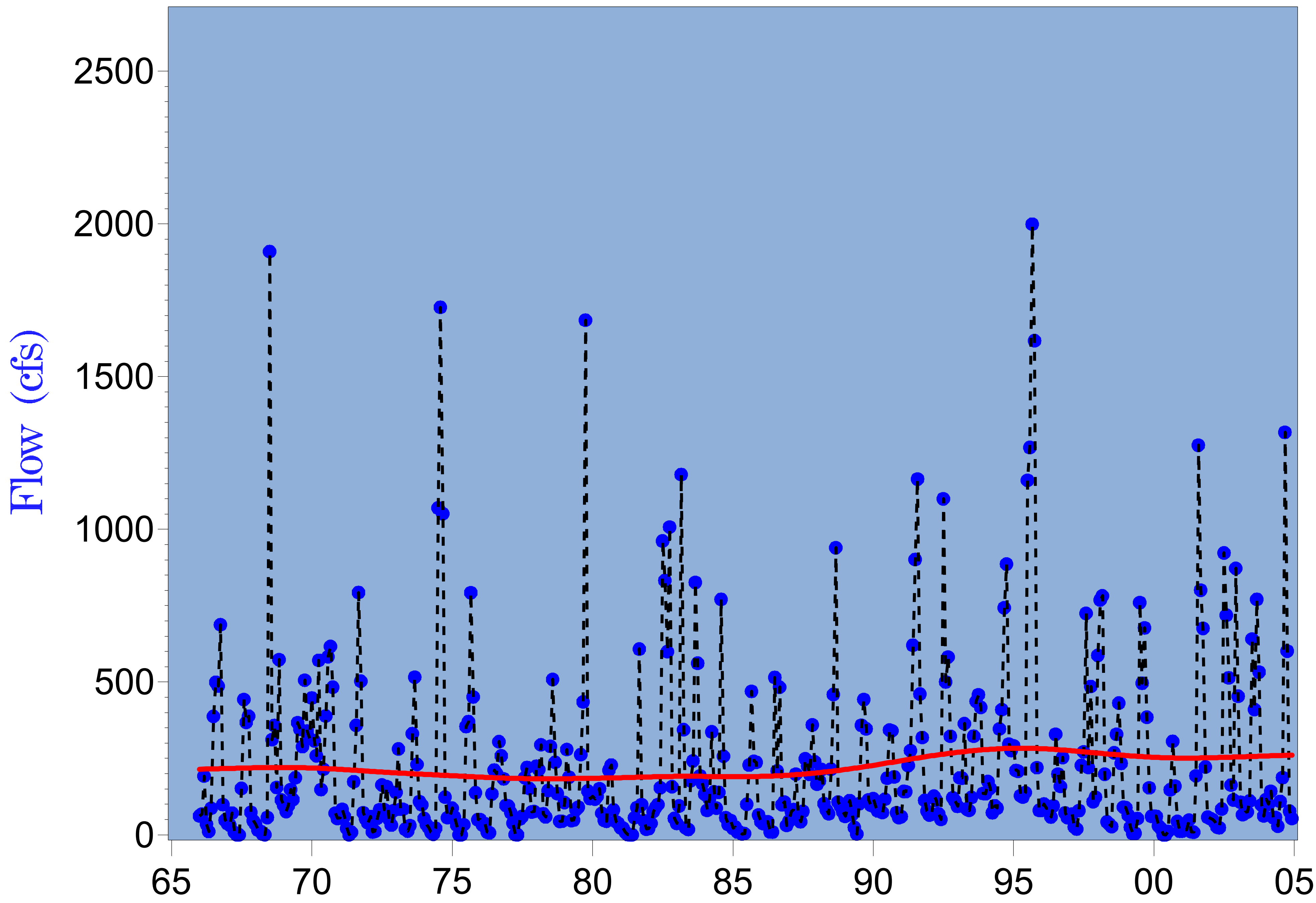


Figure 4.1.13 Monthly minimum 30-day averaged lagged flow at Shell Creek gage (1966-2004)

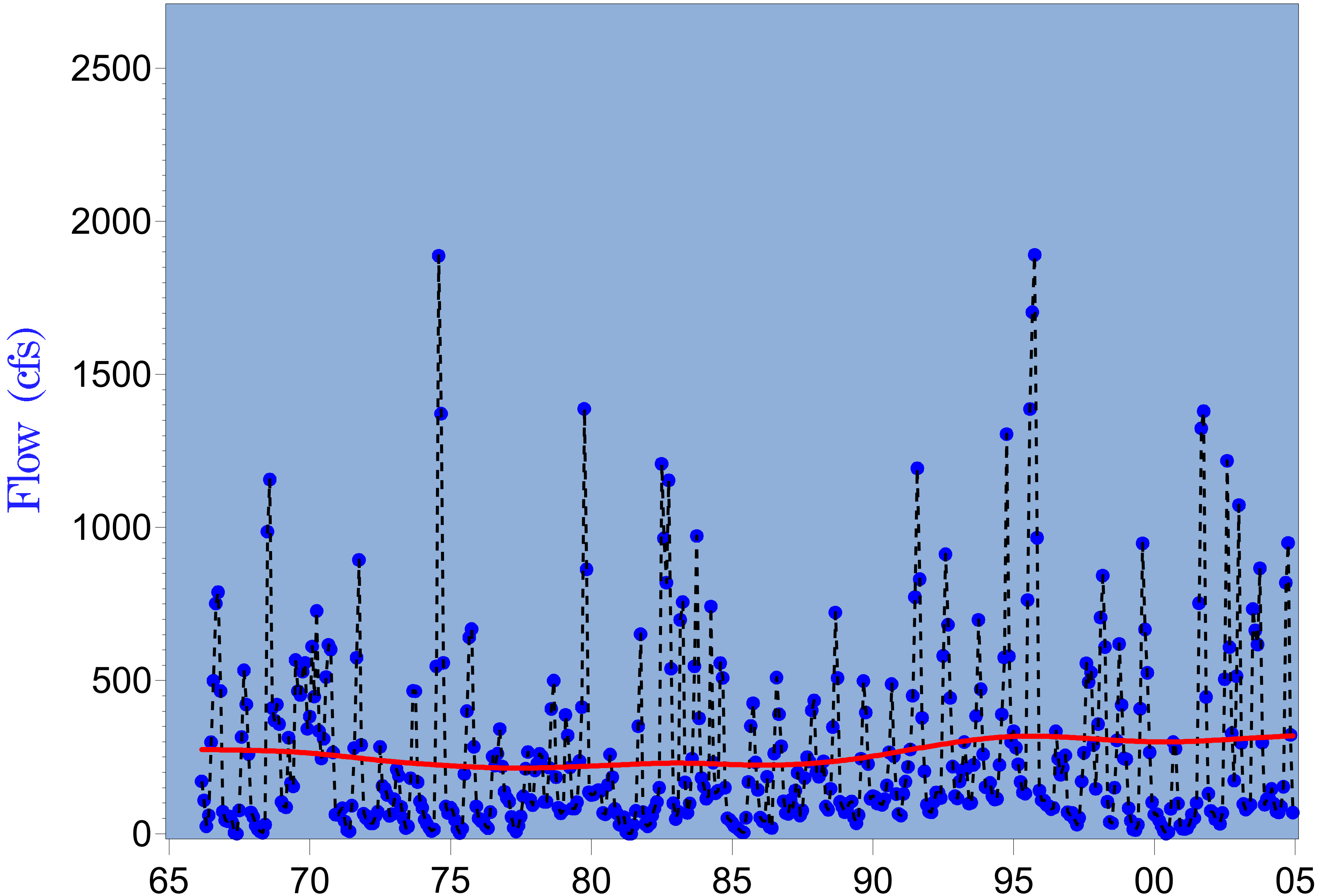


Figure 4.1.14 Monthly minimum 60-day averaged lagged flow at Shell Creek gage (1966-2004)

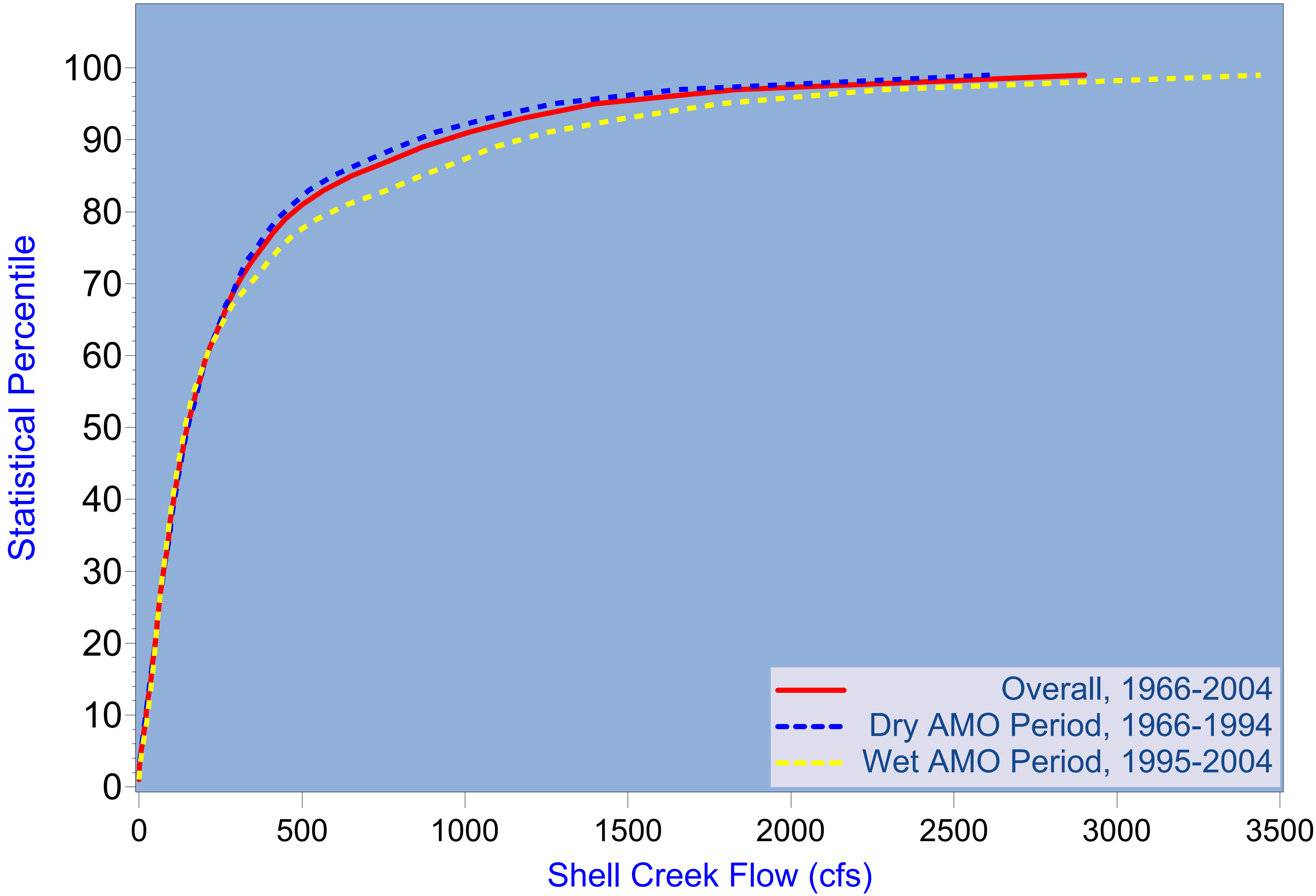


Figure 4.1.15 Differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

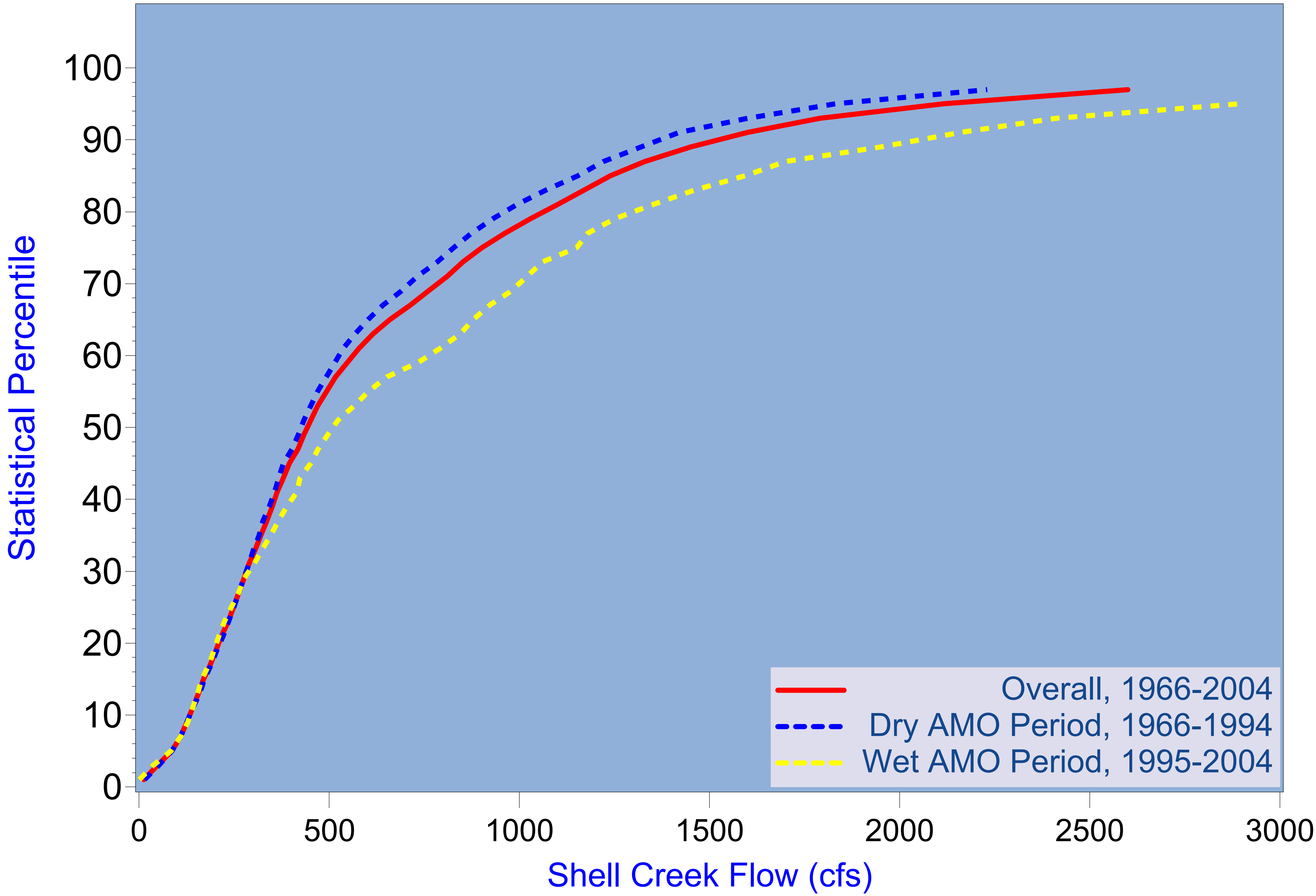


Figure 4.1.16 Wet-season differences in CDFs among AMO periods in Shell Creek flow

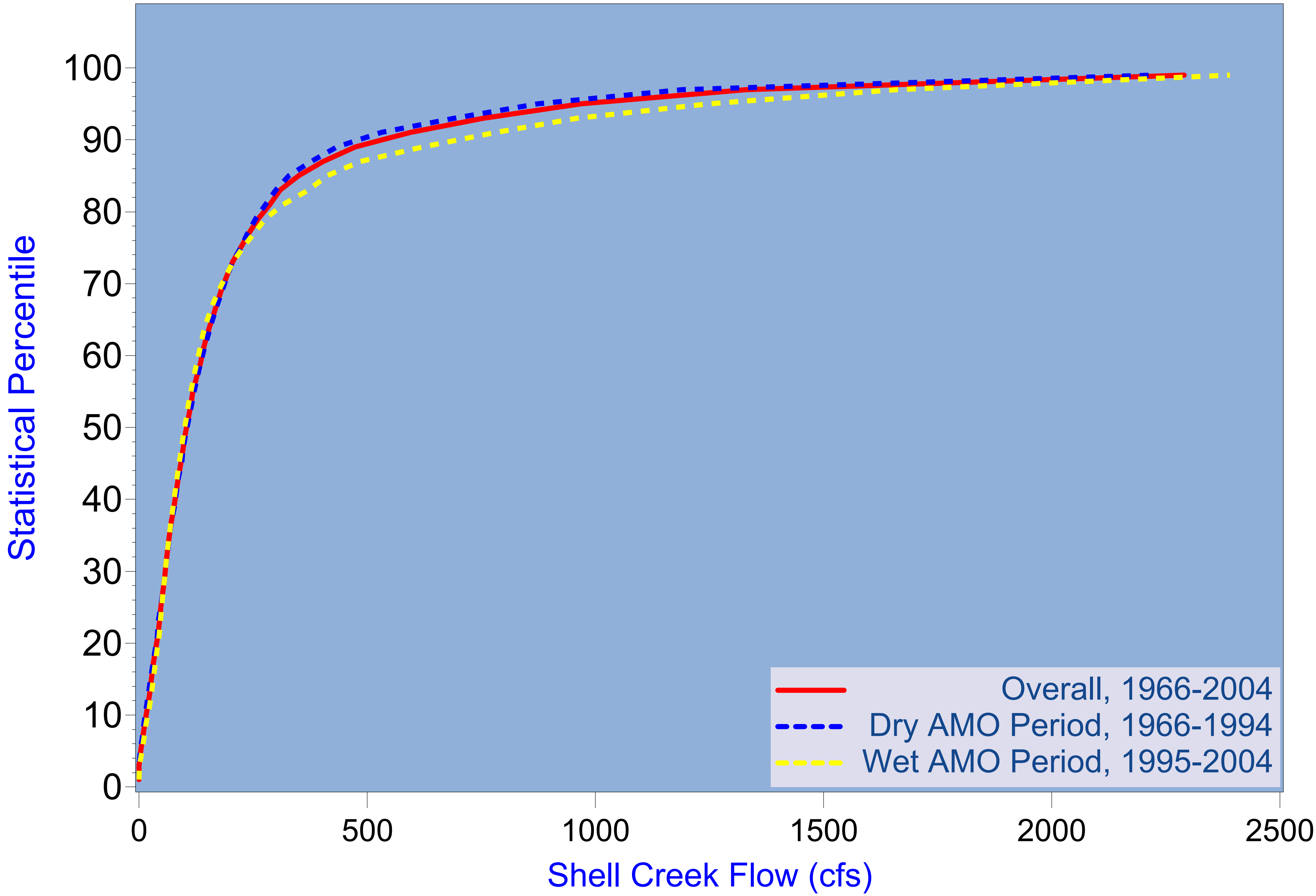


Figure 4.1.17 Dry-season differences in CDFs among AMO periods in Shell Creek flow

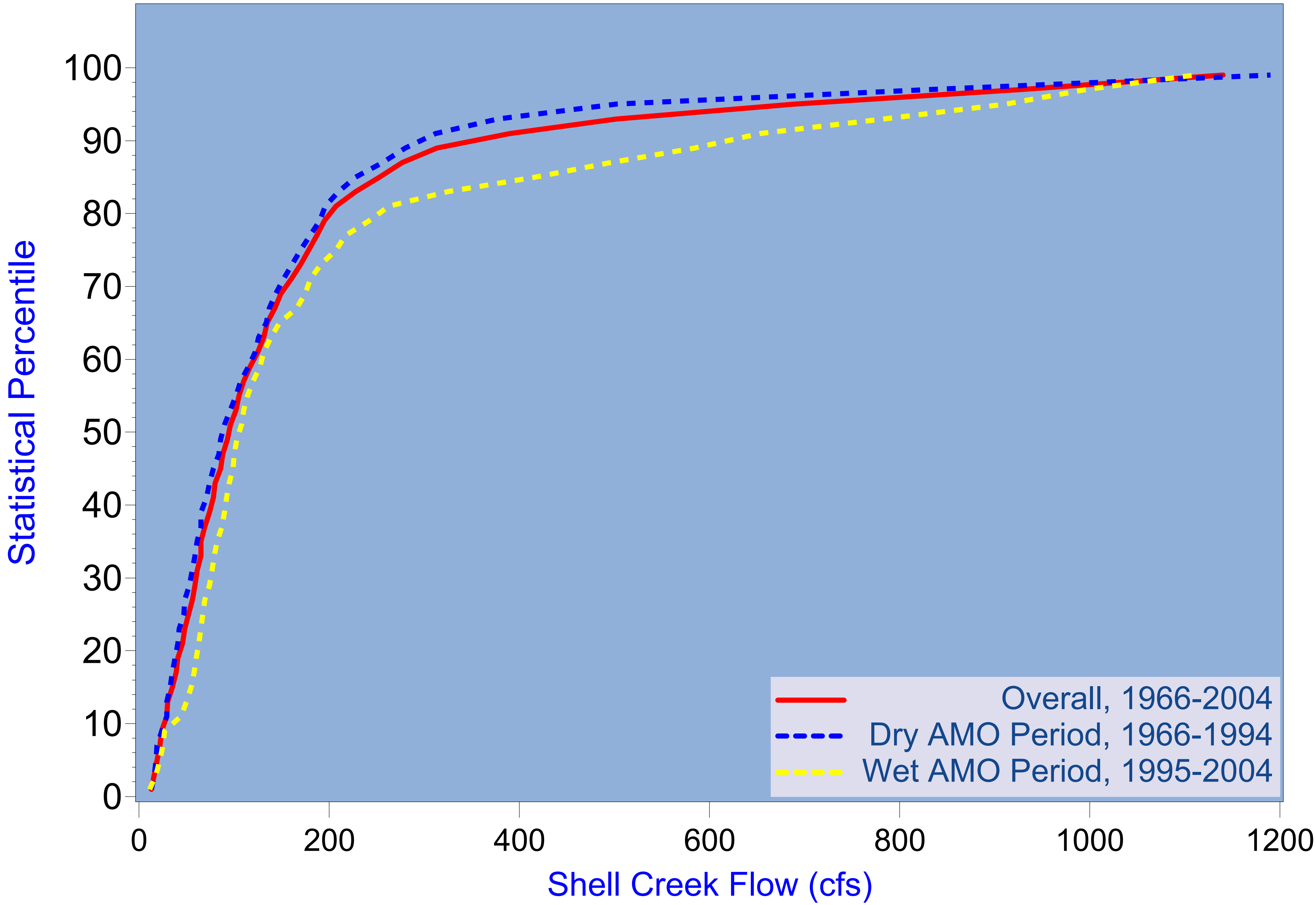


Figure 4.1.18 January differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

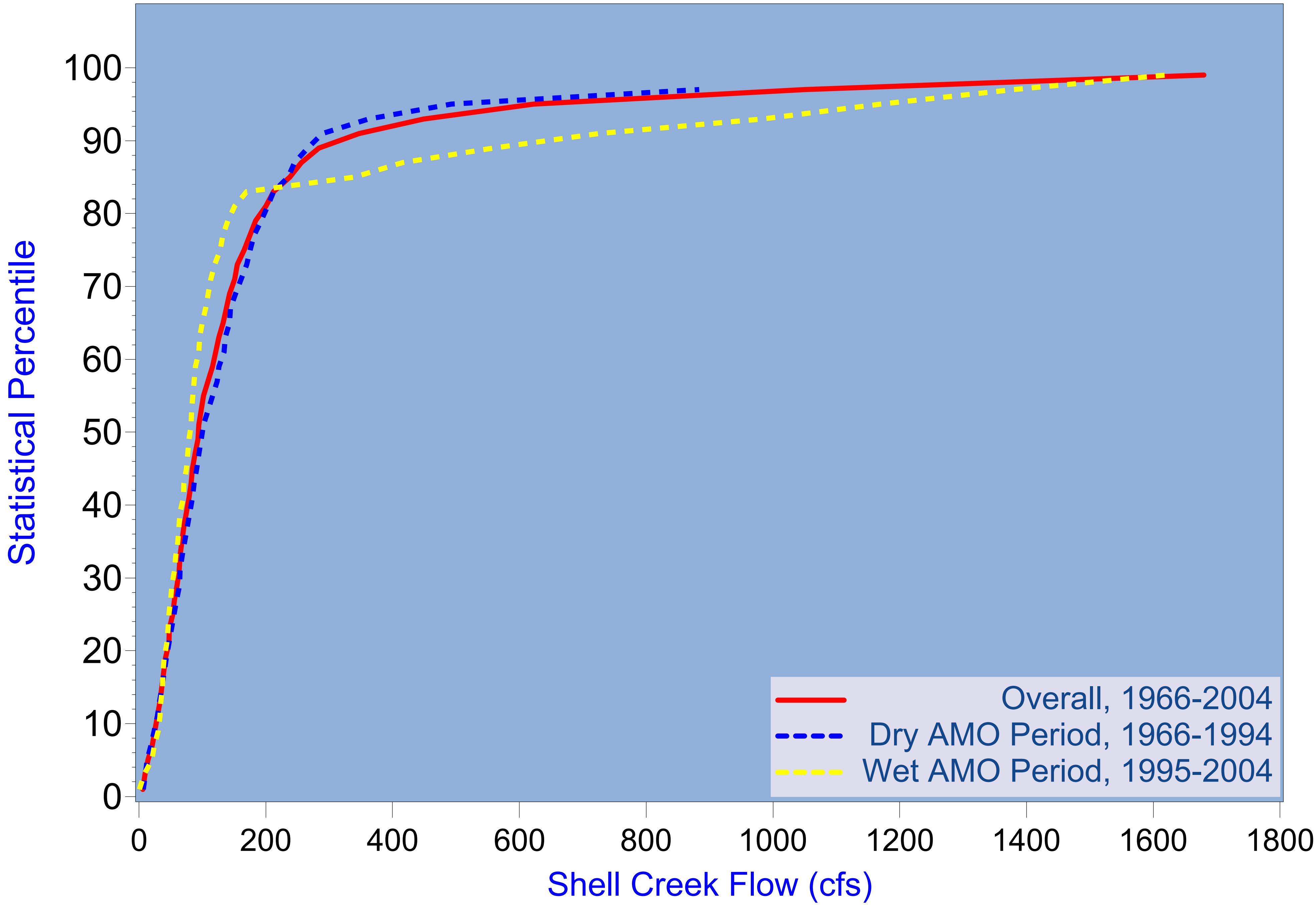


Figure 4.1.19 February differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

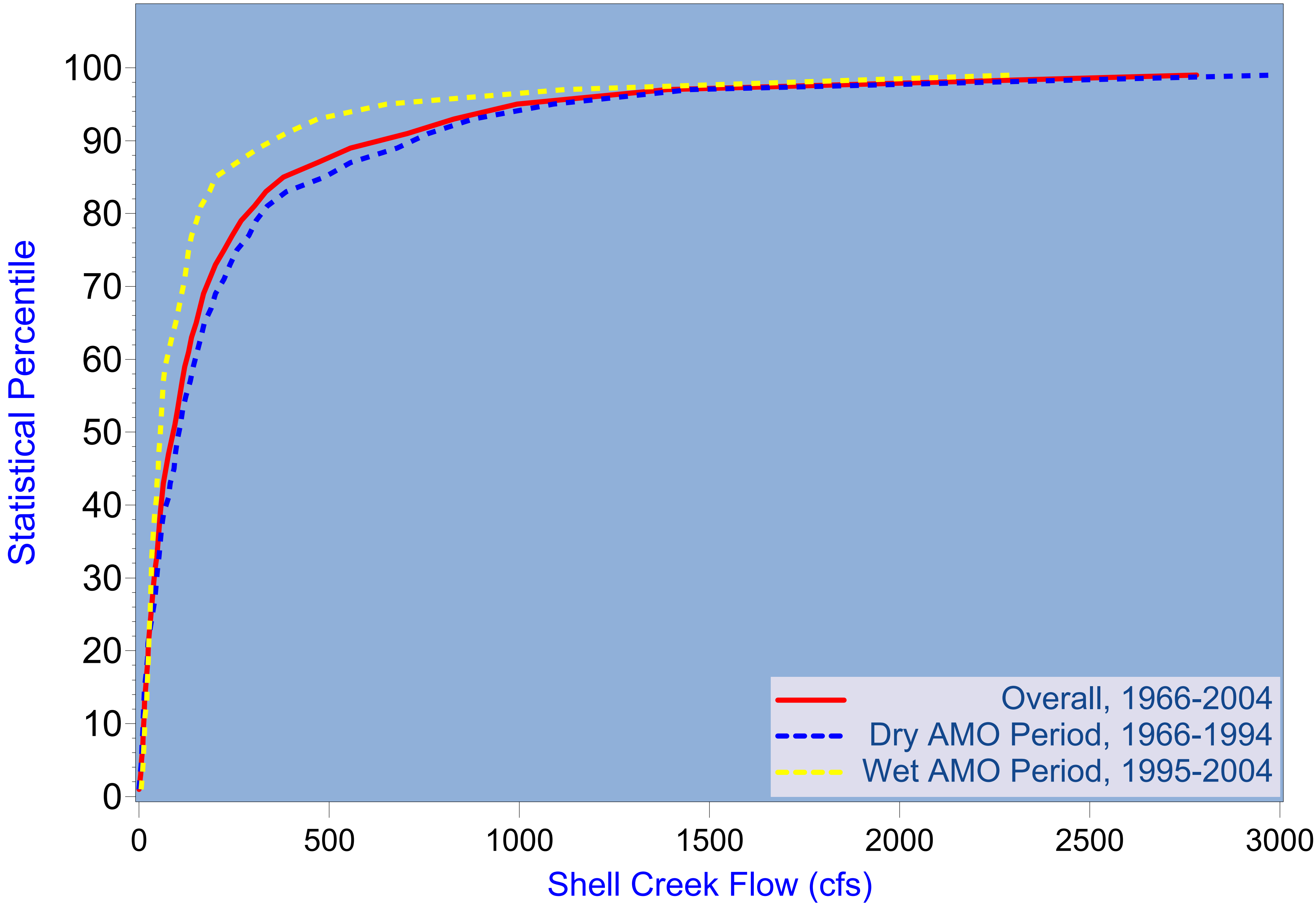


Figure 4.1.20 March differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

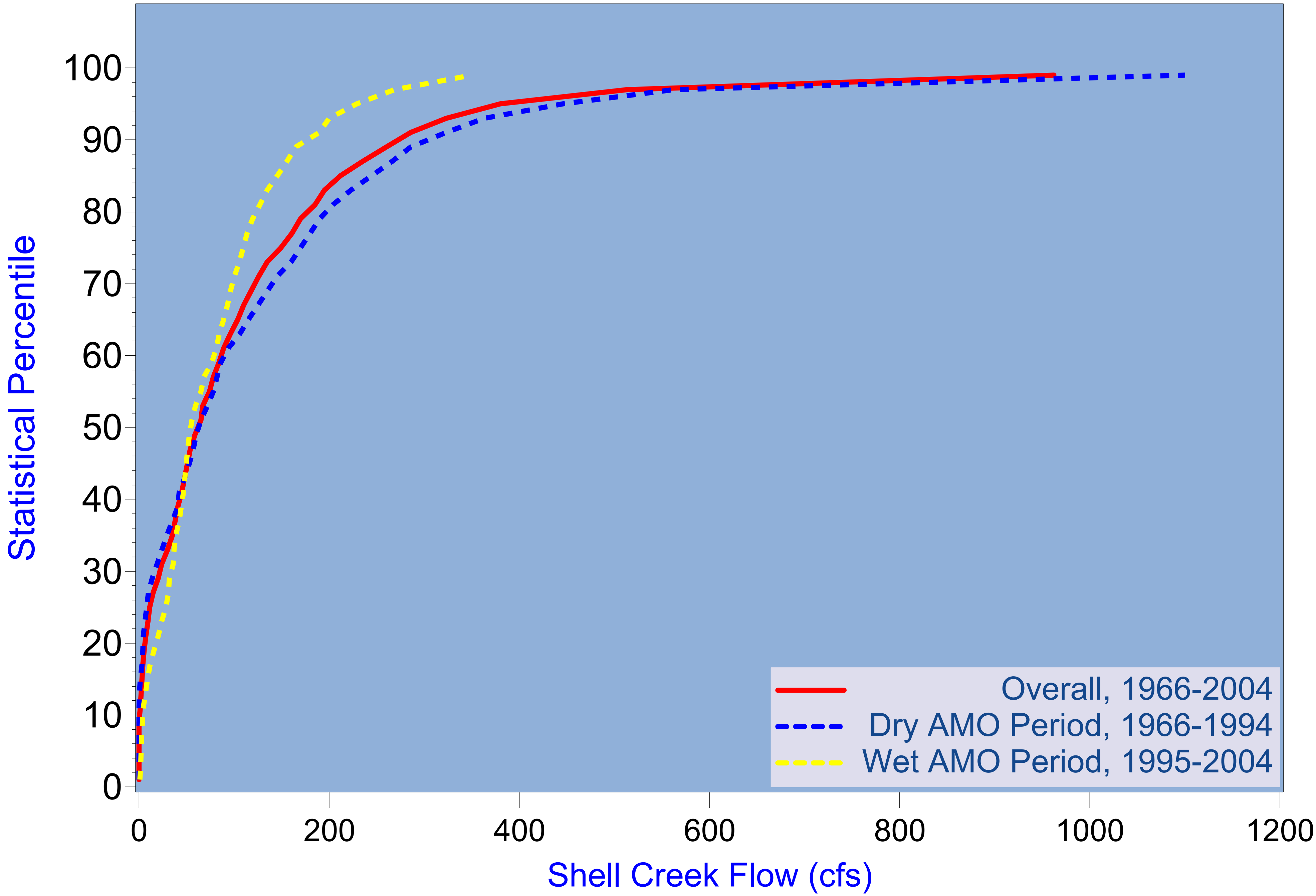


Figure 4.1.21 April differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

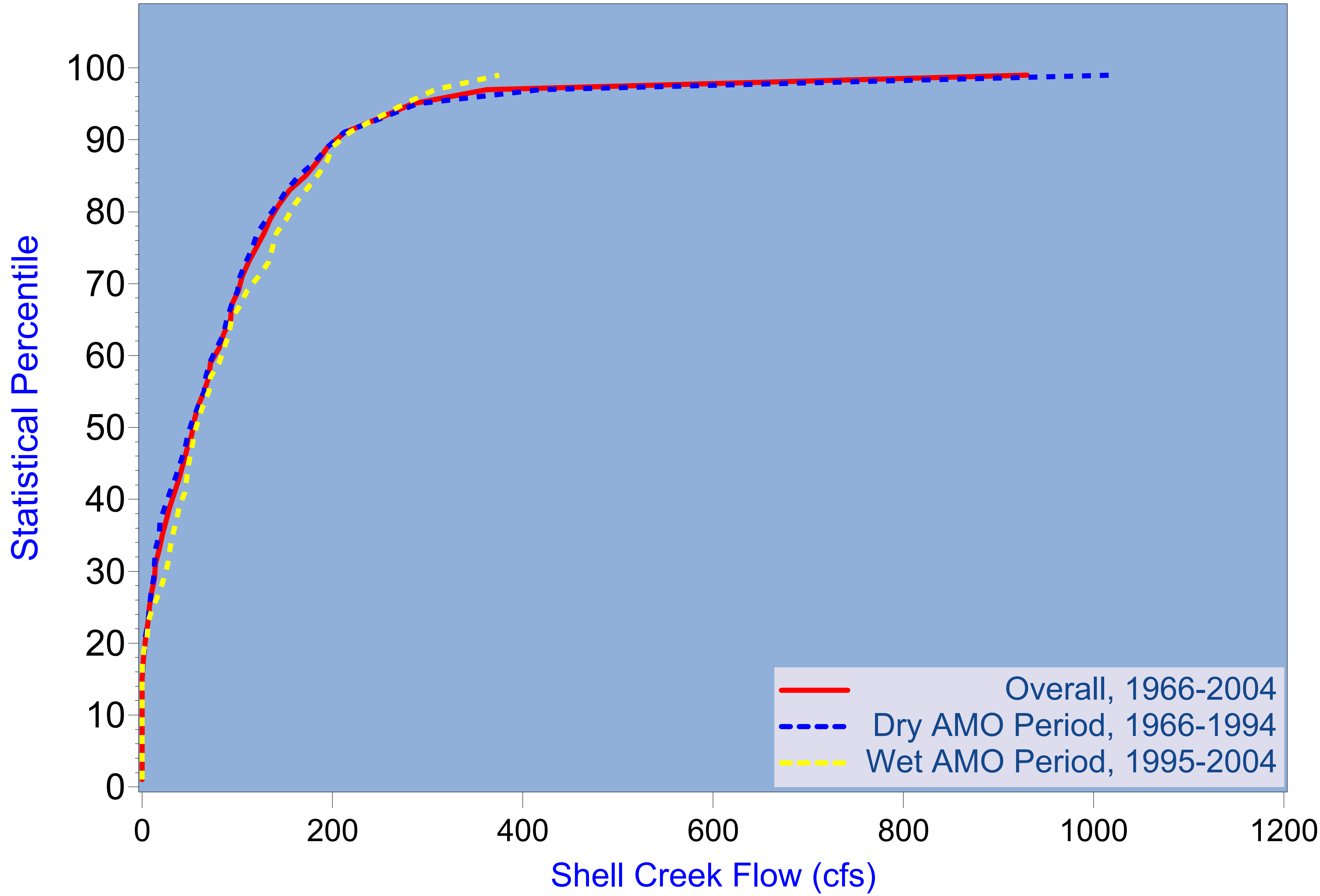


Figure 4.1.22 May differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

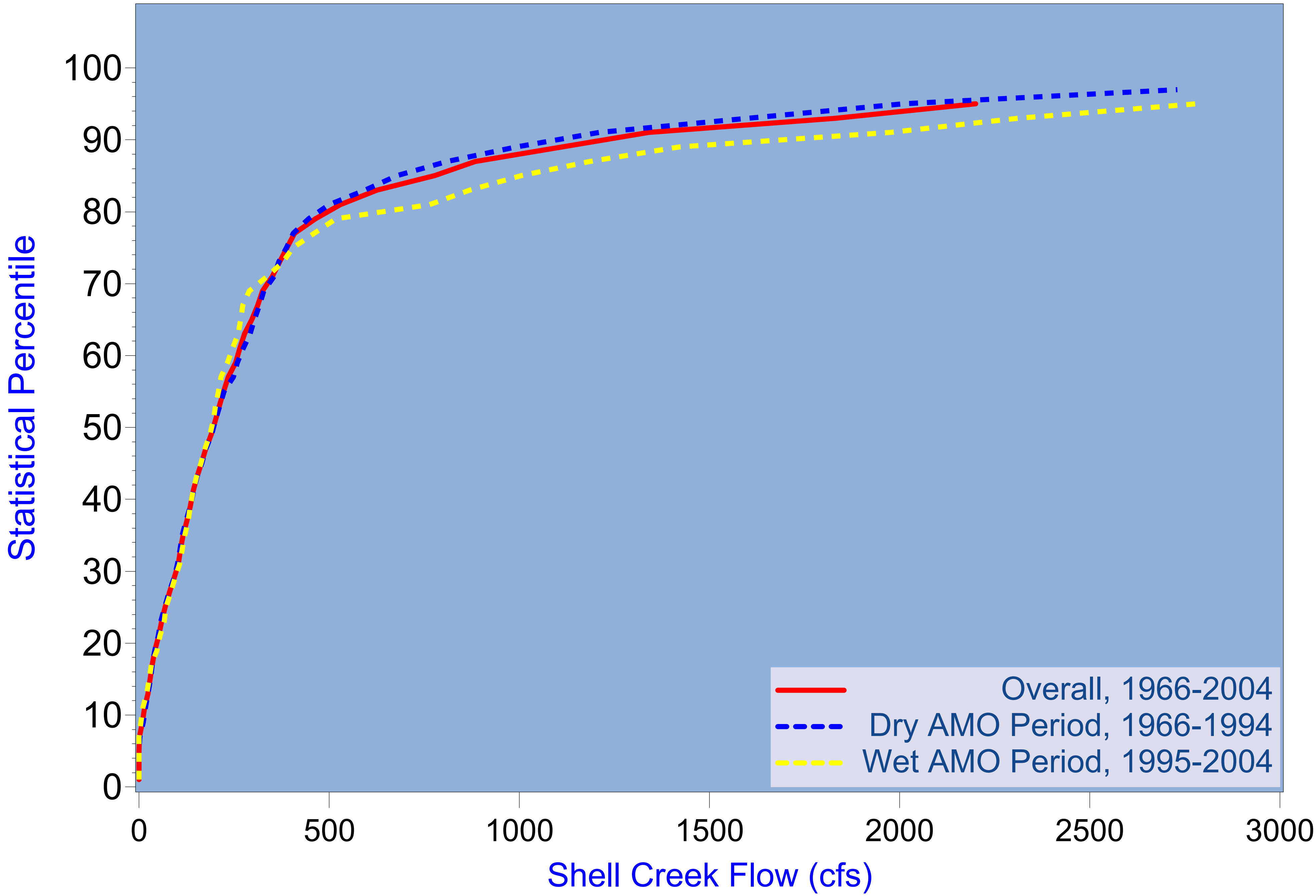


Figure 4.1.23 June differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

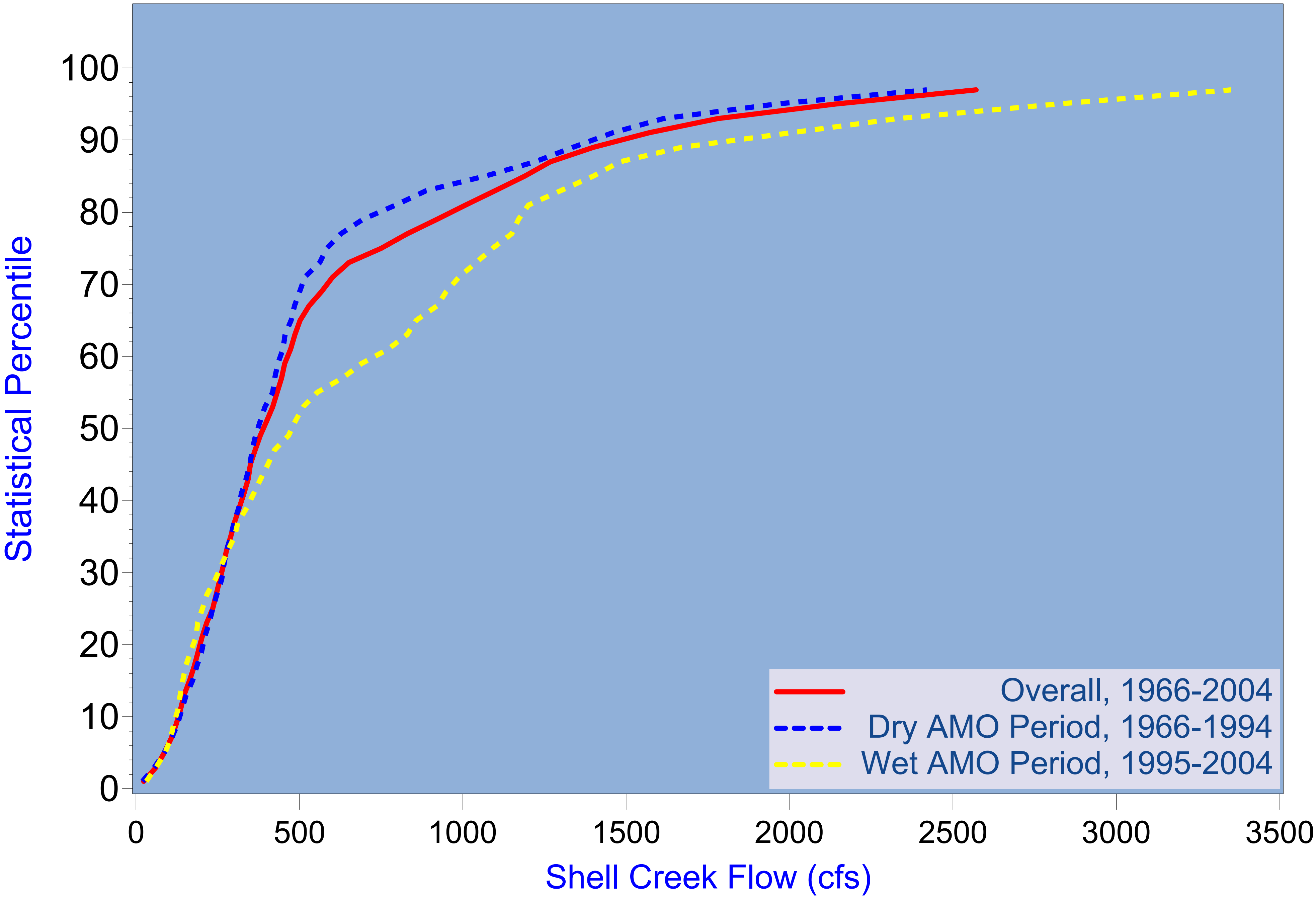


Figure 4.1.24 July differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

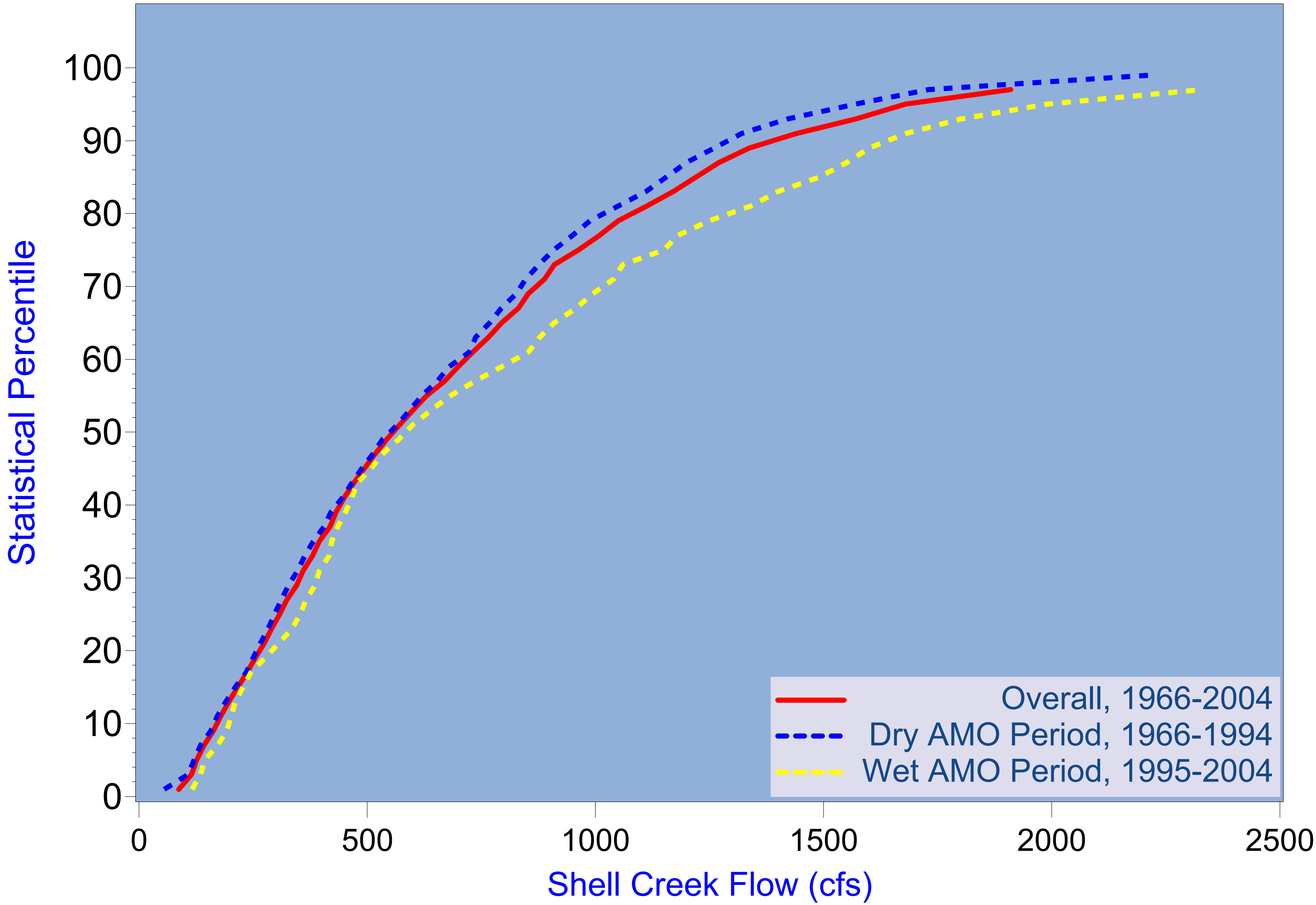


Figure 4.1.25 August differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

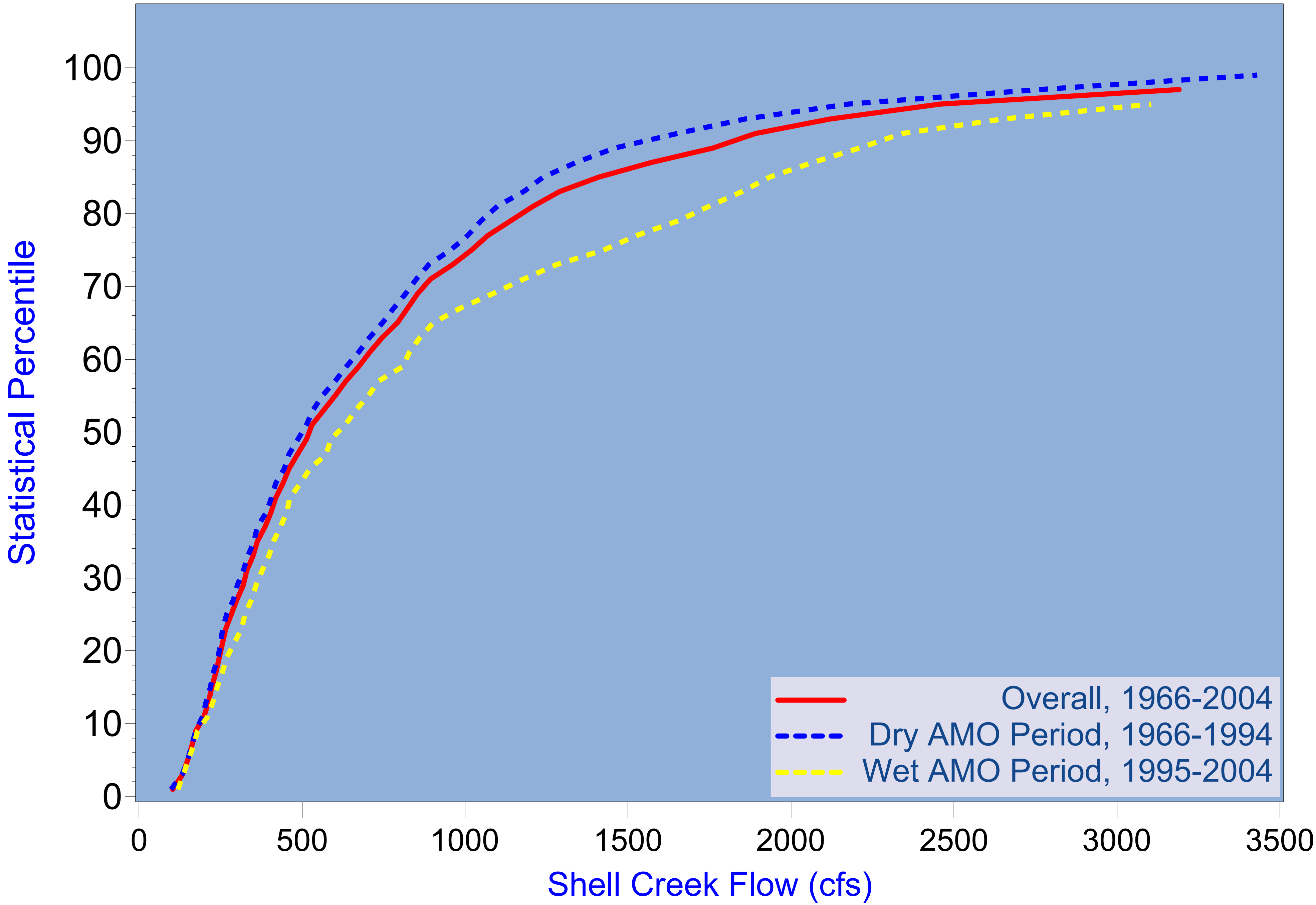


Figure 4.1.26 September differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

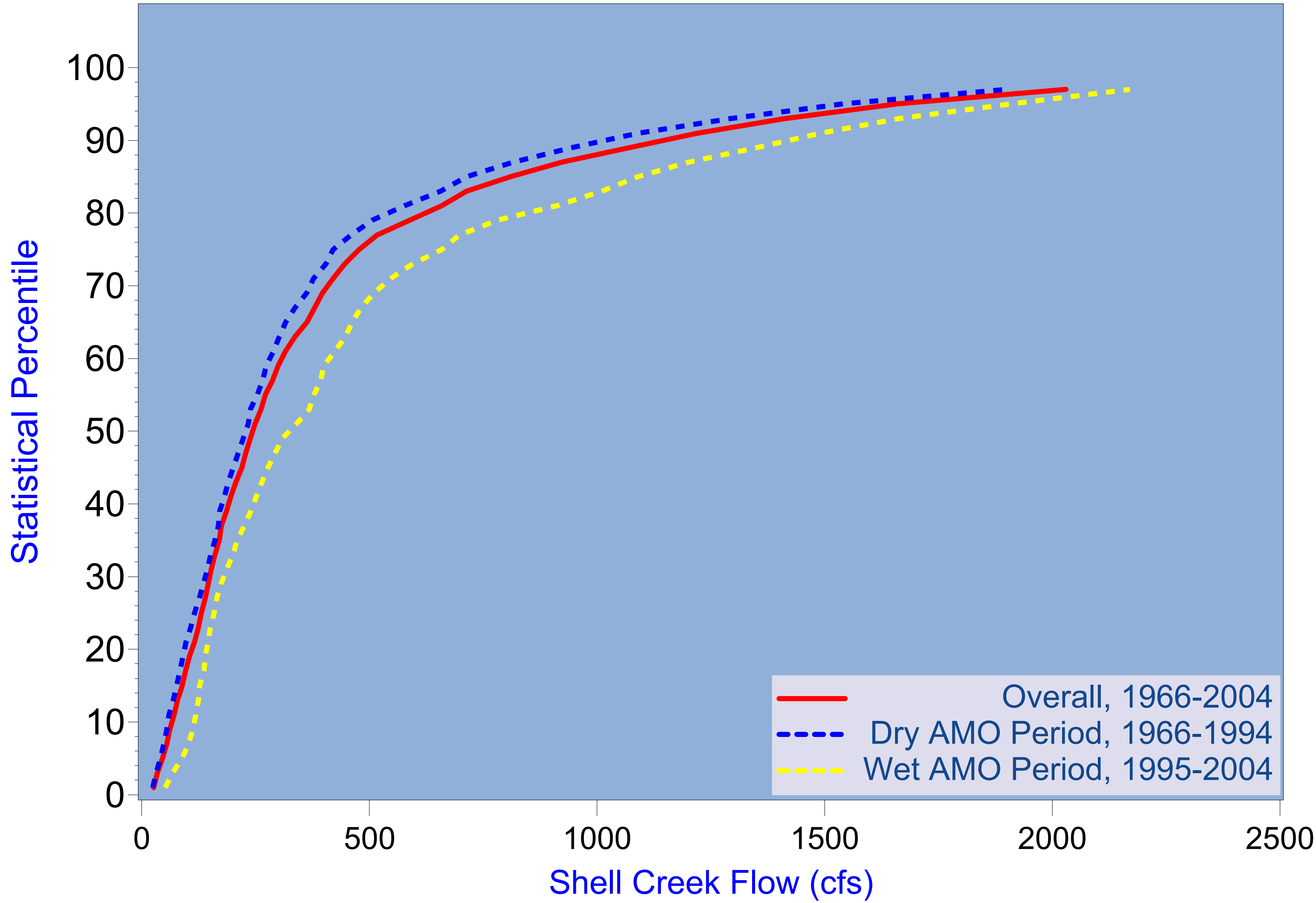


Figure 4.1.27 October differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

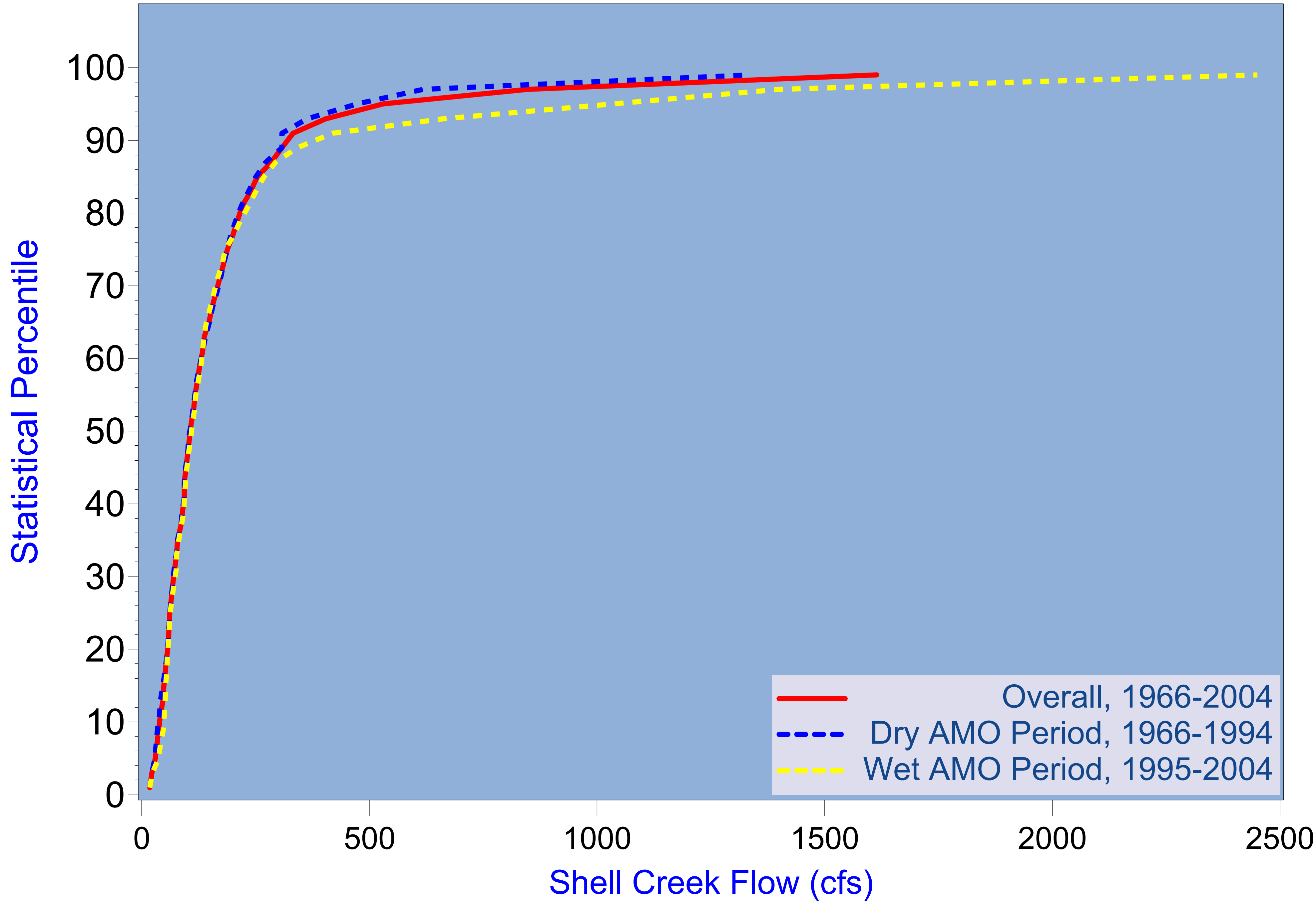


Figure 4.1.28 November differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

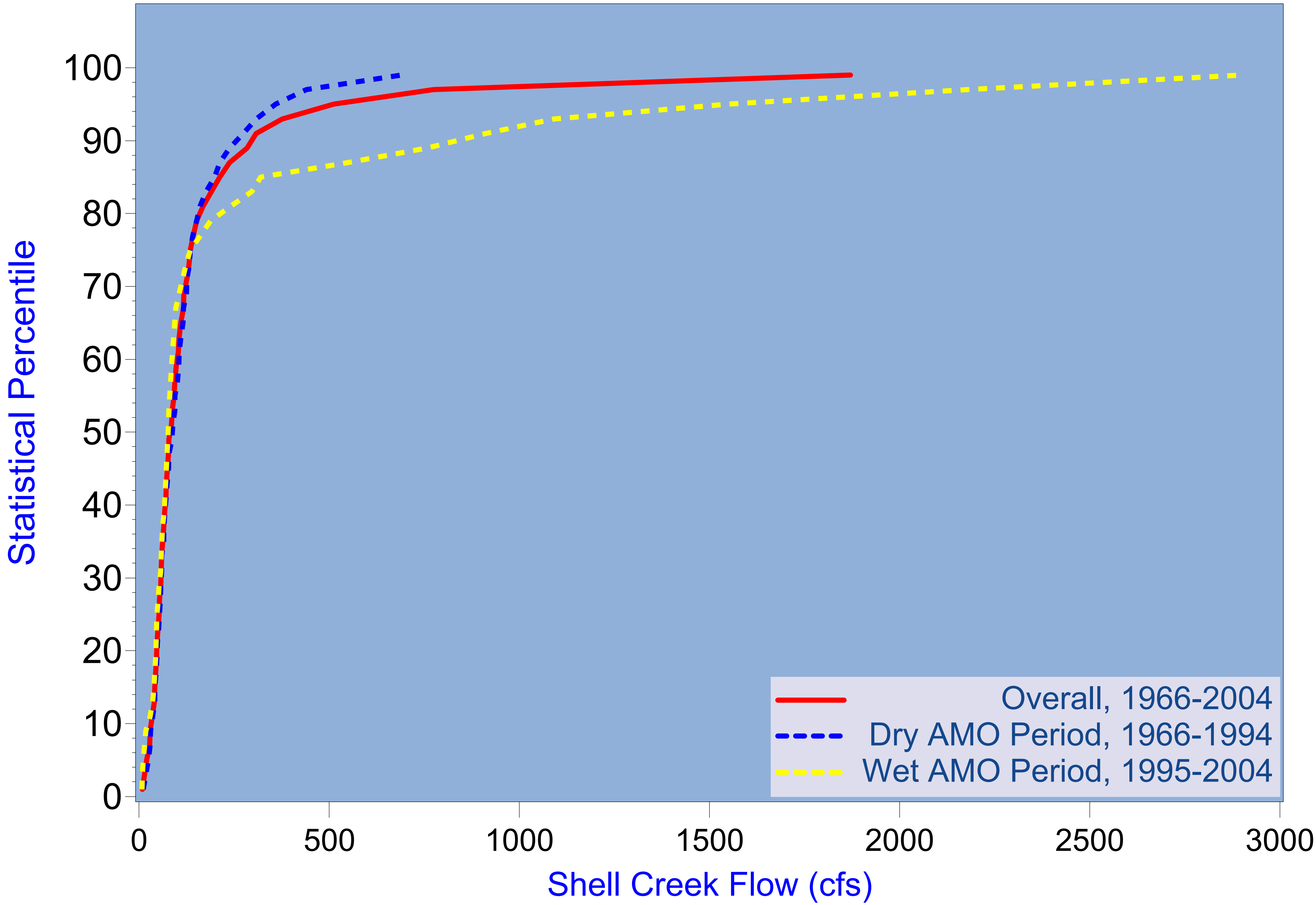


Figure 4.1.29 December differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

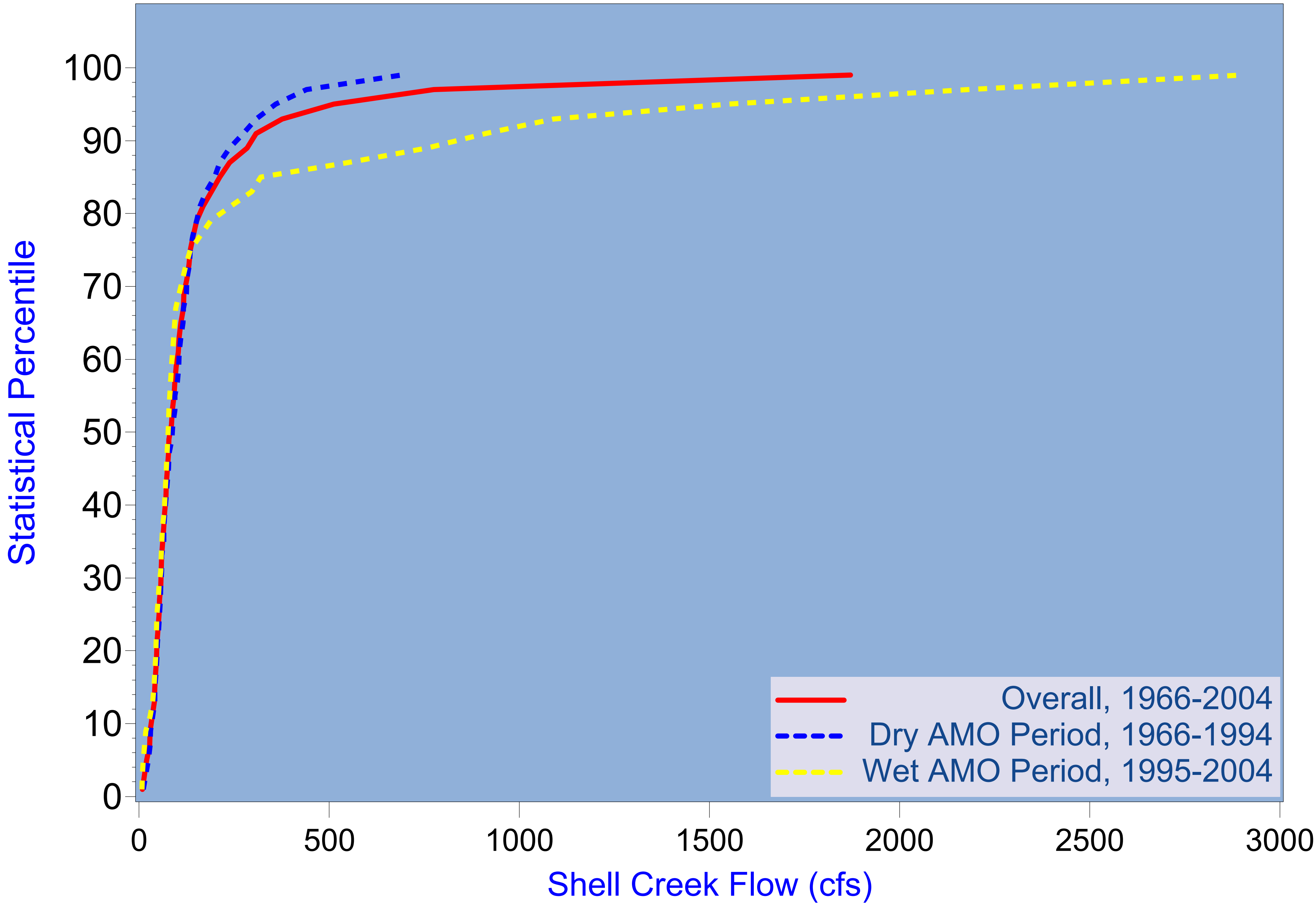


Figure 4.1.29 December differences in CDFs among AMO periods in flow at Shell Creek gage (USGS #2298202)

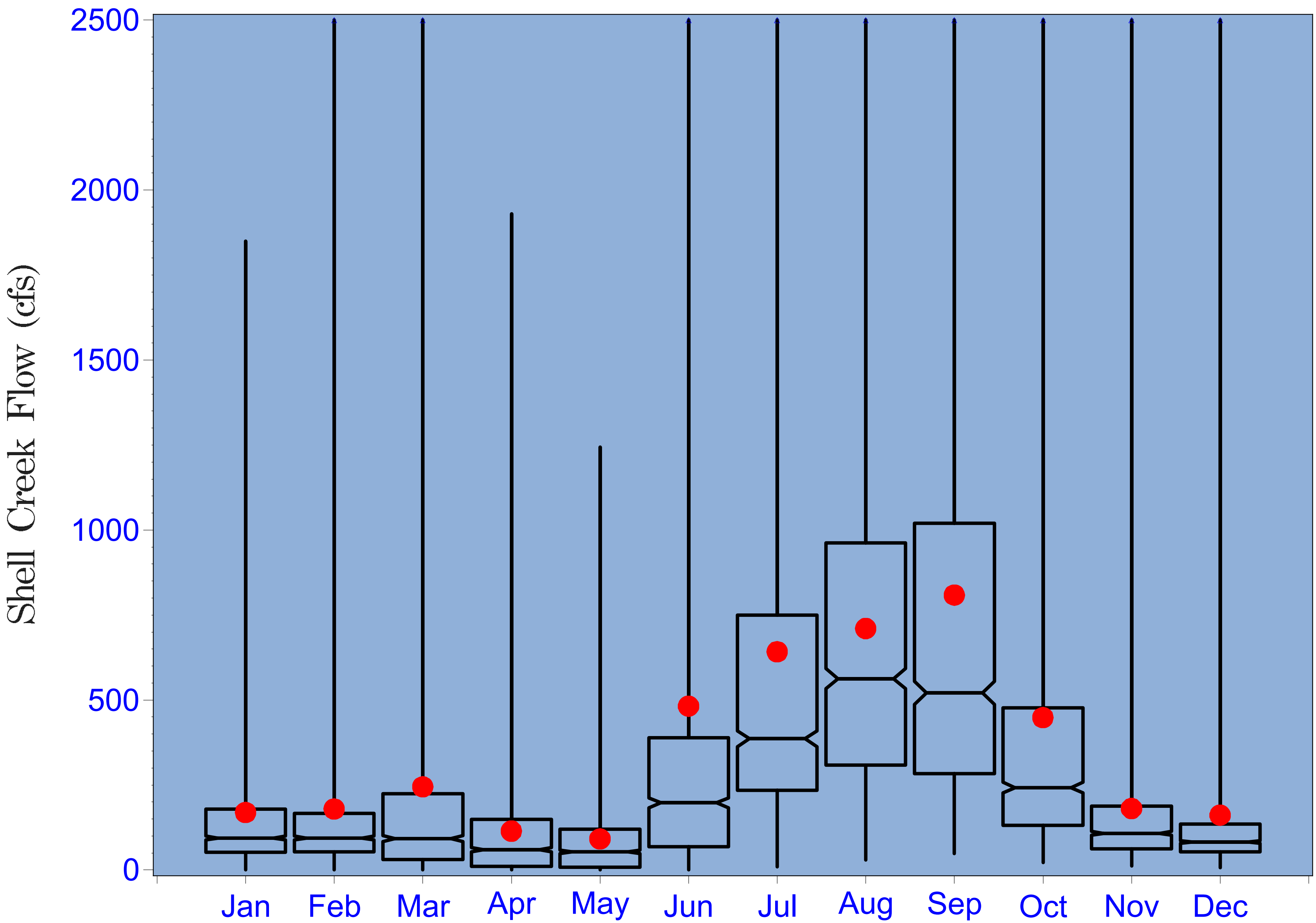


Figure 4.1.30 Box & whiskers of annual monthly Shell Creek flow (1966-2004)

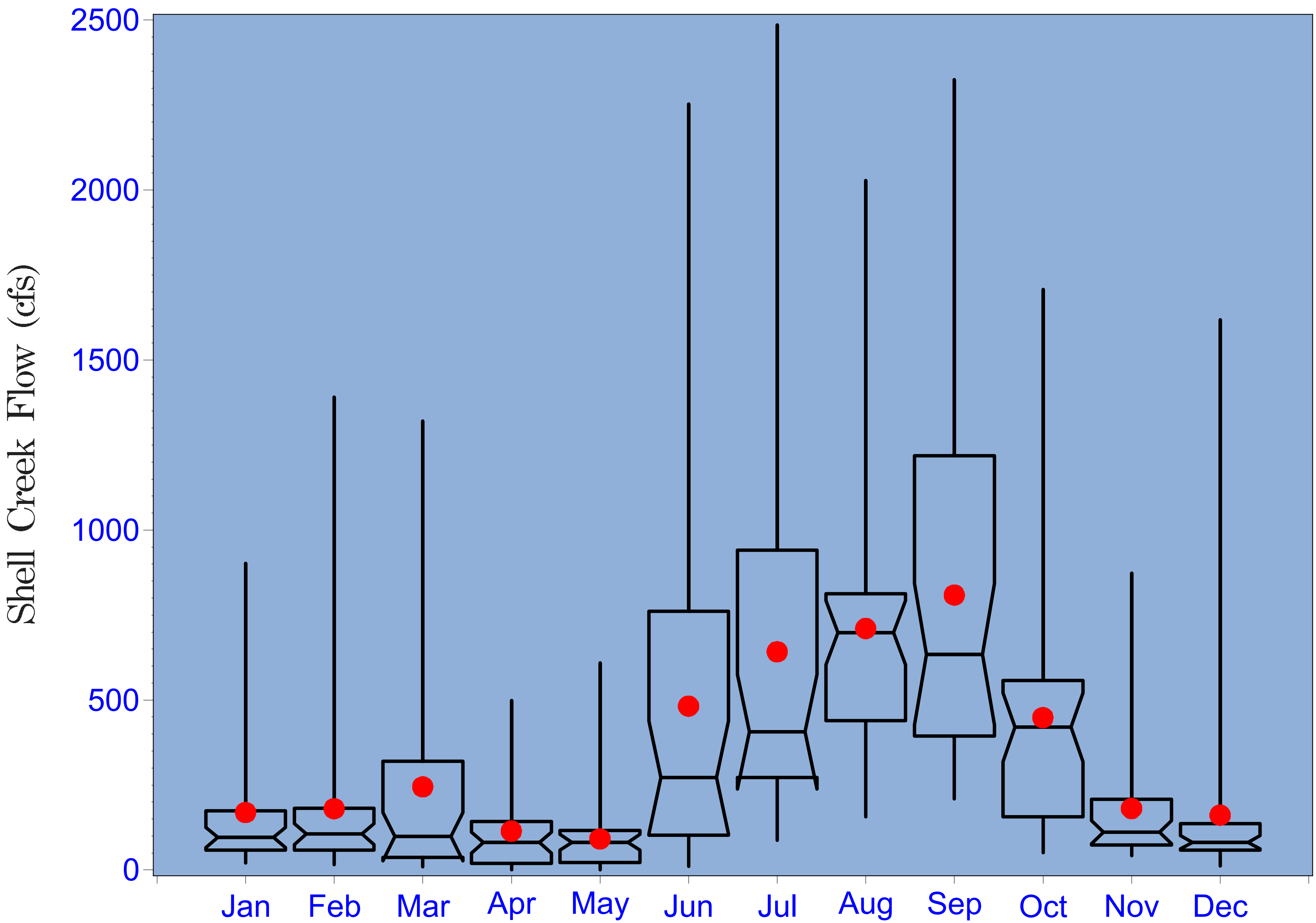


Figure 4.1.31 Box & whiskers of annual monthly mean Shell Creek flow (1966-2004)

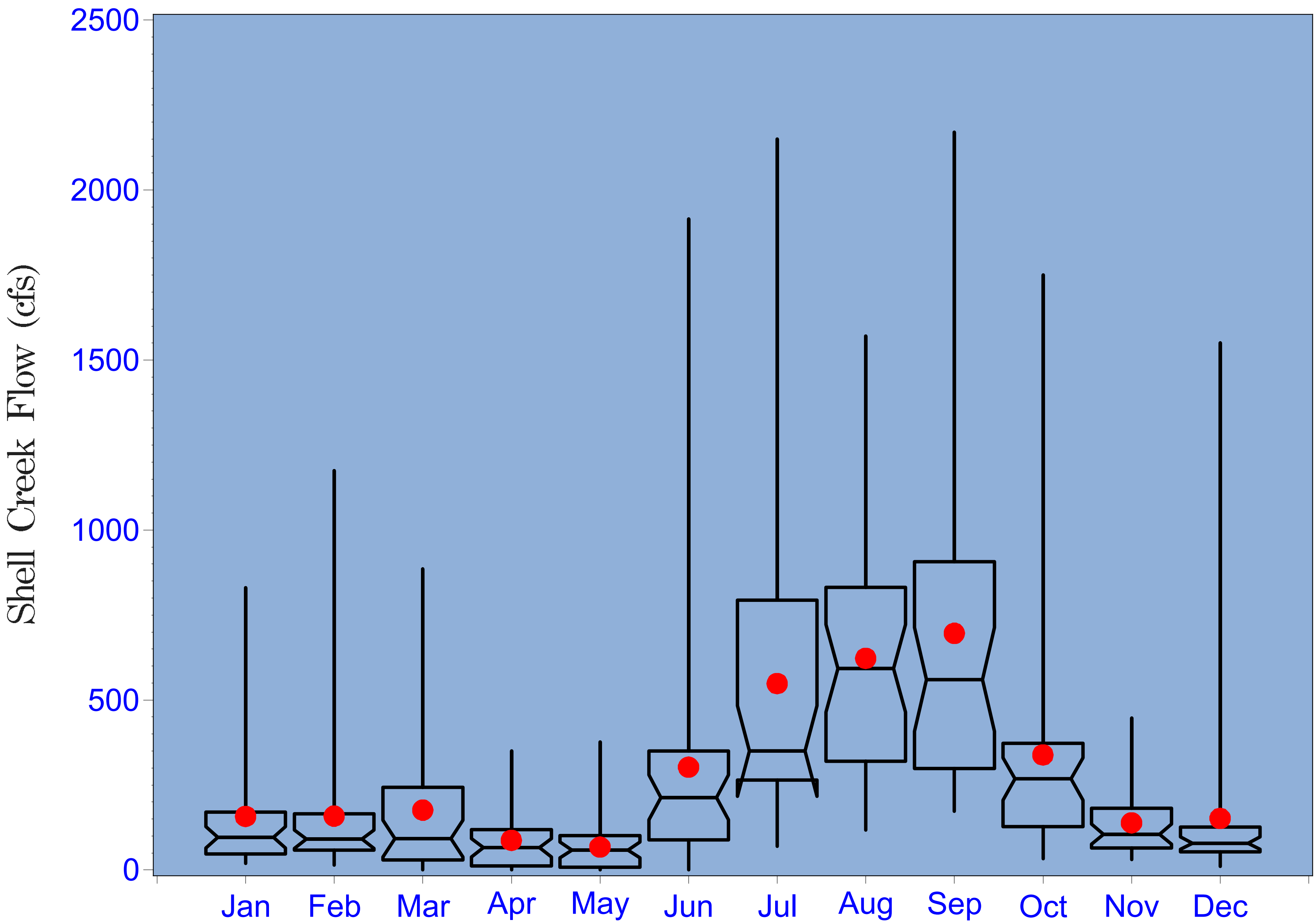


Figure 4.1.32 Box & whiskers of annual monthly median Shell Creek flow (1966-2004)

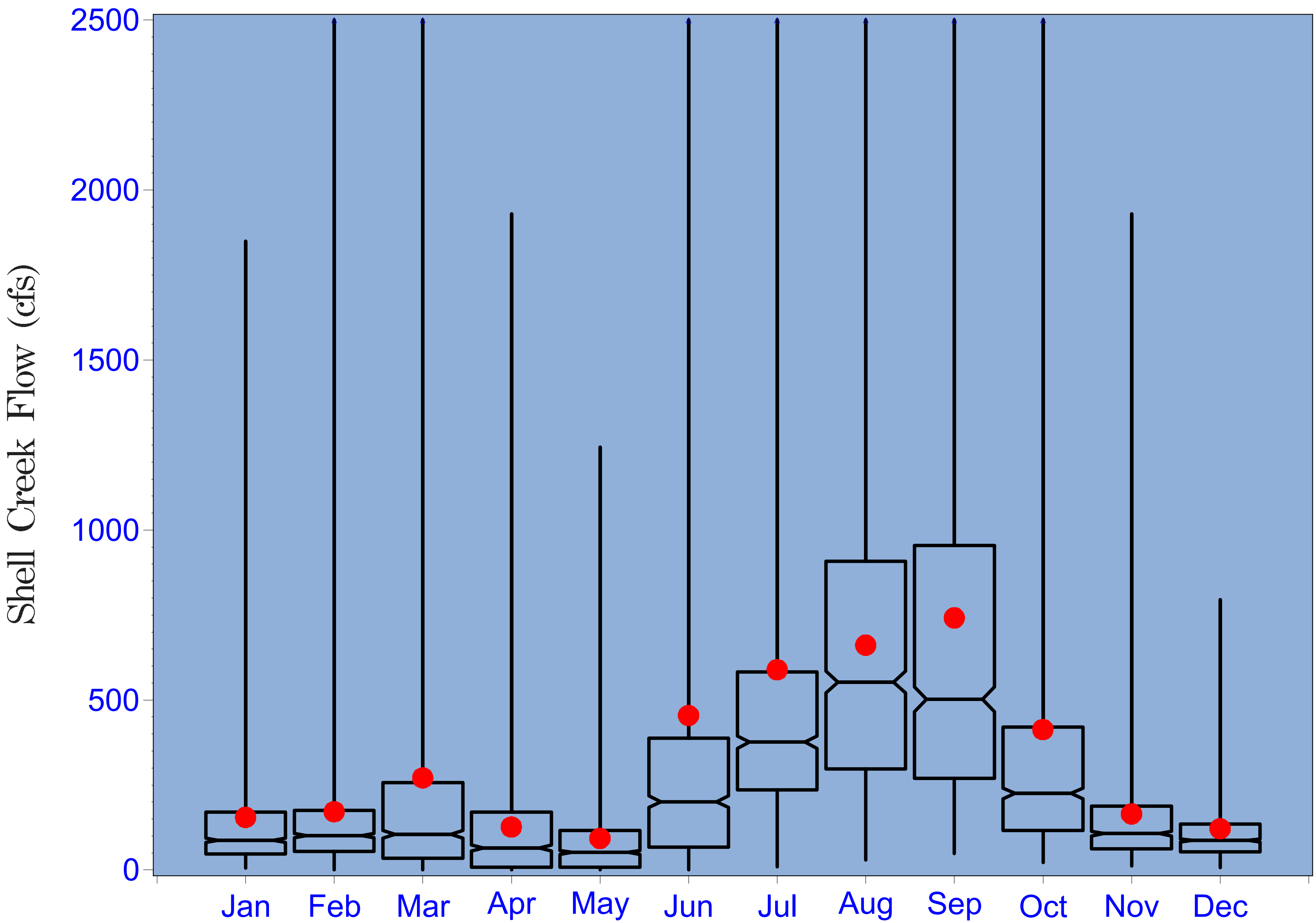


Figure 4.1.33 Box & whiskers of annual monthly Shell Creek flow (1966-1994)

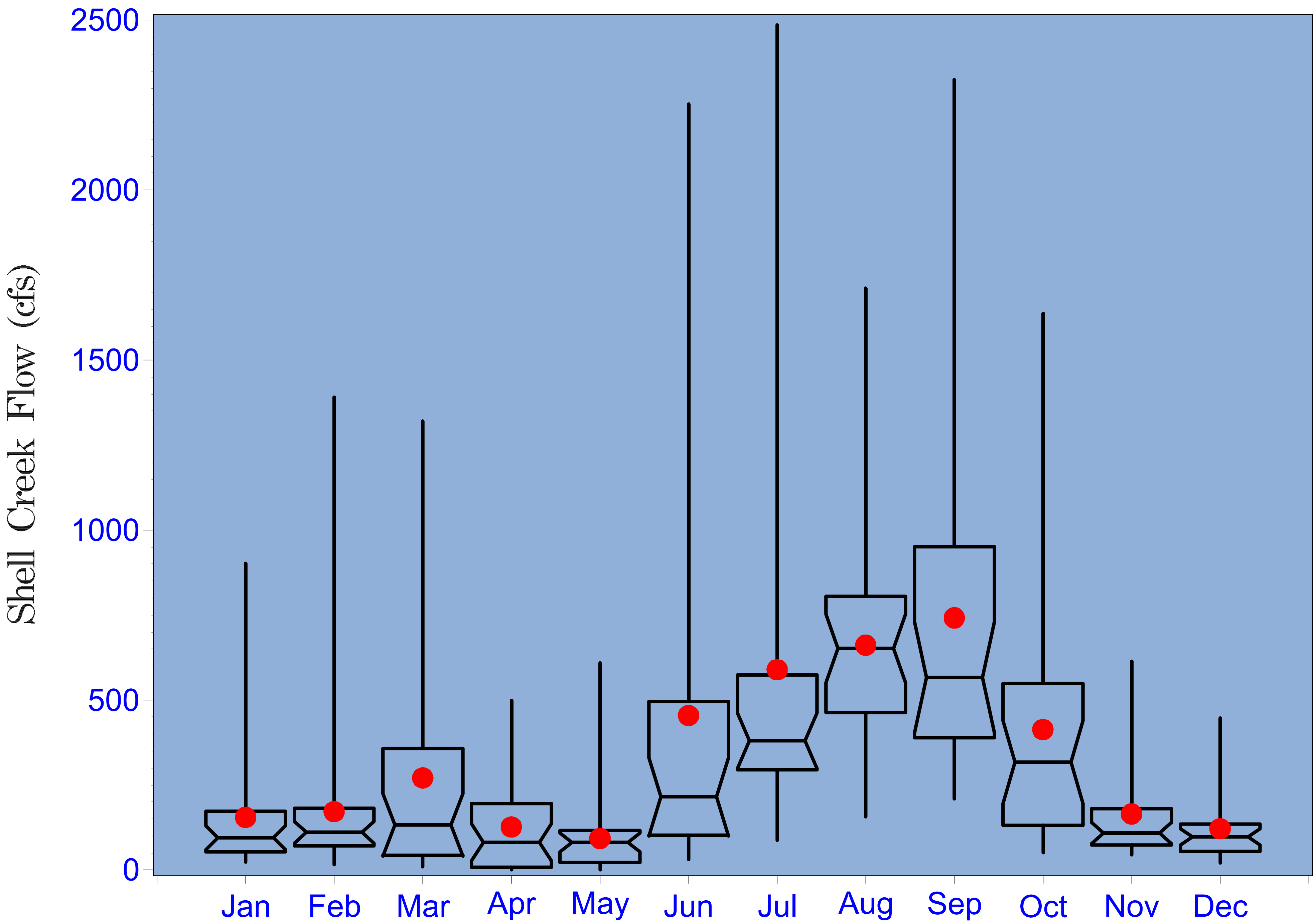


Figure 4.1.34 Box & whiskers of annual monthly mean Shell Creek flow (1966-1994)

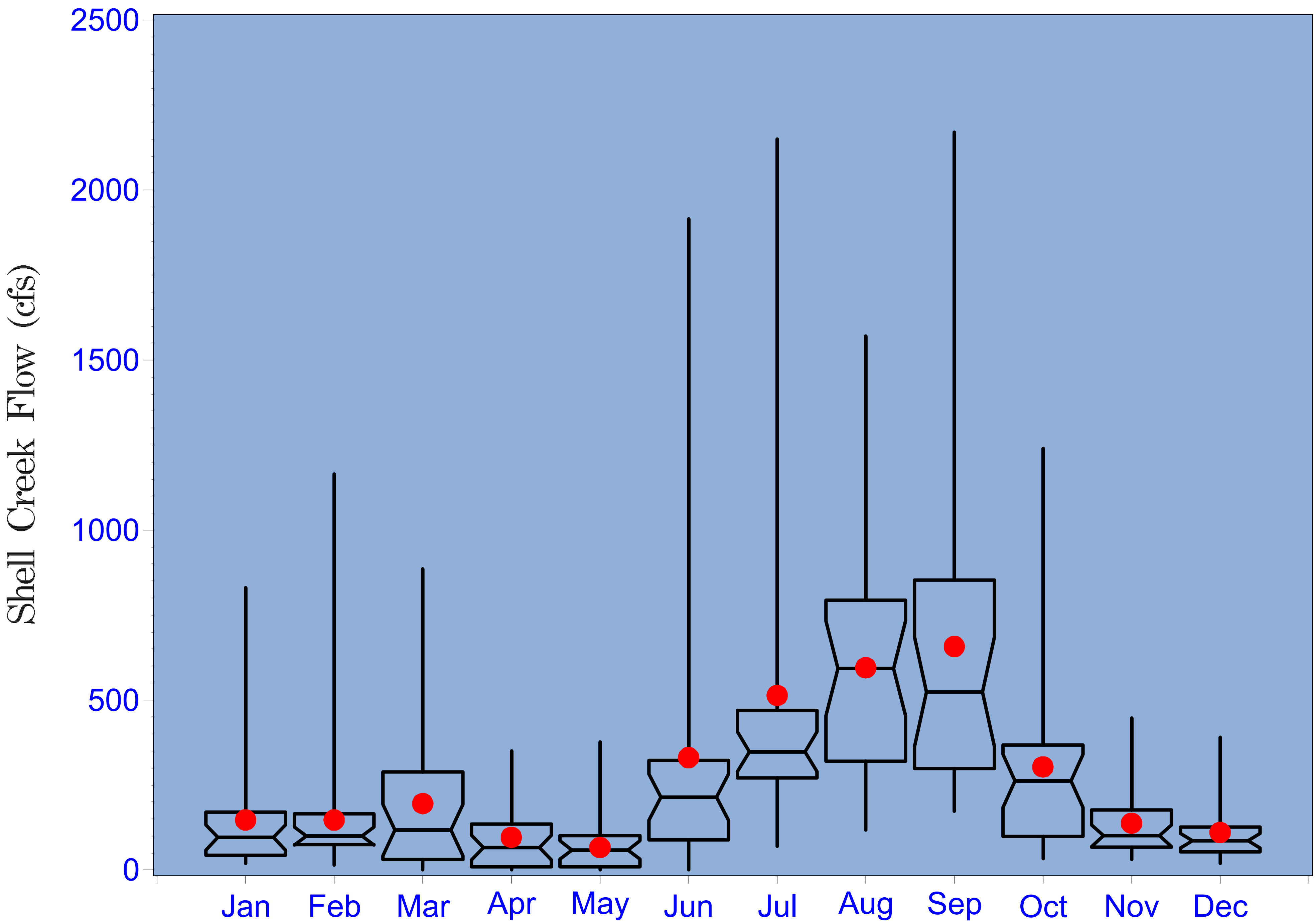


Figure 4.1.35 Box & whiskers of annual monthly median Shell Creek flow (1966-1994)

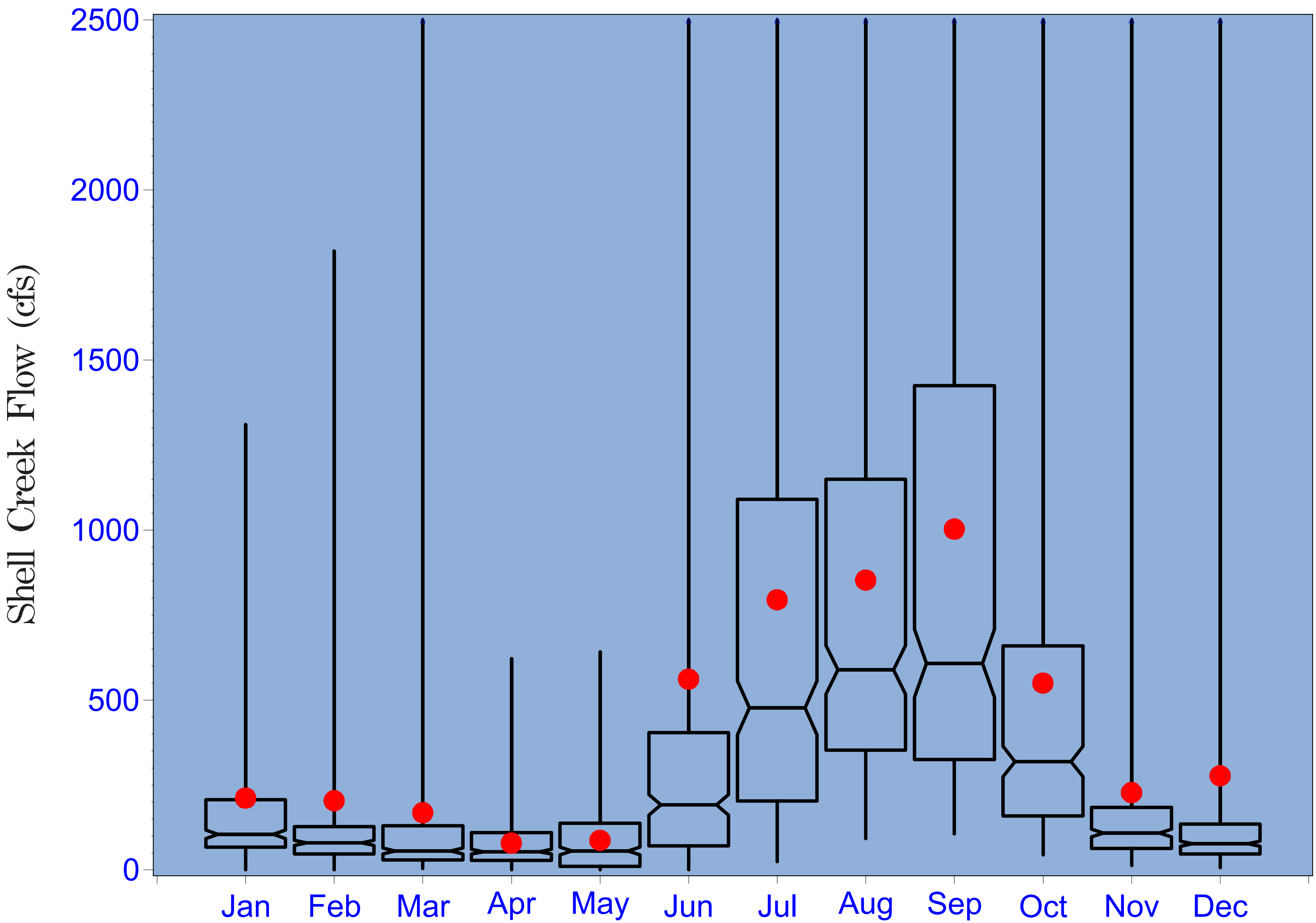


Figure 4.1.36 Box & whiskers of annual monthly Shell Creek flow (1995-2004)

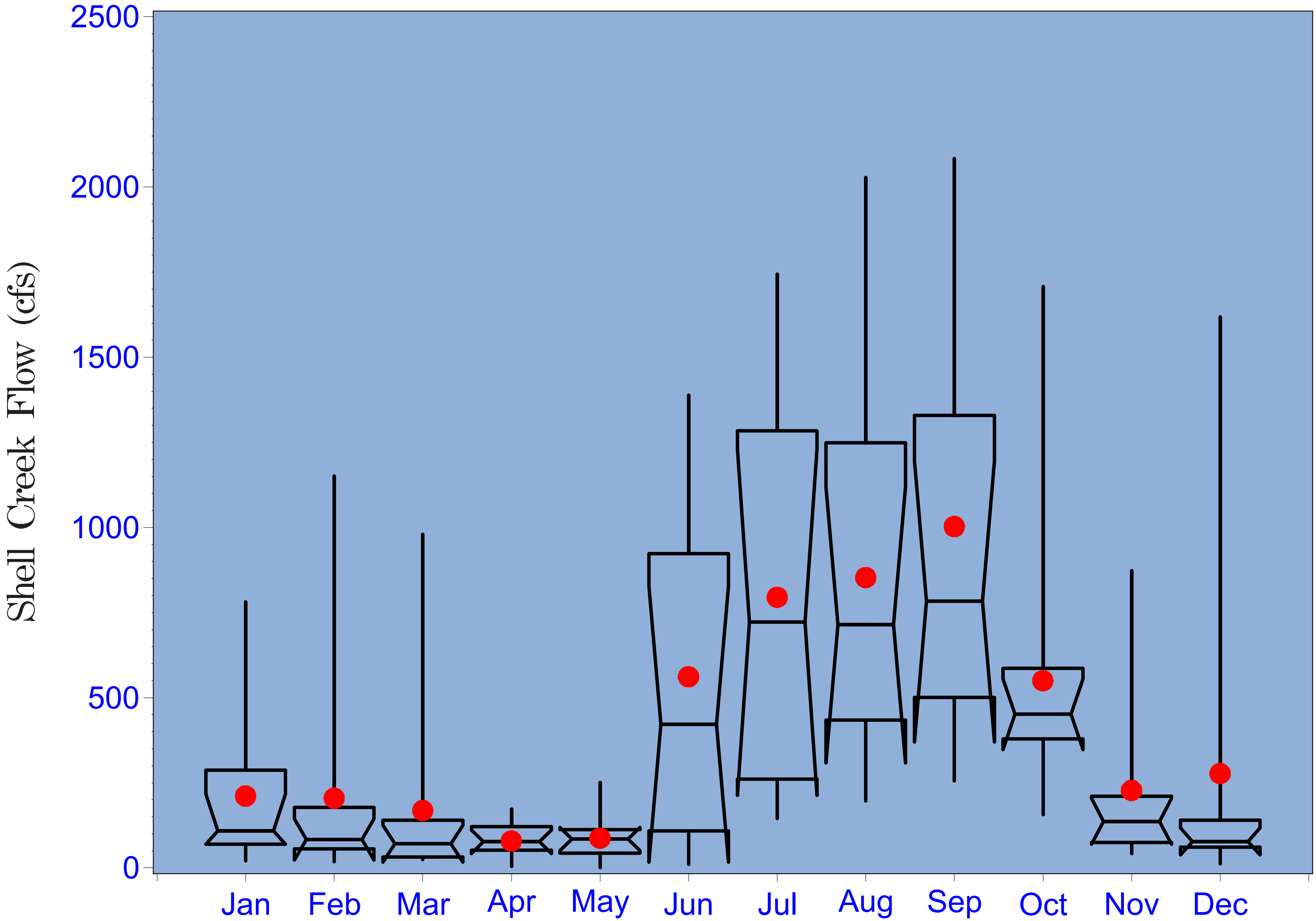


Figure 4.1.37 Box & whiskers of annual monthly mean Shell Creek flow (1995-2004)

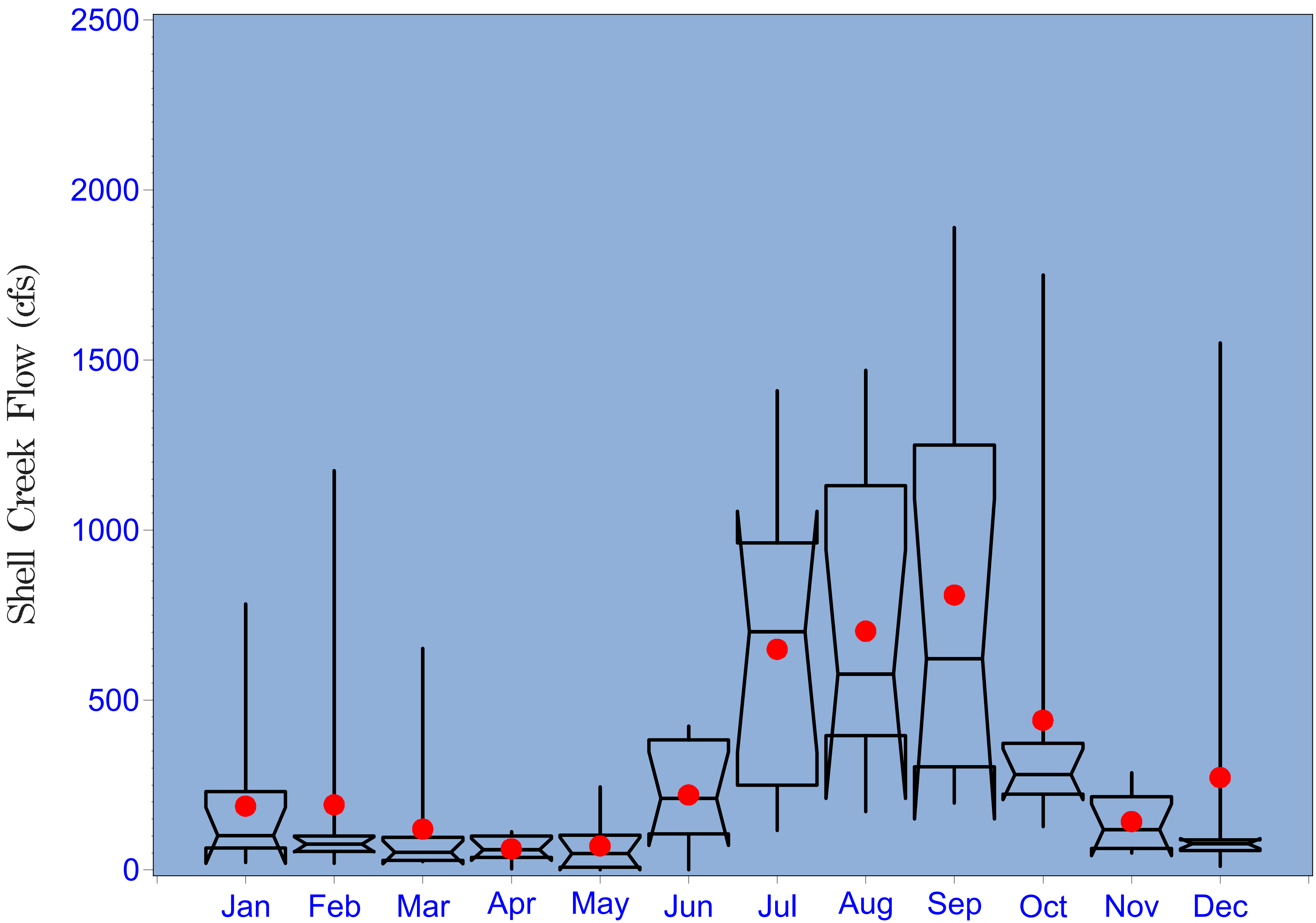


Figure 4.1.38 Box & whiskers of annual monthly median Shell Creek flow (1995-2004)

Appendix B

Influences of Withdrawals on Flows

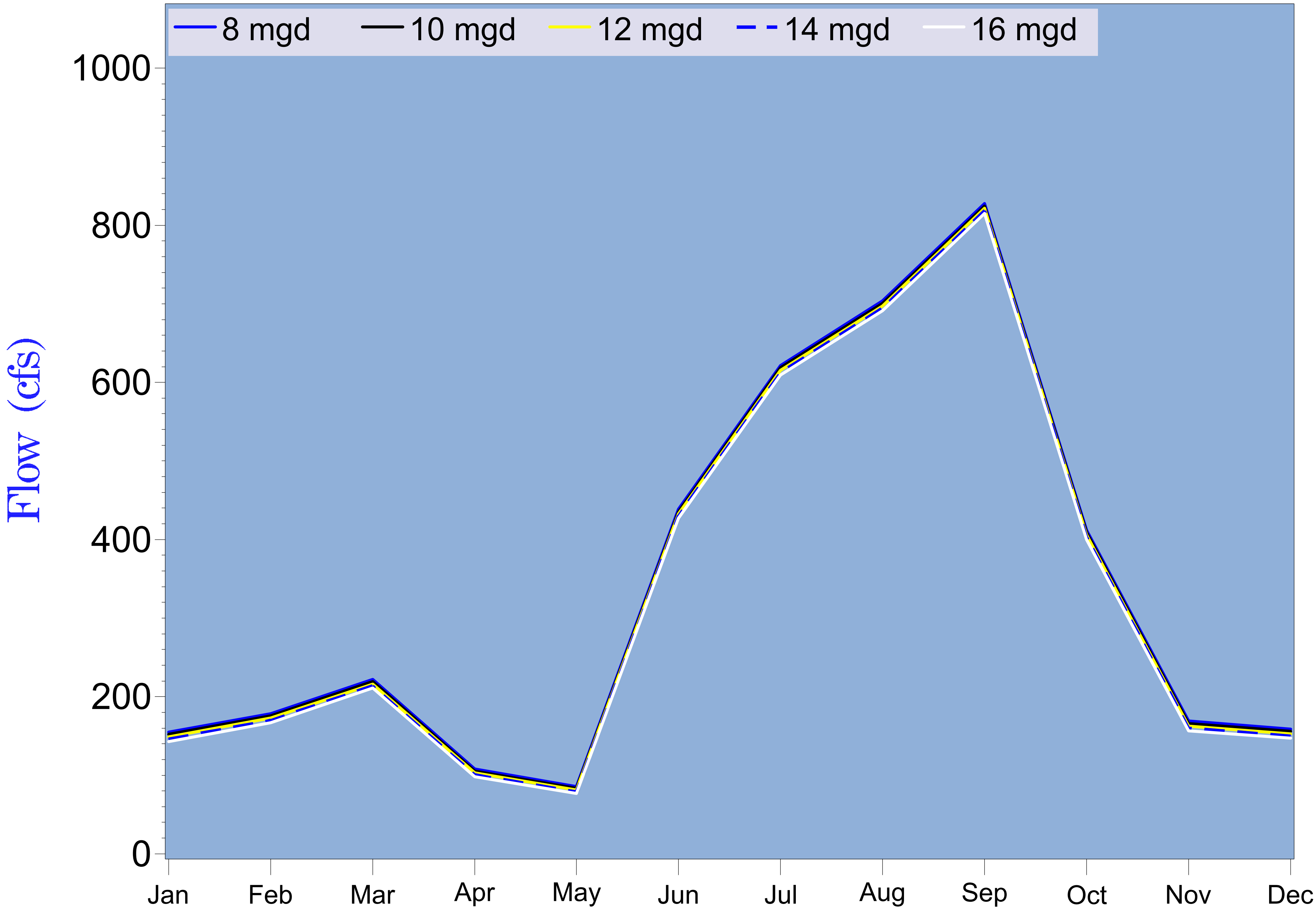


Figure 4.2.1 Differences in monthly average mean Shell Creek flow under different maximum withdrawals (1972-2004)

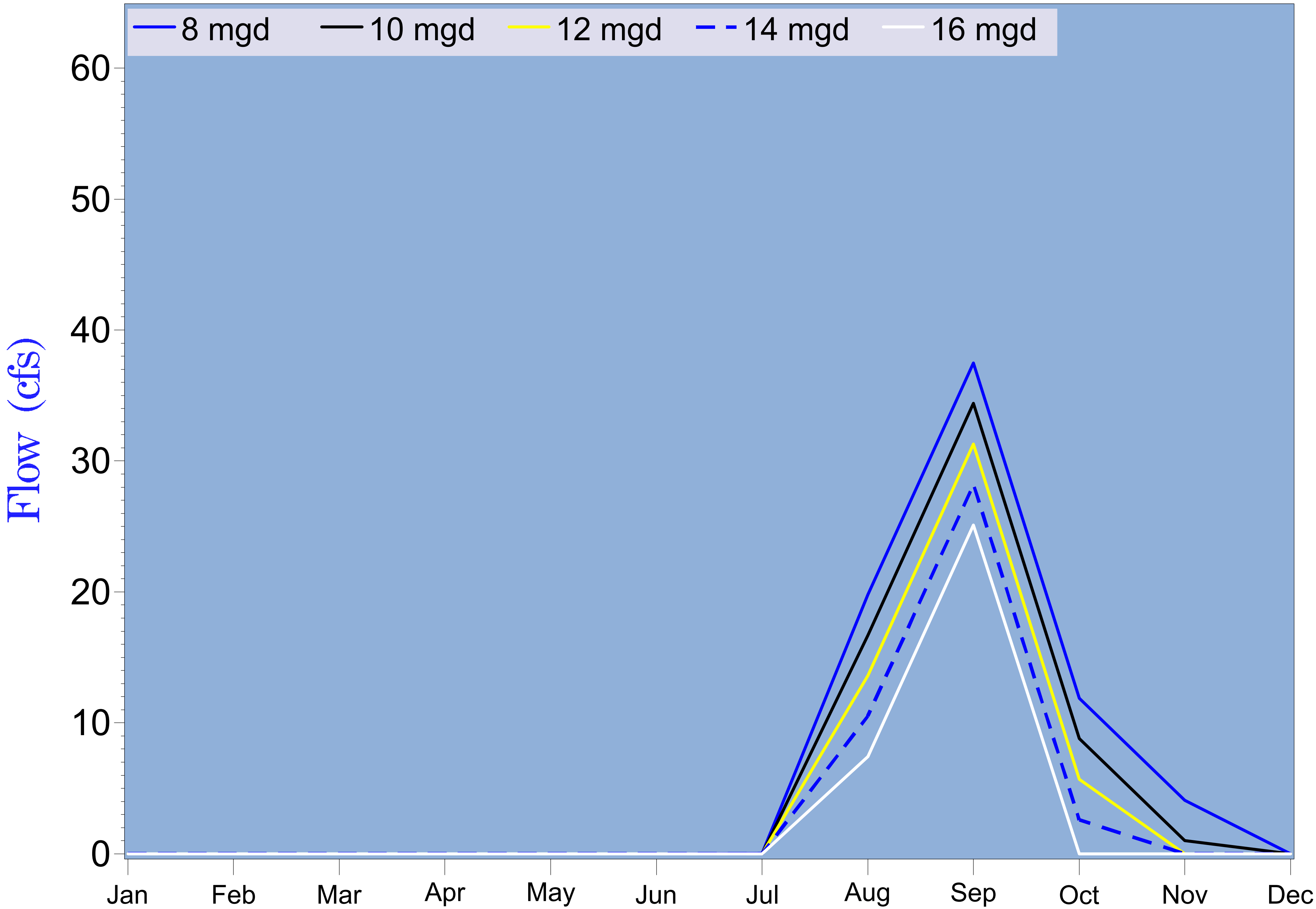


Figure 4.2.2 Differences in monthly average minimum Shell Creek flow under different maximum withdrawals (1972-2004)

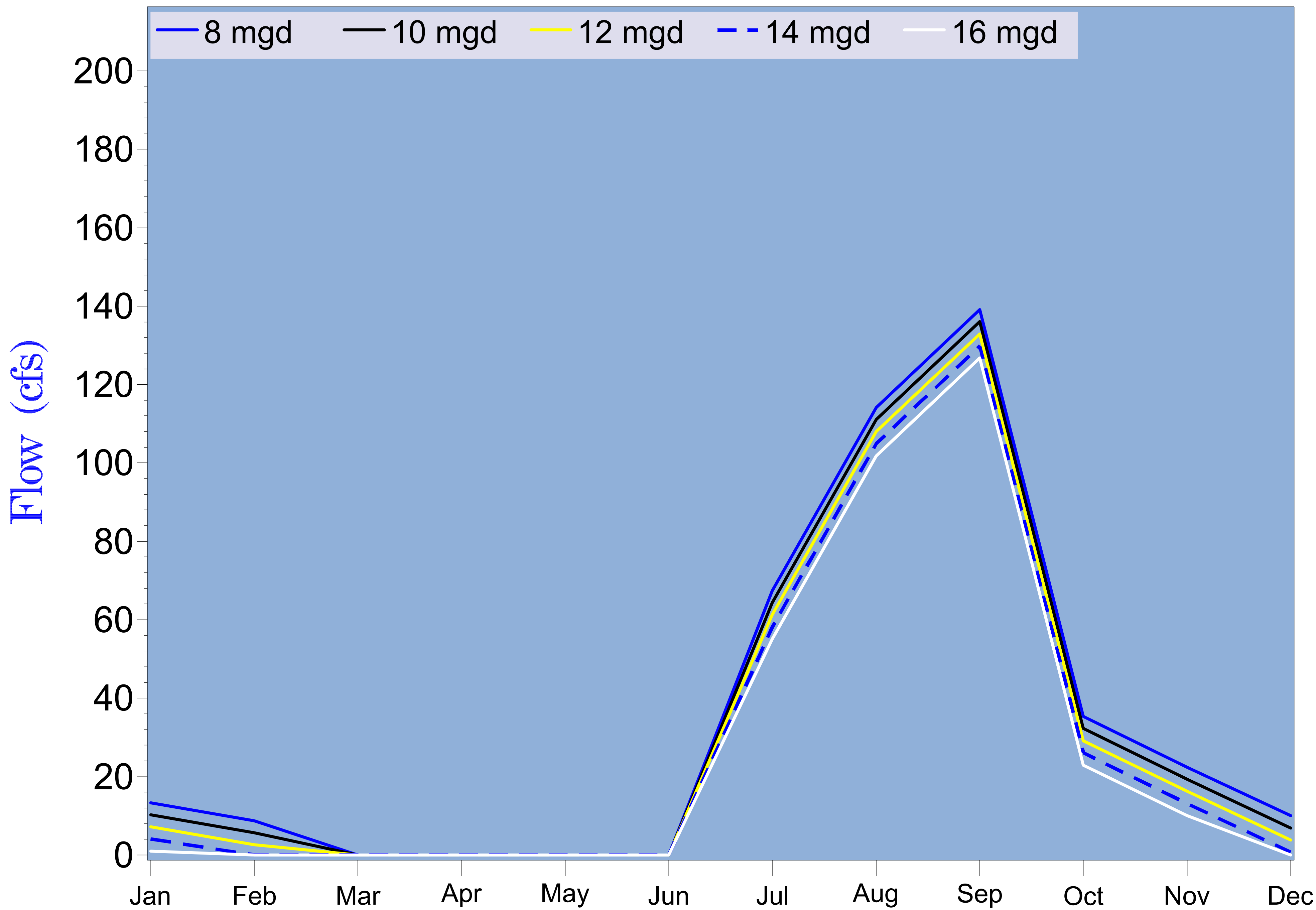


Figure 4.2.3 Differences in monthly average Q95 Shell Creek flow under different maximum withdrawals (1972-2004)

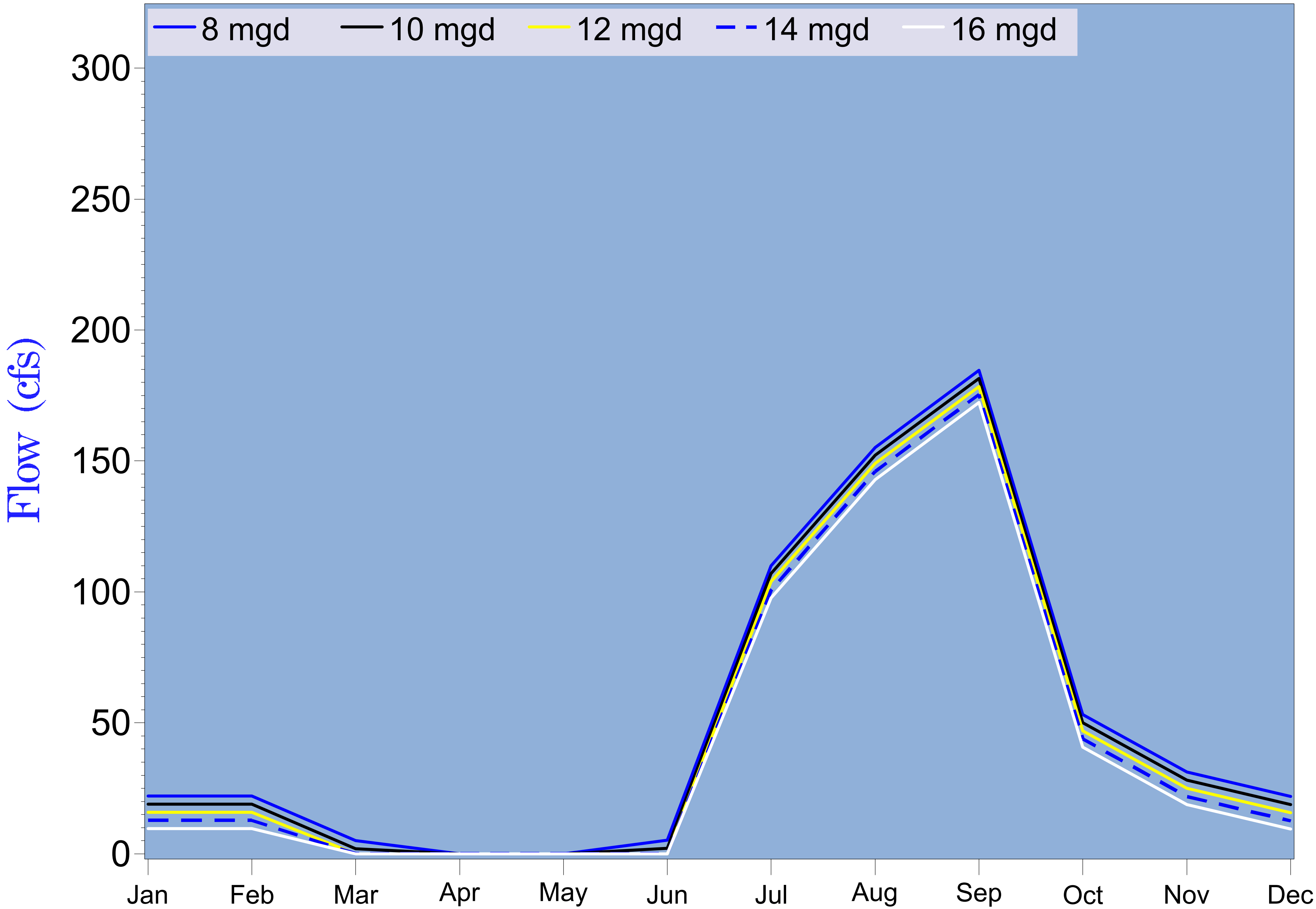


Figure 4.2.4 Differences in monthly average Q90 Shell Creek flow under different maximum withdrawals (1972-2004)

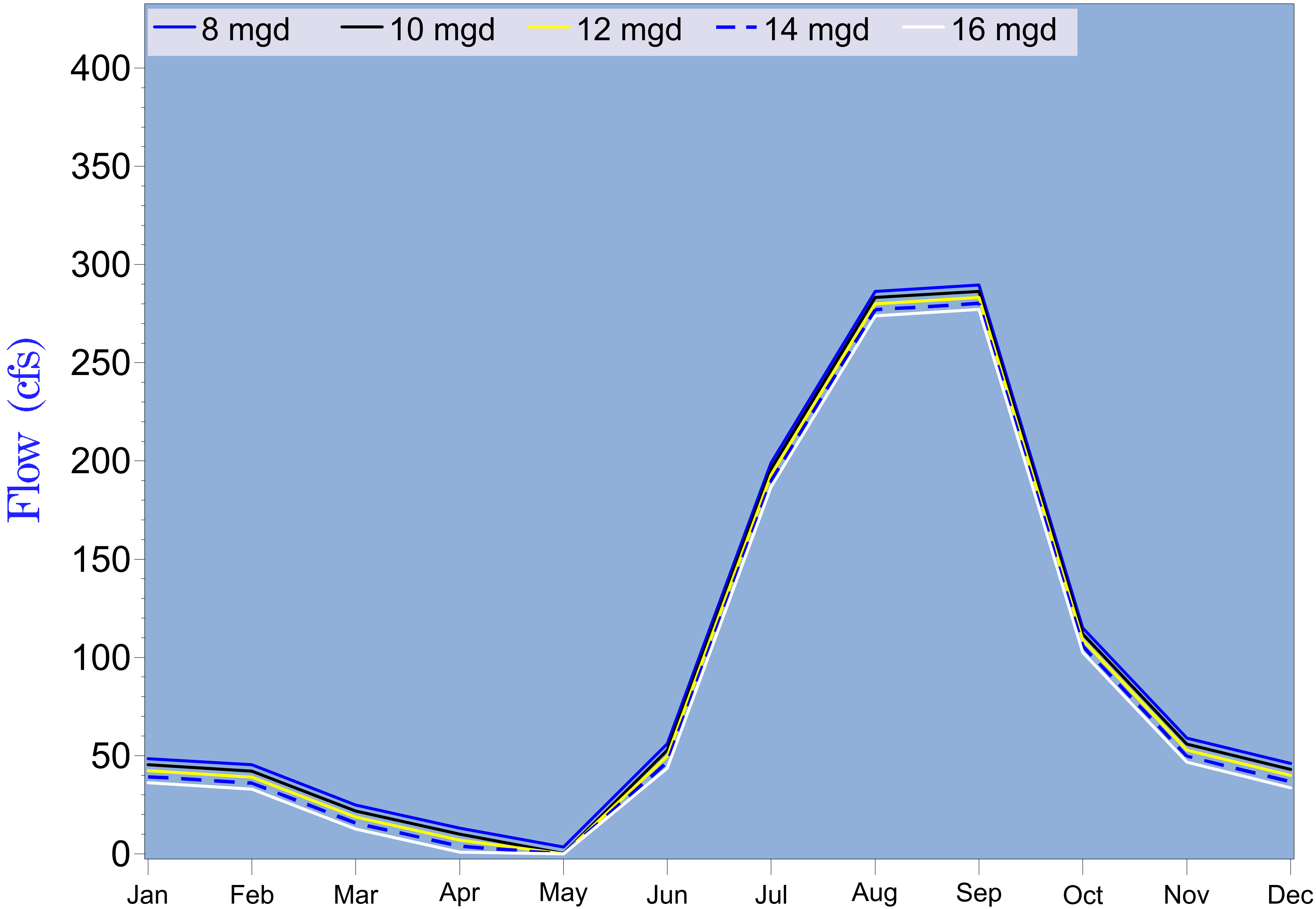


Figure 4.2.5 Differences in monthly average Q75 Shell Creek flow under different maximum withdrawals (1972-2004)

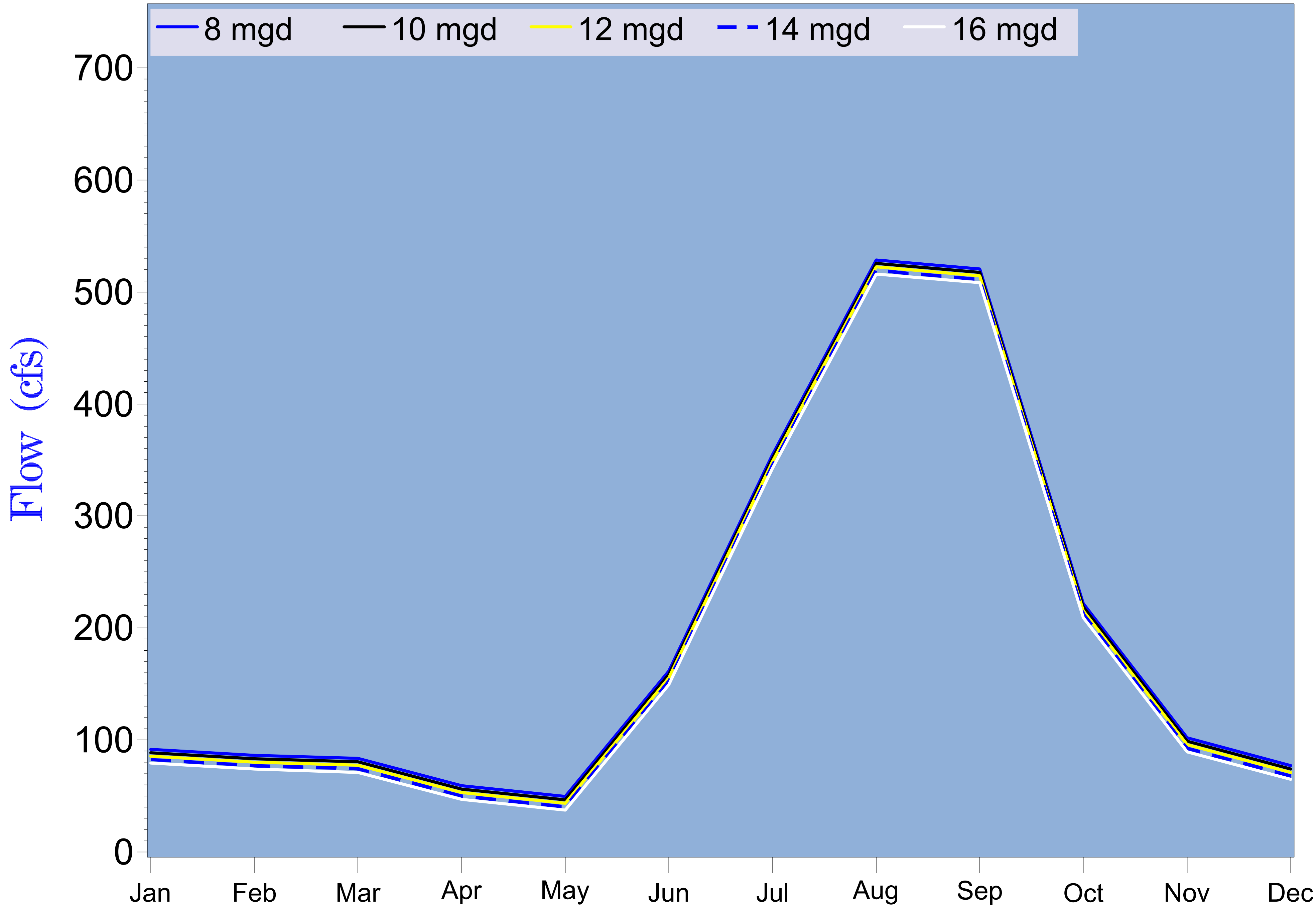


Figure 4.2.6 Differences in monthly average Q50 (median) Shell Creek flow under different maximum withdrawals (1972-2004)

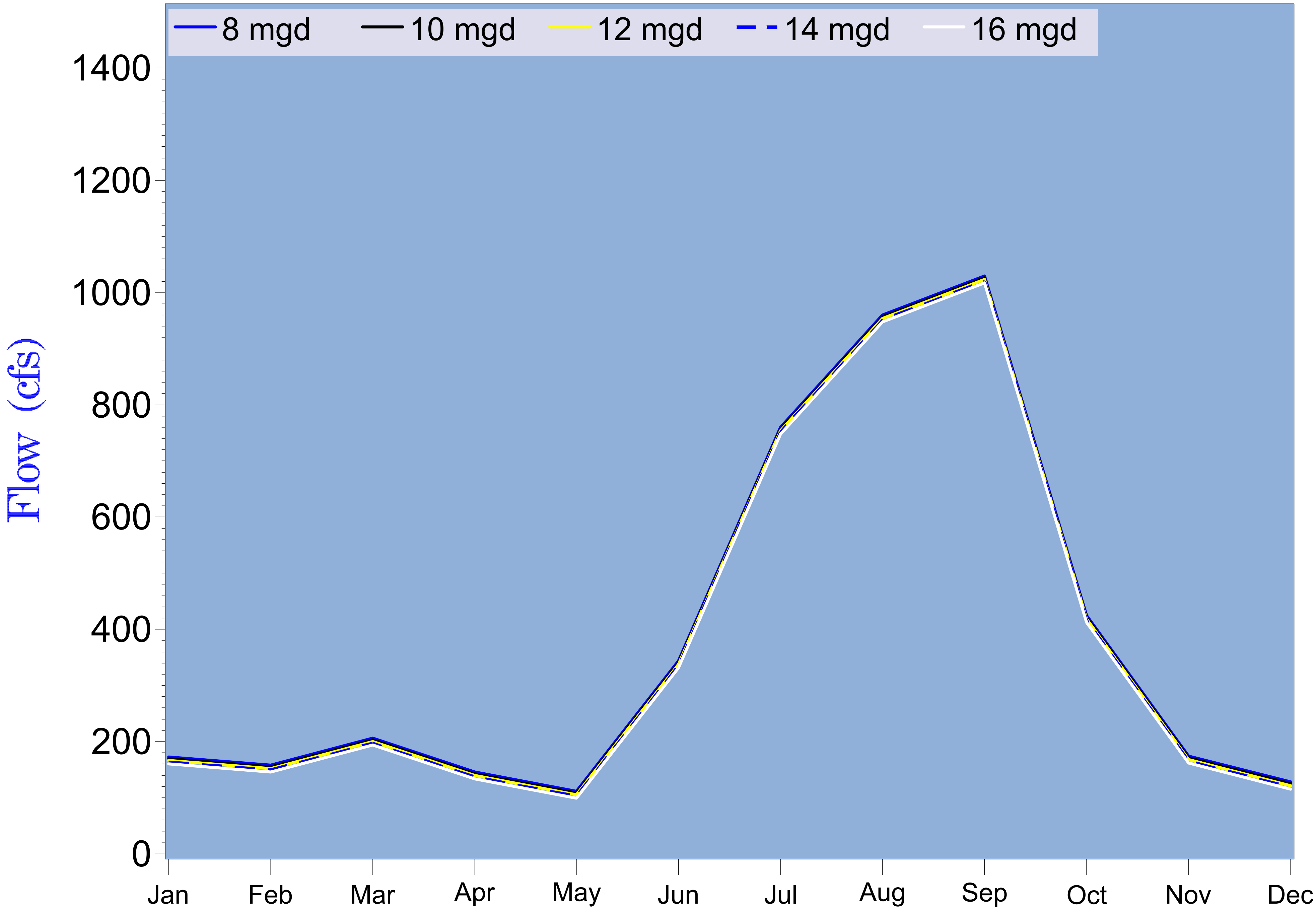


Figure 4.2.7 Differences in monthly average Q25 Shell Creek flow under different maximum withdrawals (1972-2004)

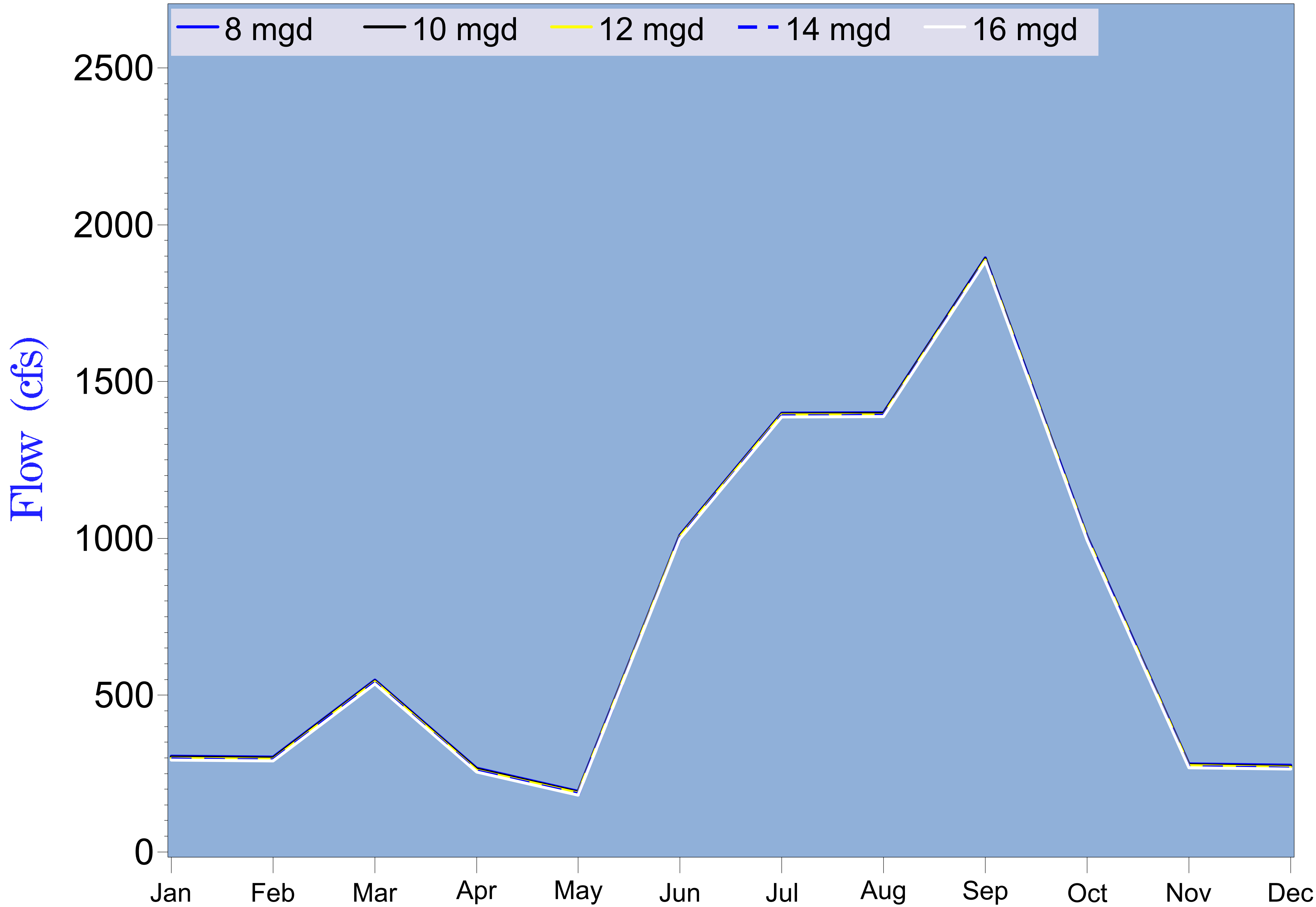


Figure 4.2.8 Differences in monthly average Q10 Shell Creek flow under different maximum withdrawals (1972-2004)

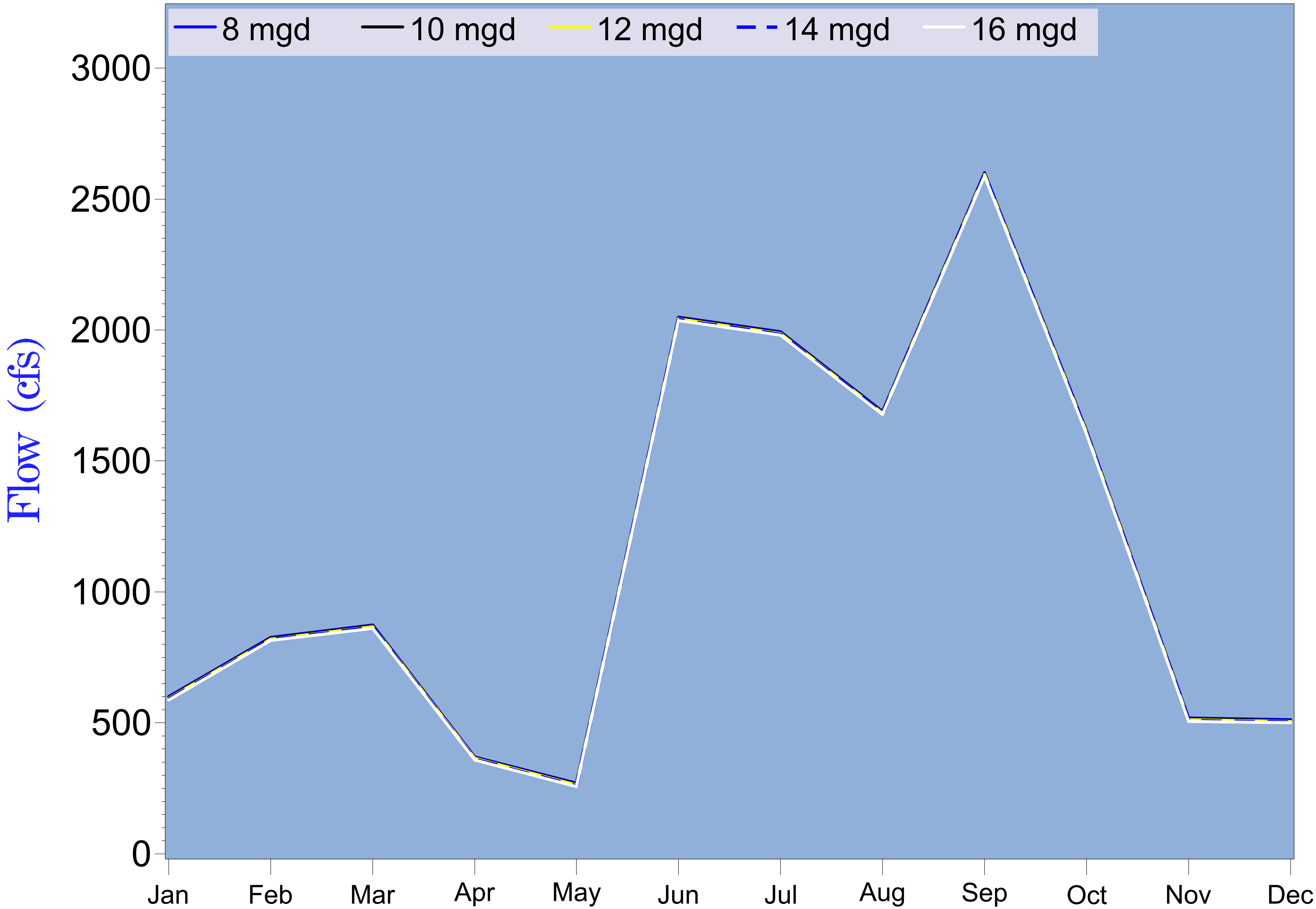


Figure 4.2.9 Differences in monthly average Q5 Shell Creek flow under different maximum withdrawals (1972-2004)

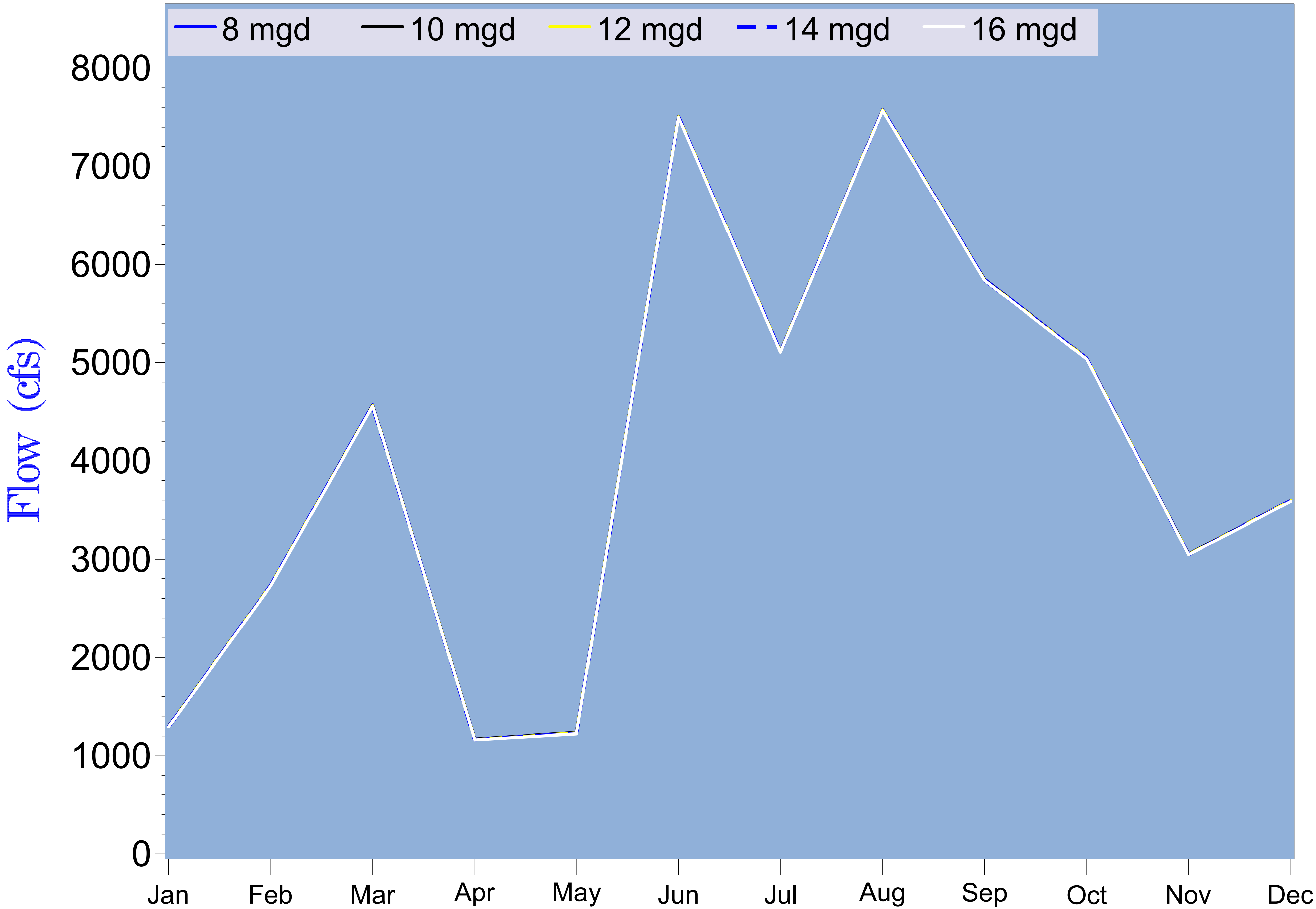


Figure 4.2.10 Differences in monthly average maximum Shell Creek flow under different maximum withdrawals (1972-2004)

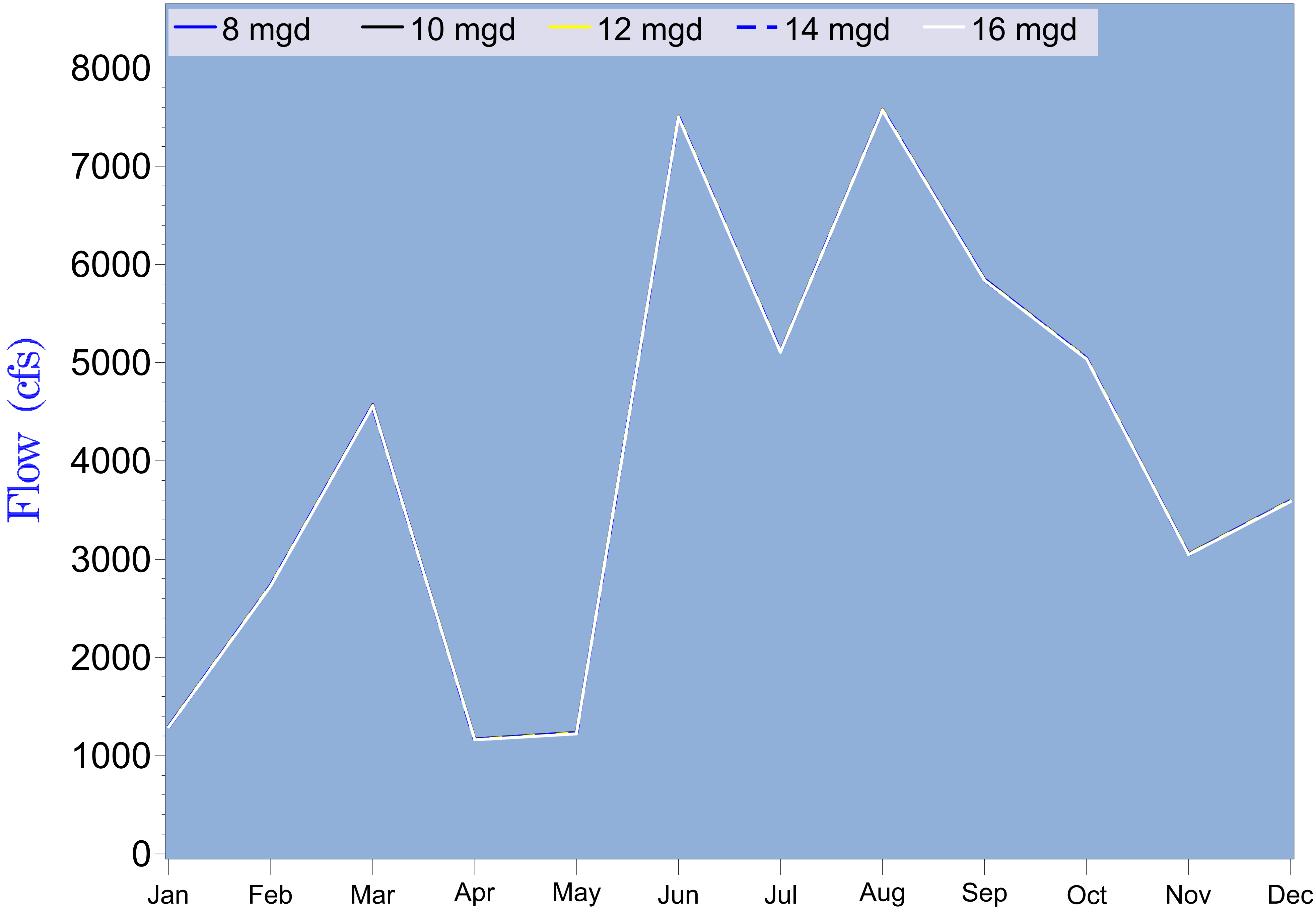


Figure 4.2.10 Differences in monthly average maximum Shell Creek flow under different maximum withdrawals (1972-2004)

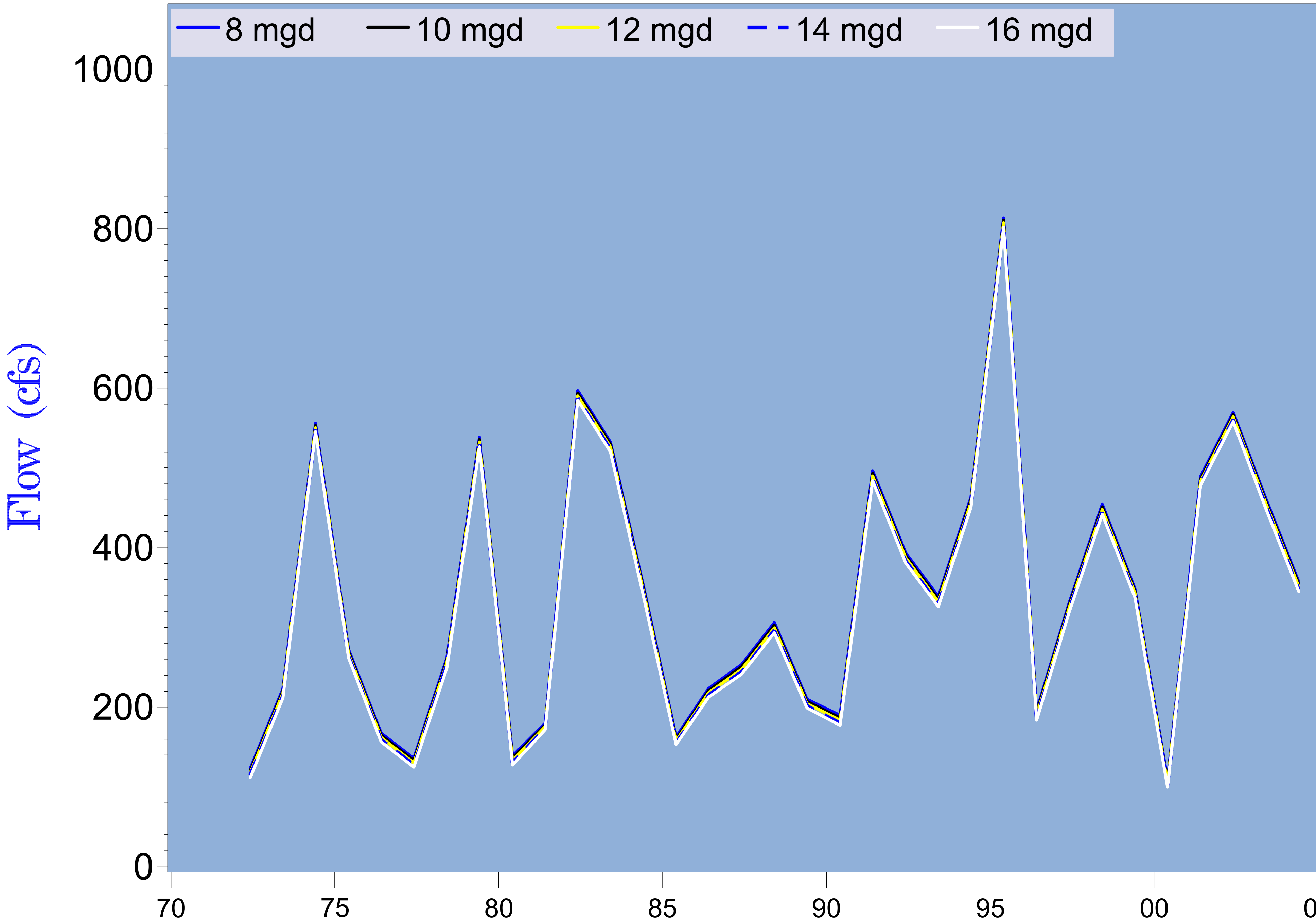


Figure 4.2.11 Differences in monthly average mean Shell Creek flow under different maximum withdrawals (1972-2004)

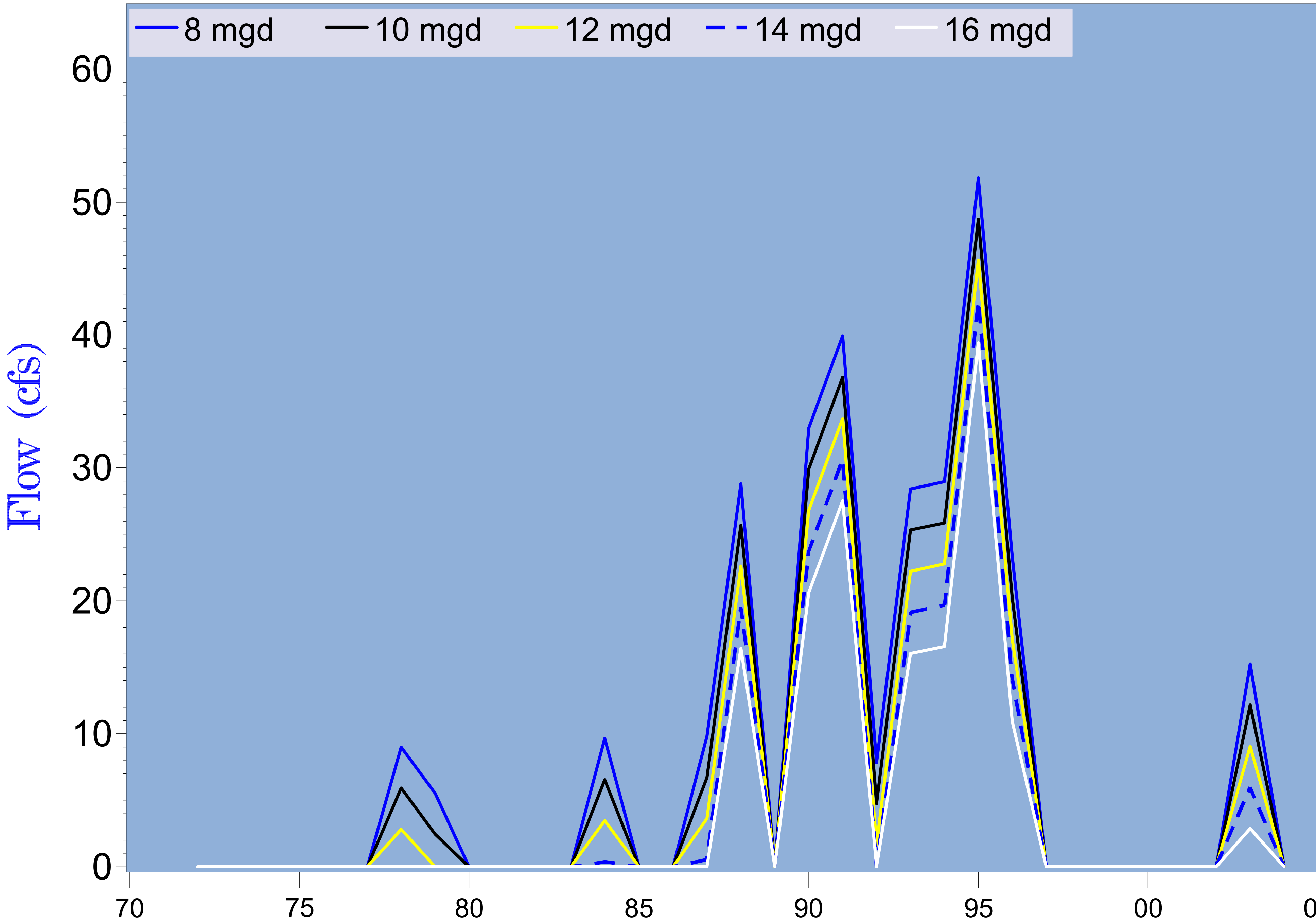


Figure 4.2.12 Differences in monthly average minimum Shell Creek flow under different maximum withdrawals (1972-2004)

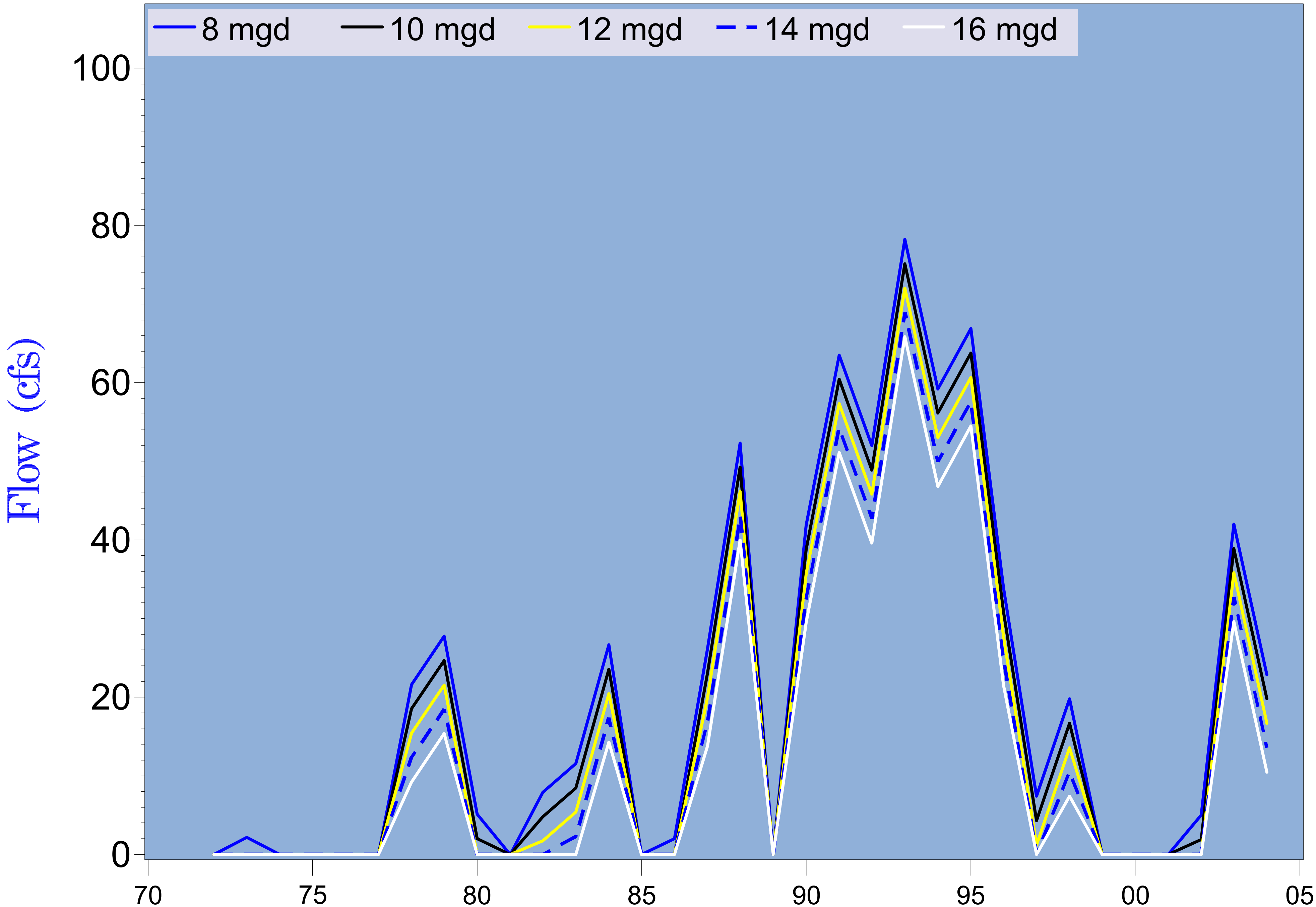


Figure 4.2.13 Differences in monthly average Q95 Shell Creek flow under different maximum withdrawals (1972-2004)

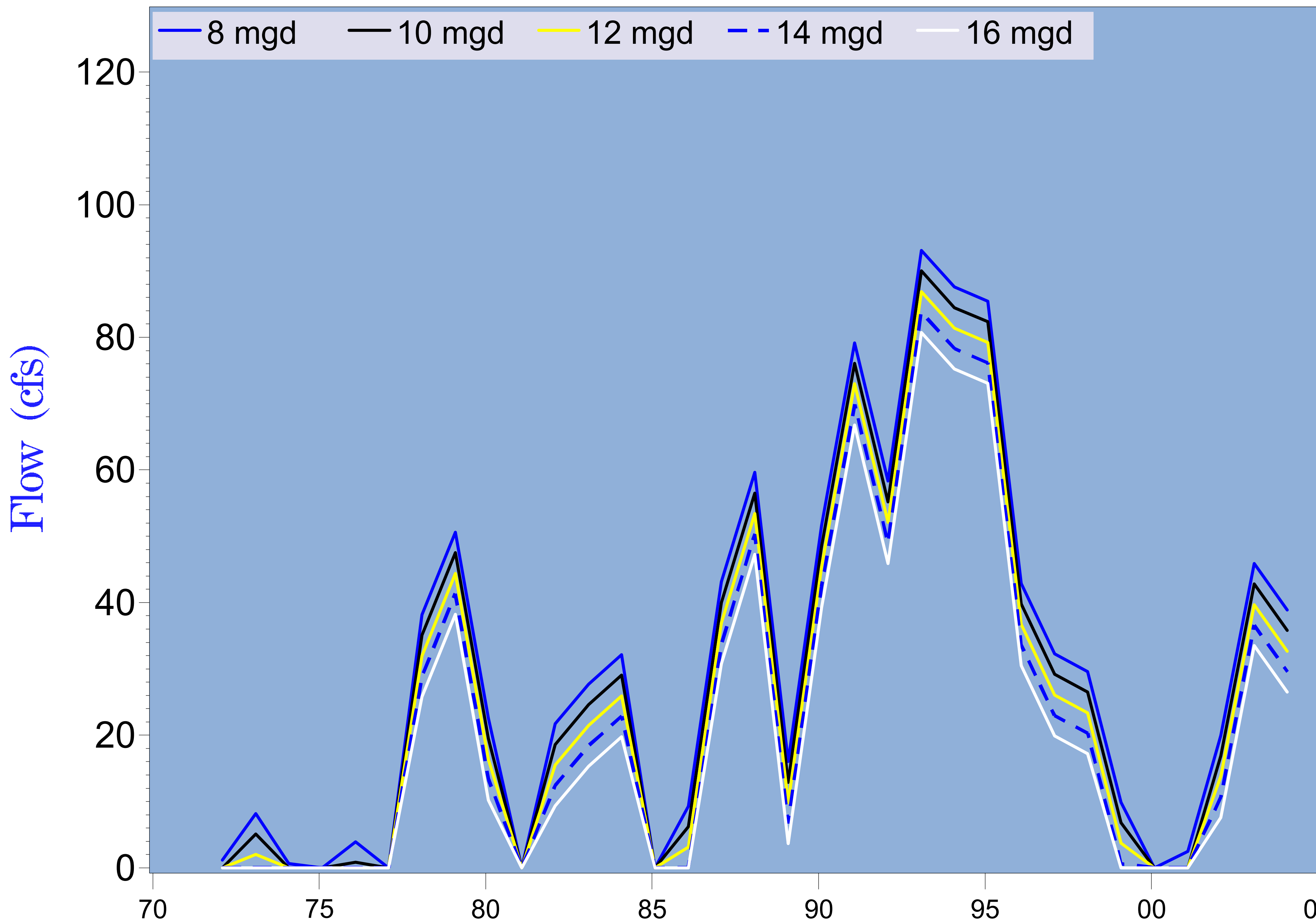


Figure 4.2.14 Differences in monthly average Q90 Shell Creek flow under different maximum withdrawals (1972-2004)

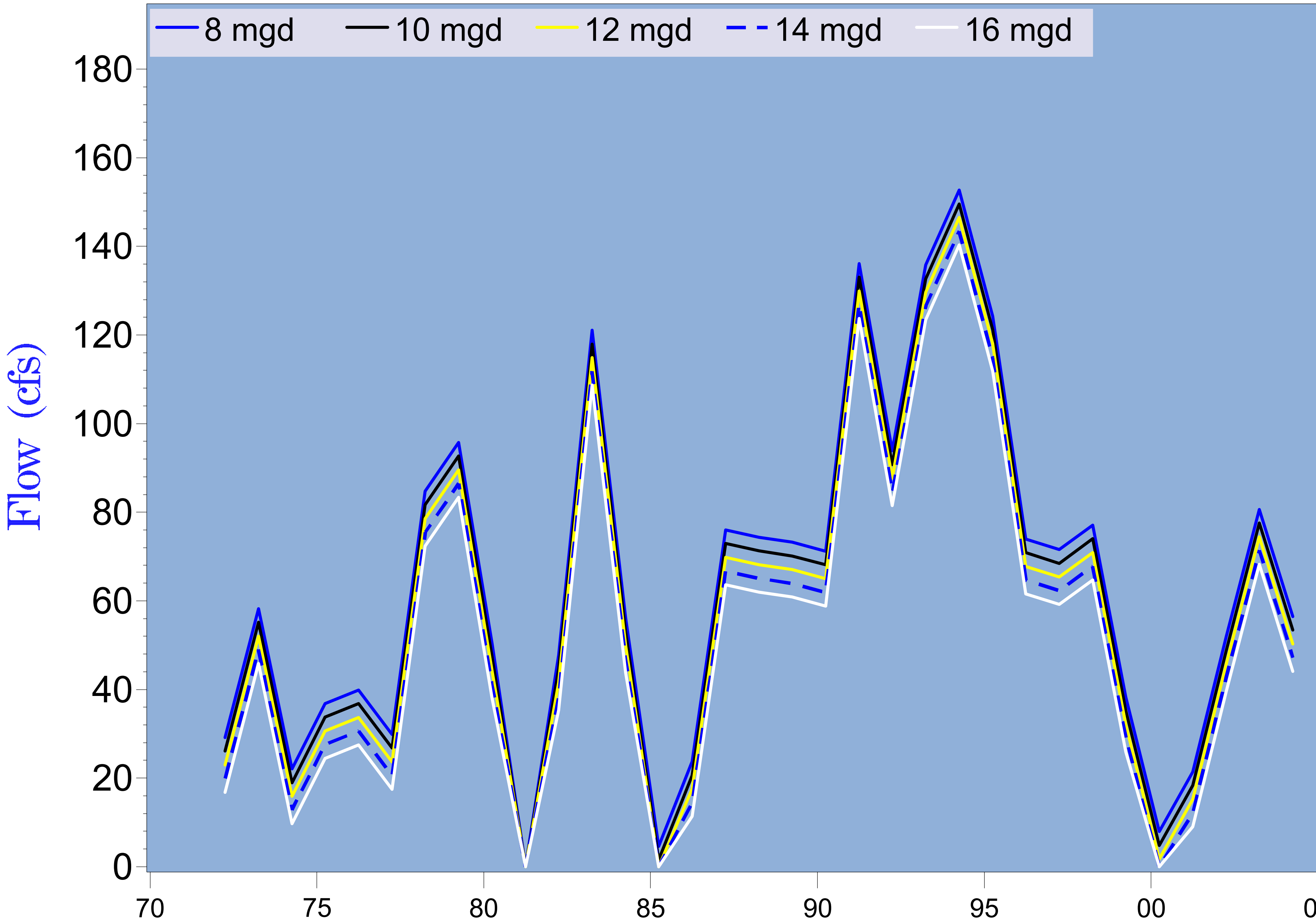


Figure 4.2.15 Differences in monthly average Q75 Shell Creek flow under different maximum withdrawals (1972-2004)

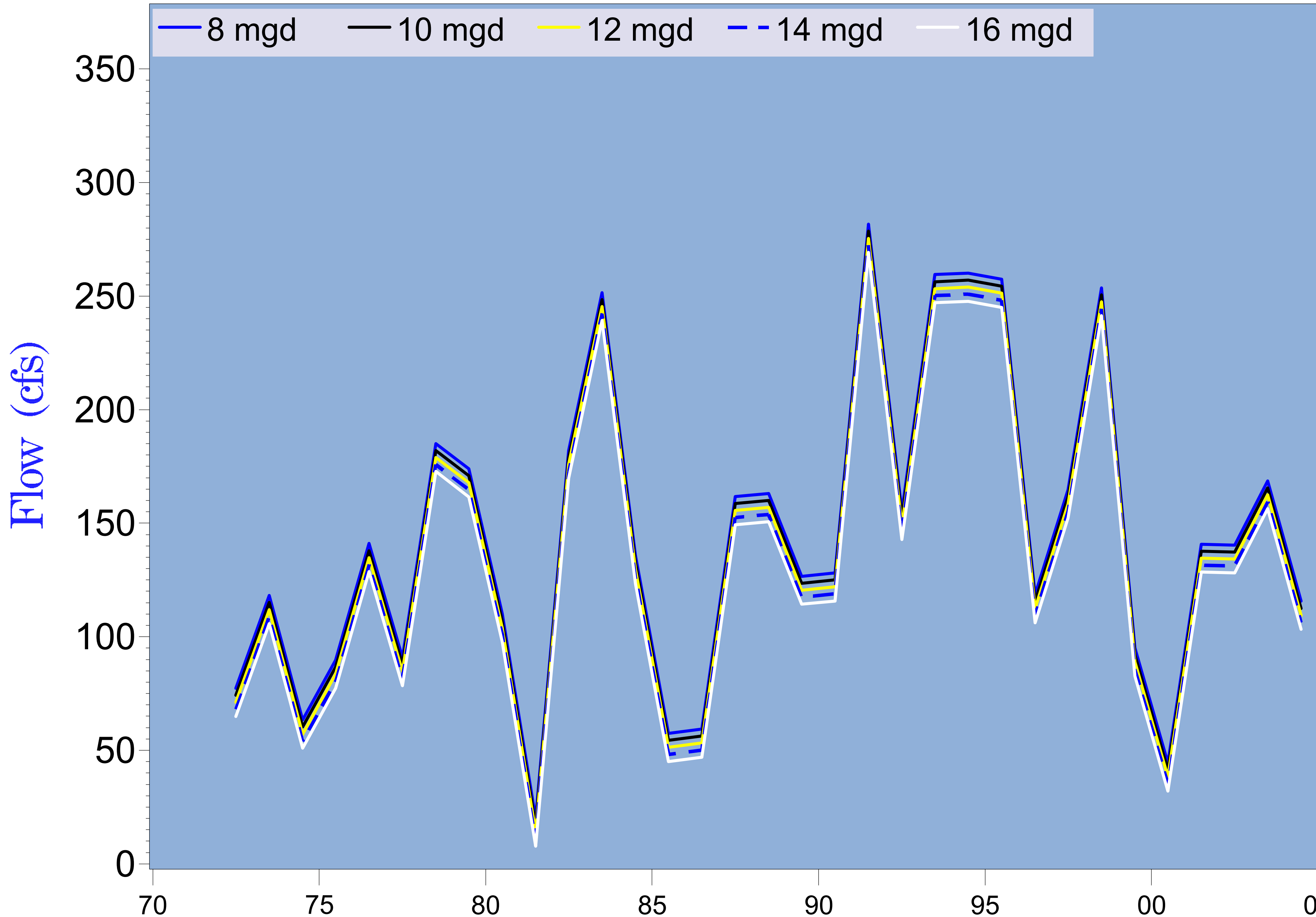


Figure 4.2.16 Differences in monthly average Q50 (median) Shell Creek flow under different maximum withdrawals (1972-2004)

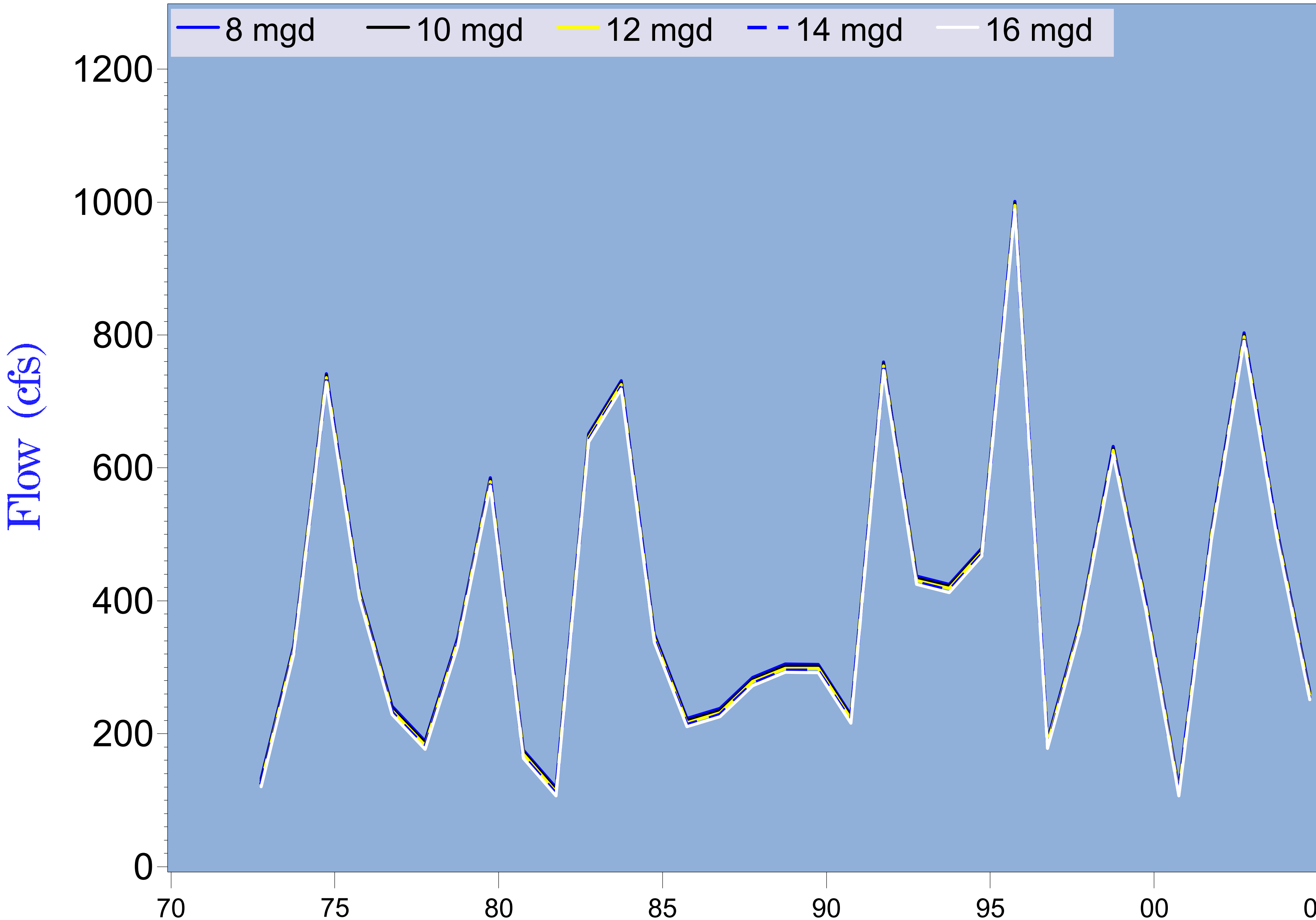


Figure 4.2.17 Differences in monthly average Q25 Shell Creek flow under different maximum withdrawals (1972-2004)

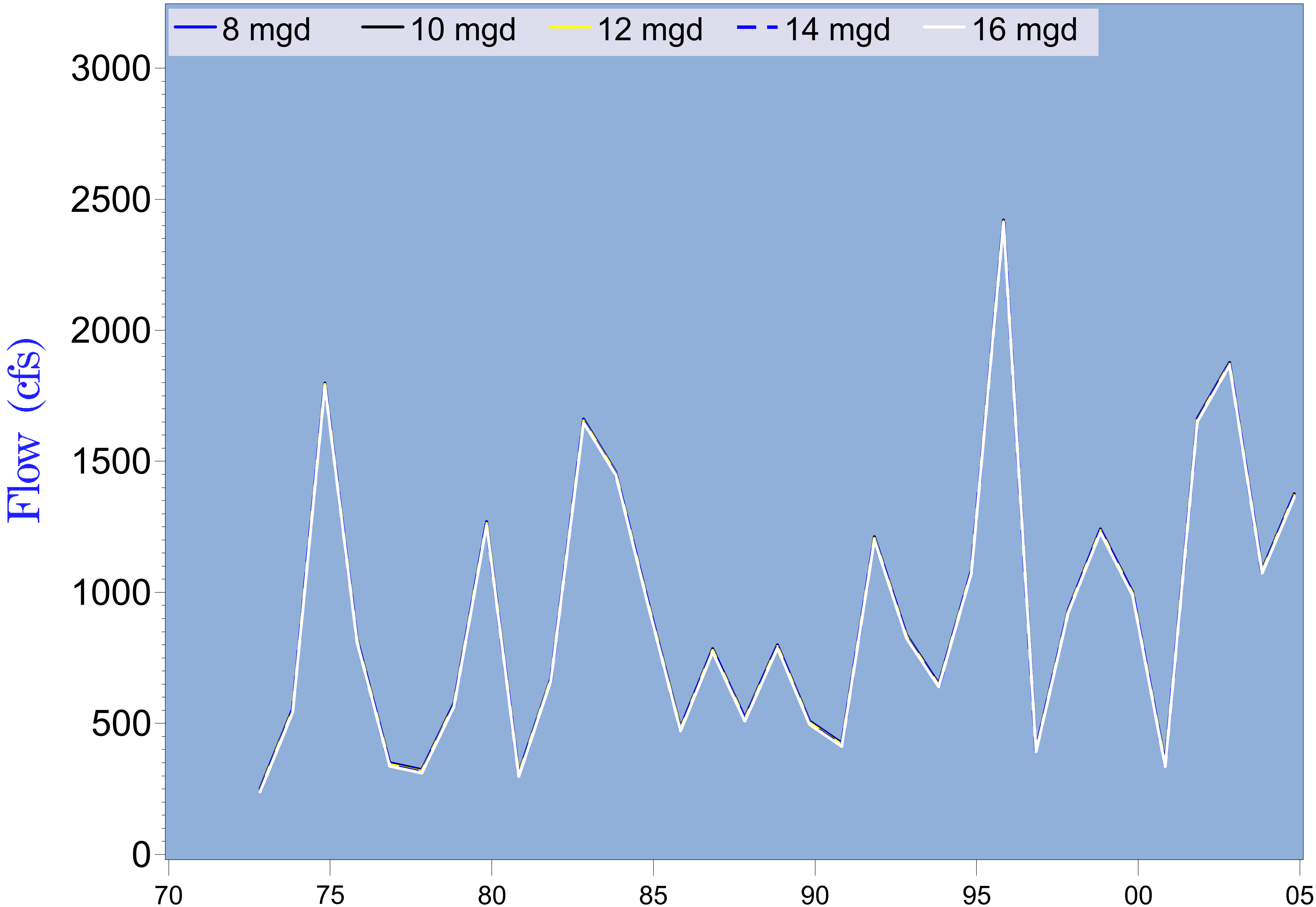


Figure 4.2.18 Differences in monthly average Q10 Shell Creek flow under different maximum withdrawals (1972-2004)

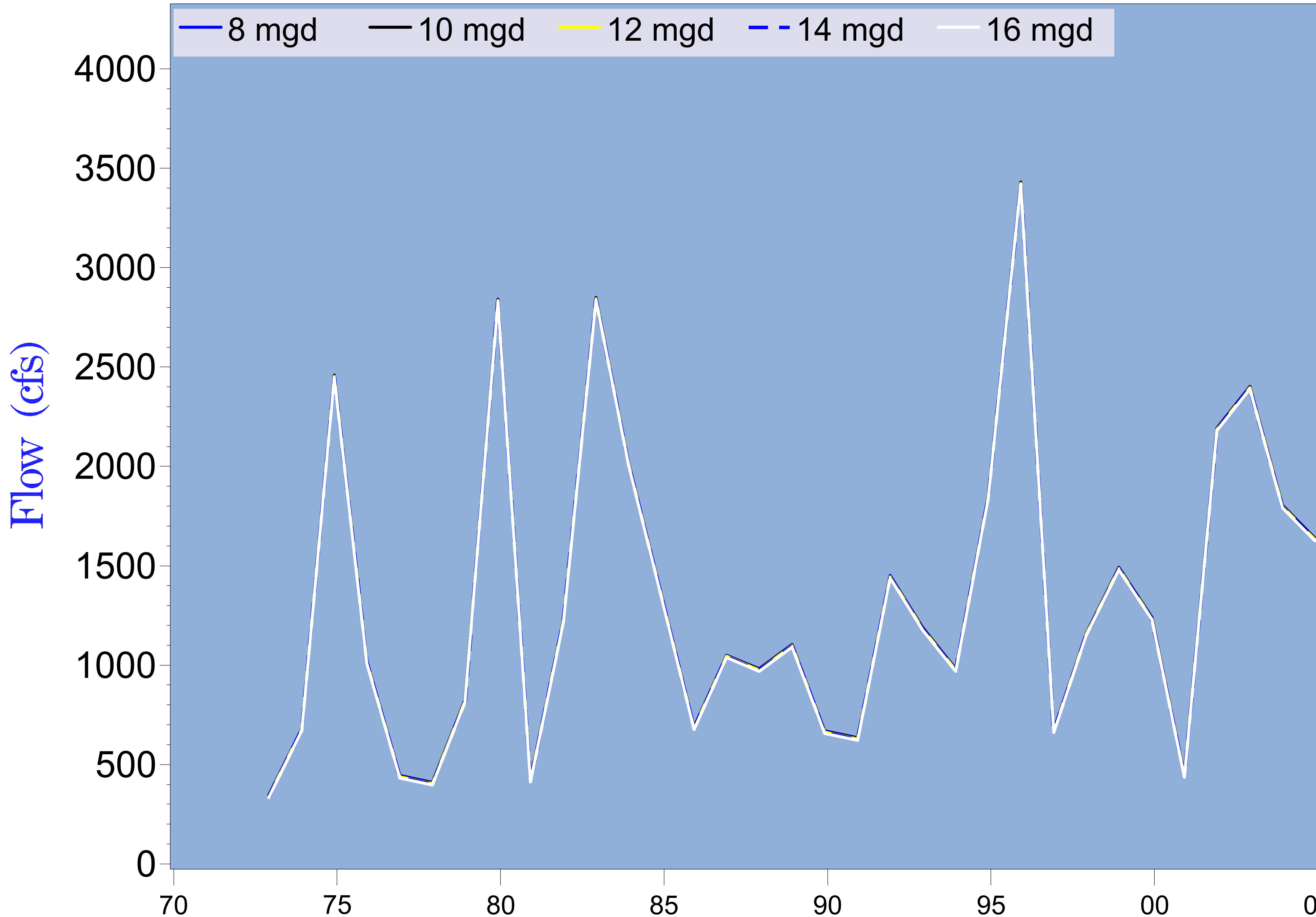


Figure 4.2.19 Differences in monthly average Q5 Shell Creek flow under different maximum withdrawals (1972-2004)

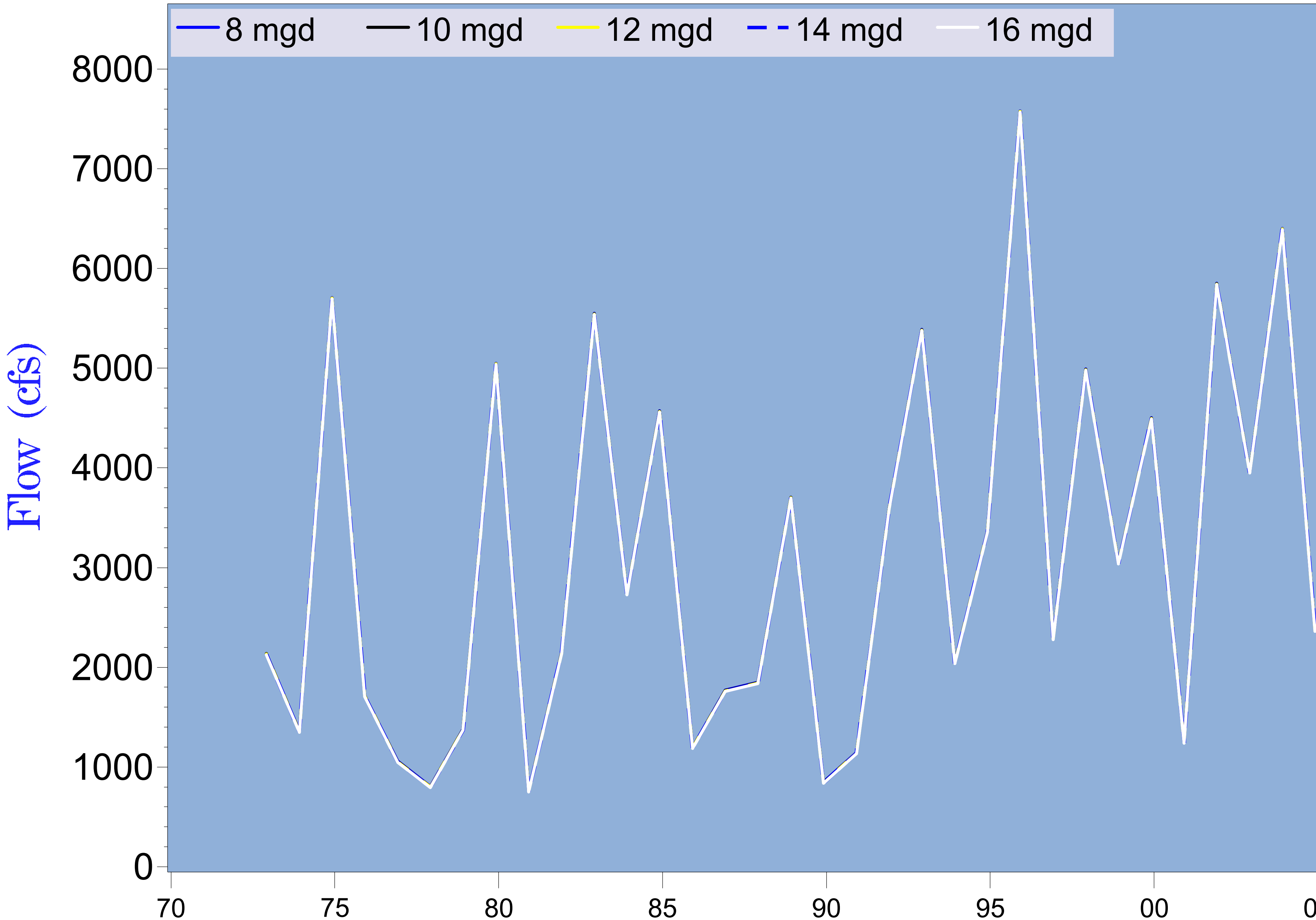


Figure 4.2.20 Differences in monthly average maximum Shell Creek flow under different maximum withdrawals (1972-2004)

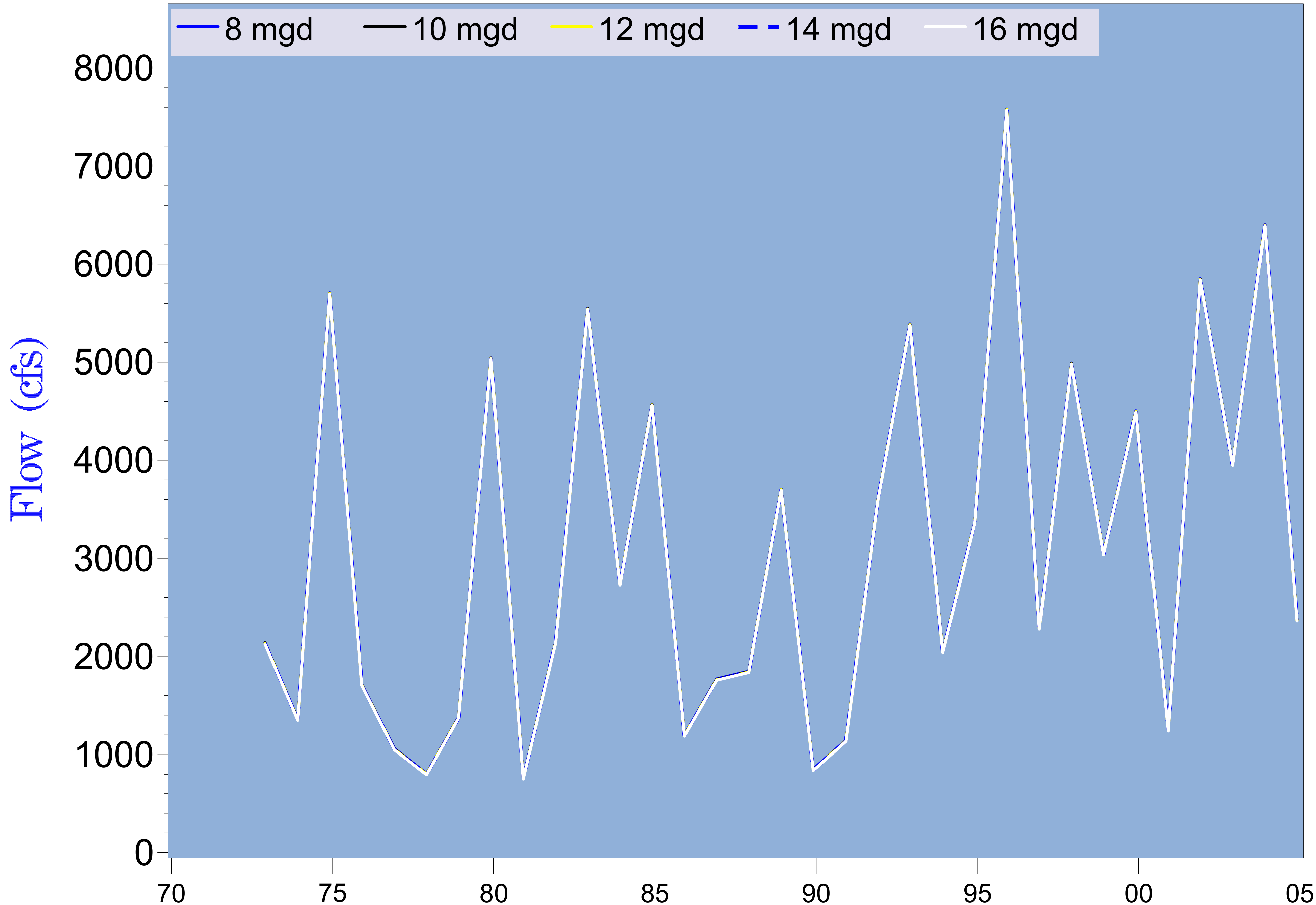


Figure 4.2.20 Differences in monthly average maximum Shell Creek flow under different maximum withdrawals (1972-2004)

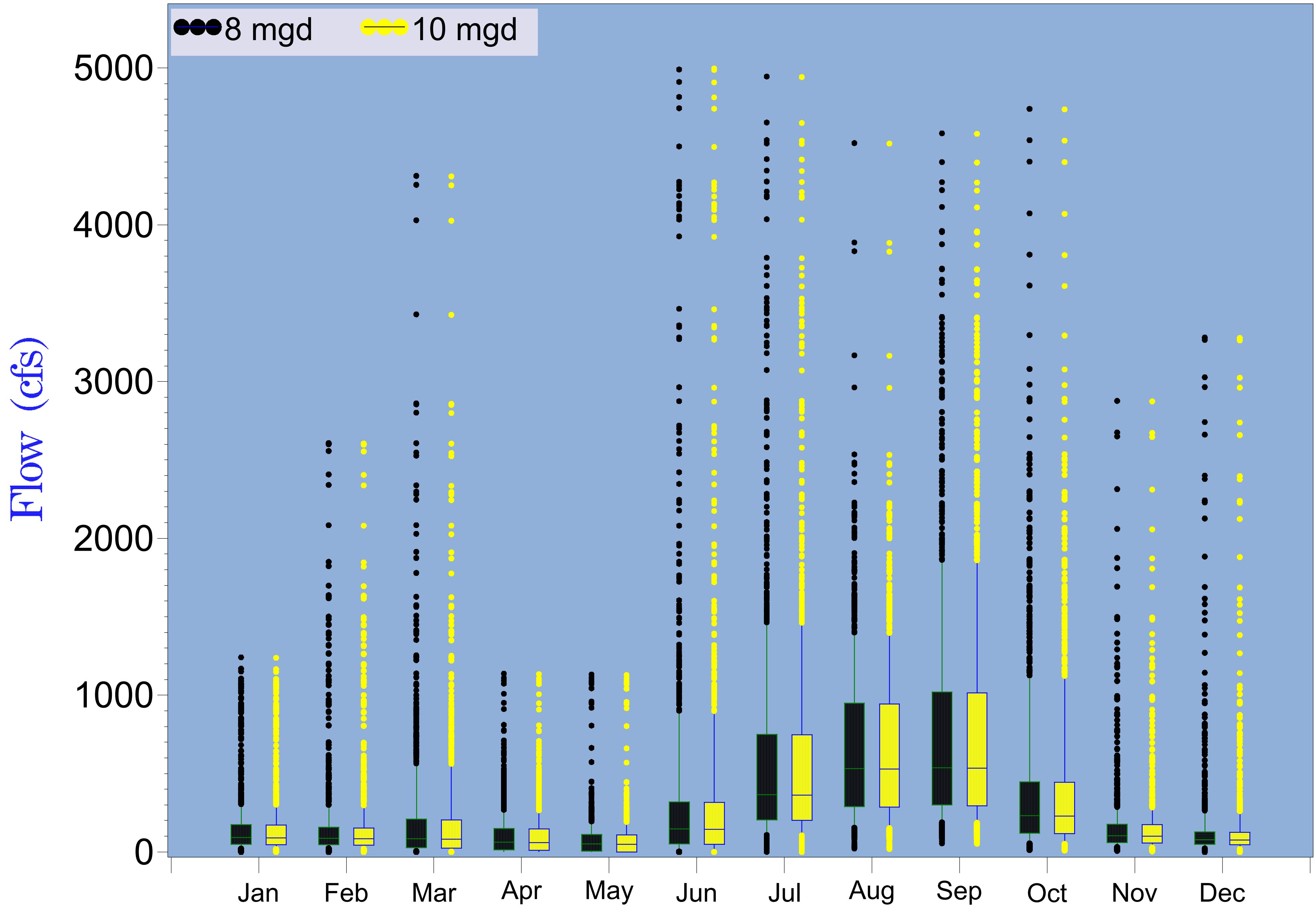


Figure 4.2.21 Monthly differences in average 3-day Shell Creek flow between 8 and 10 mgd withdrawals (1972-2004)

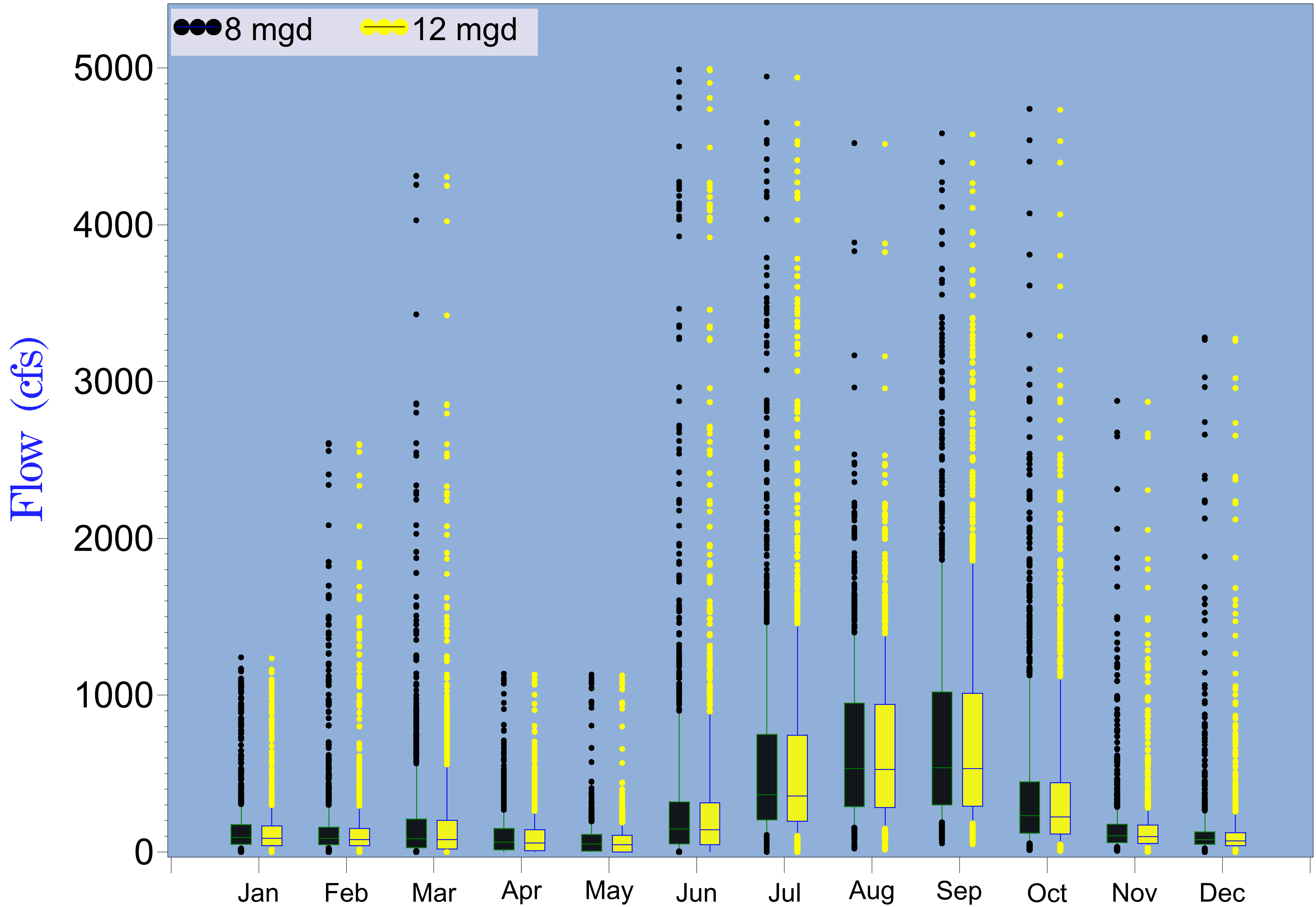


Figure 4.2.22 Monthly differences in average 3-day Shell Creek flow between 8 and 12 mgd withdrawals (1972-2004)

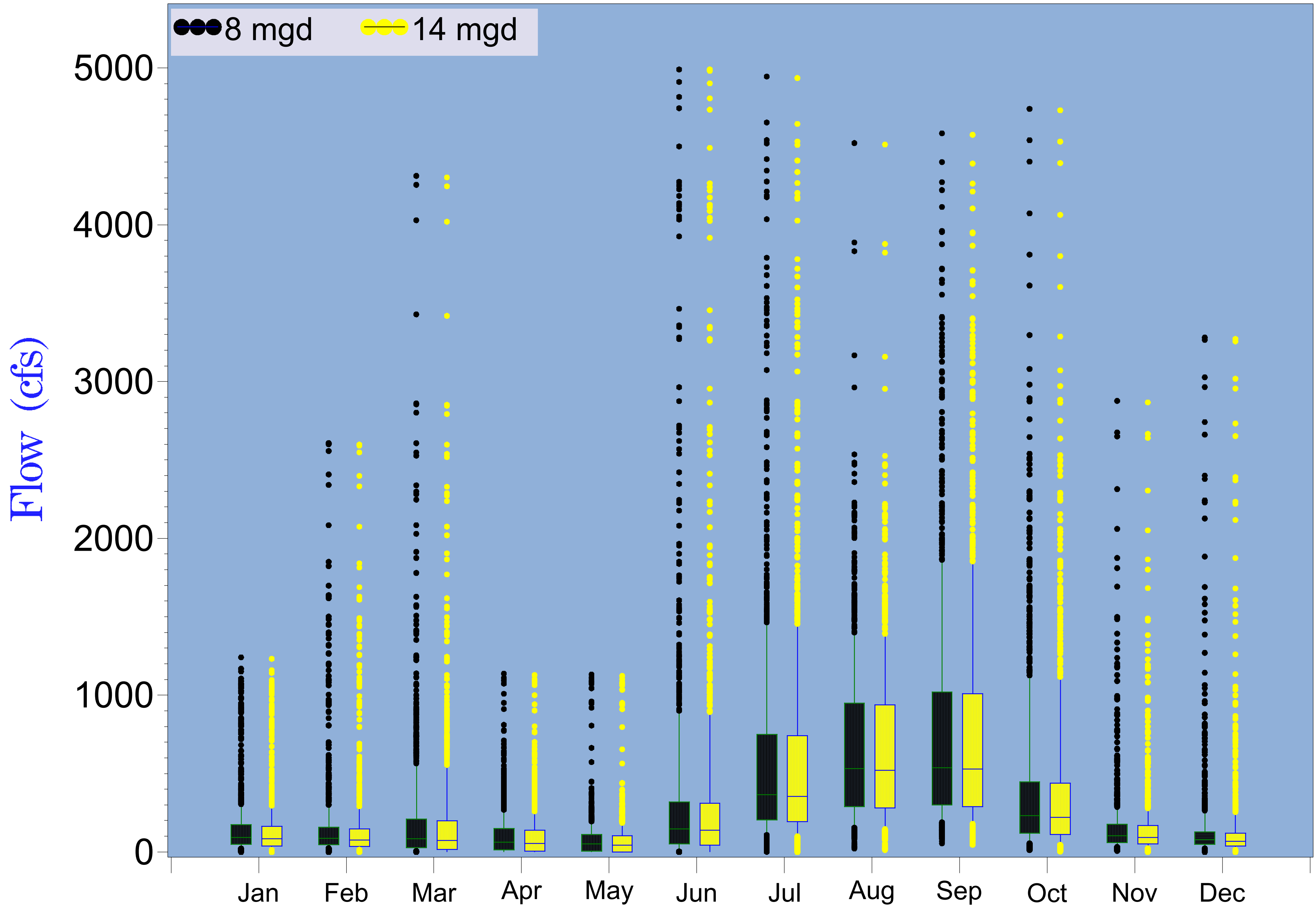


Figure 4.2.23 Monthly differences in average 3-day Shell Creek flow between 8 and 14 mgd withdrawals (1972-2004)

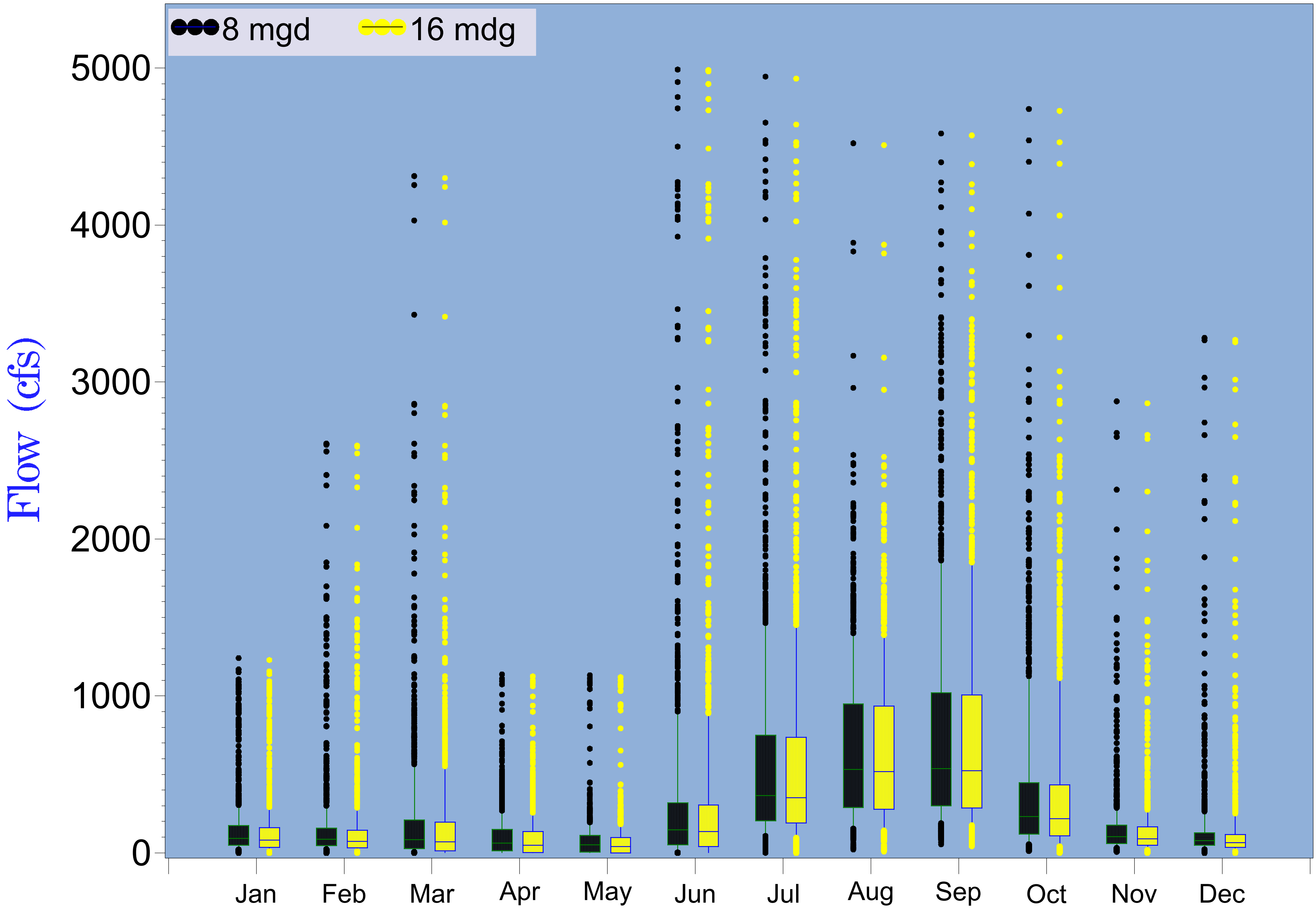


Figure 4.2.24 Monthly differences in average 3-day Shell Creek flow between 8 and 16 mgd withdrawals (1972-2004)

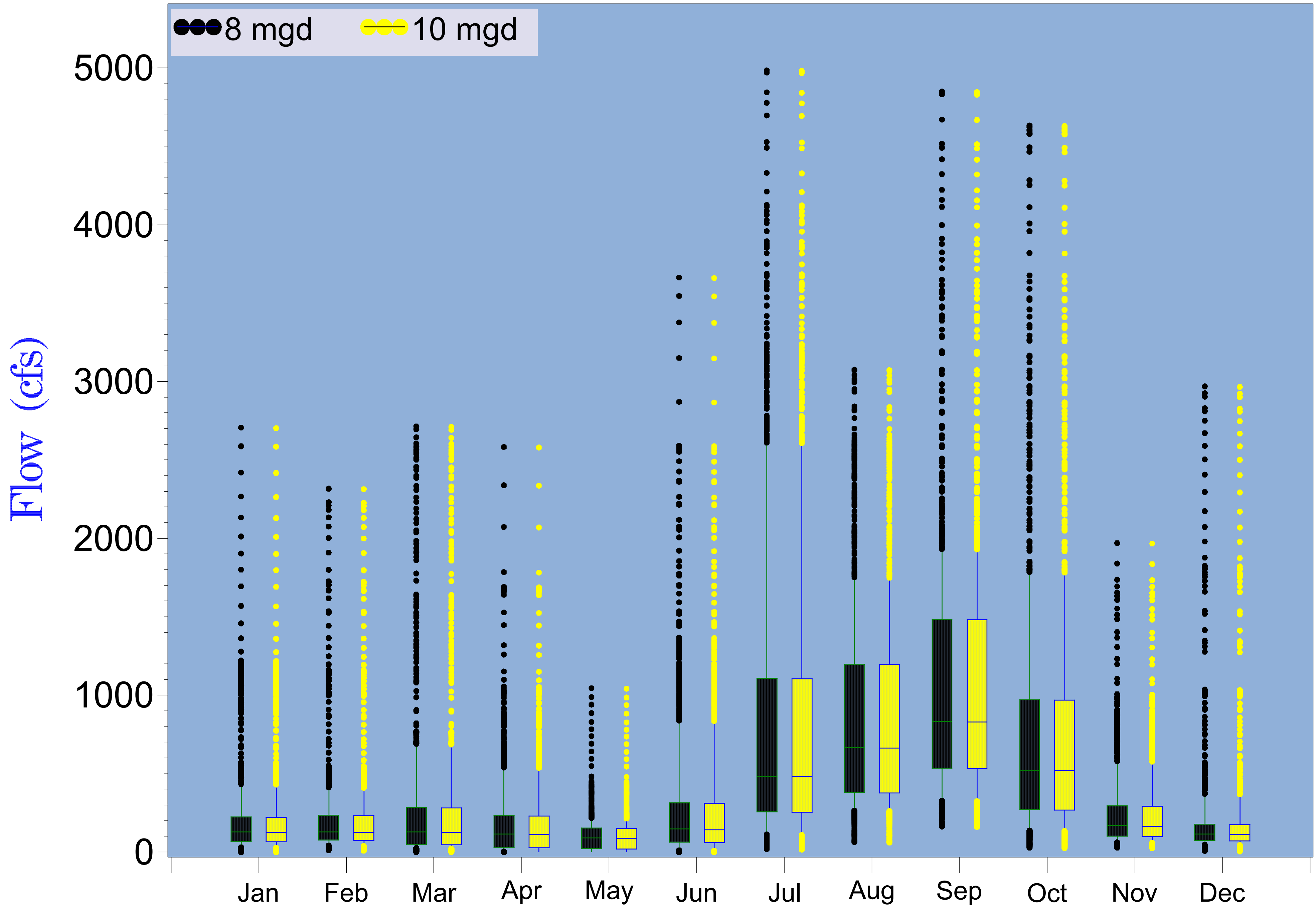


Figure 4.2.25 Monthly differences in average 15-day Shell Creek flow between 8 and 10 mgd withdrawals (1972-2004)

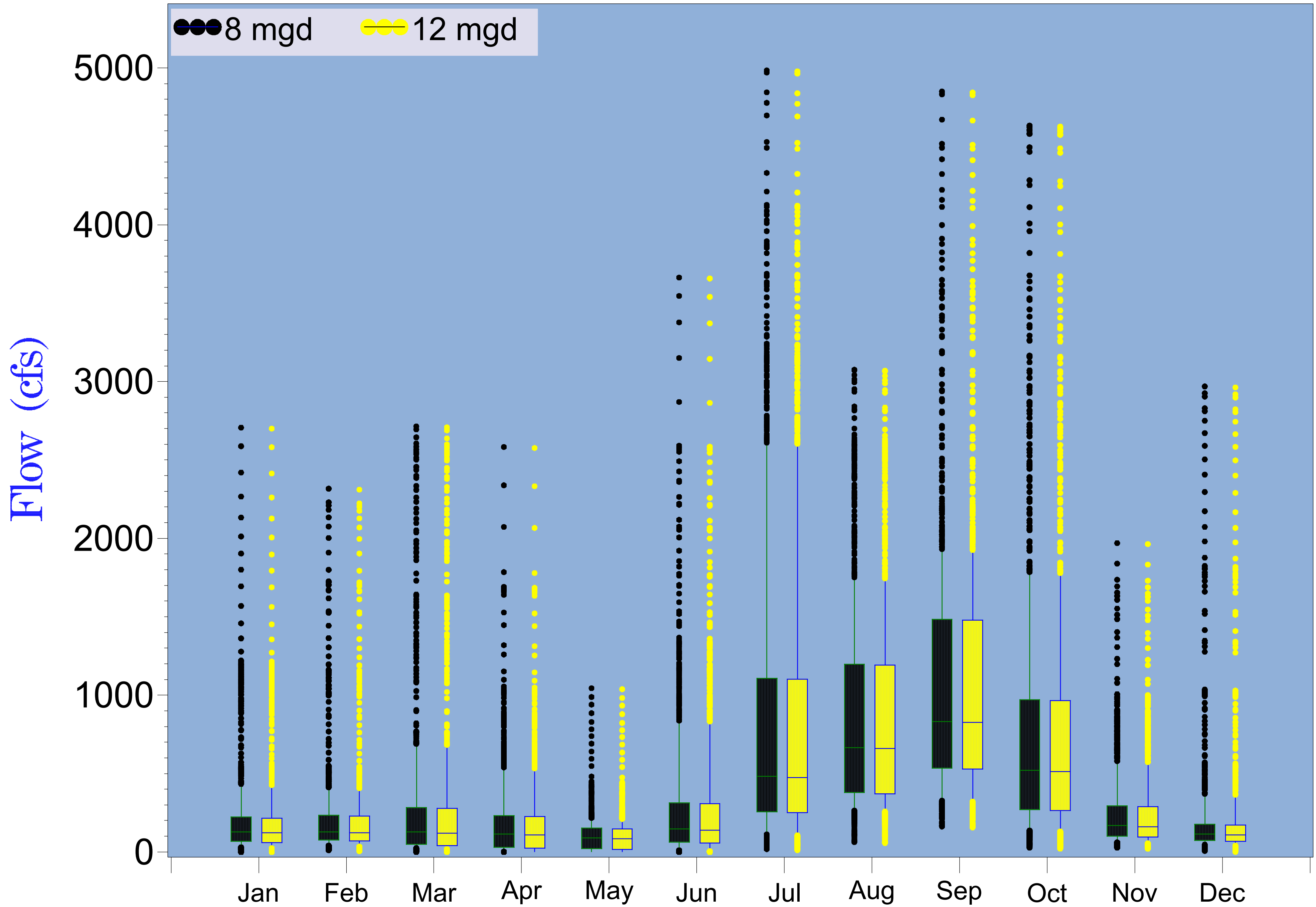


Figure 4.2.26 Monthly differences in average 15-day Shell Creek flow between 8 and 12 mgd withdrawals (1972-2004)

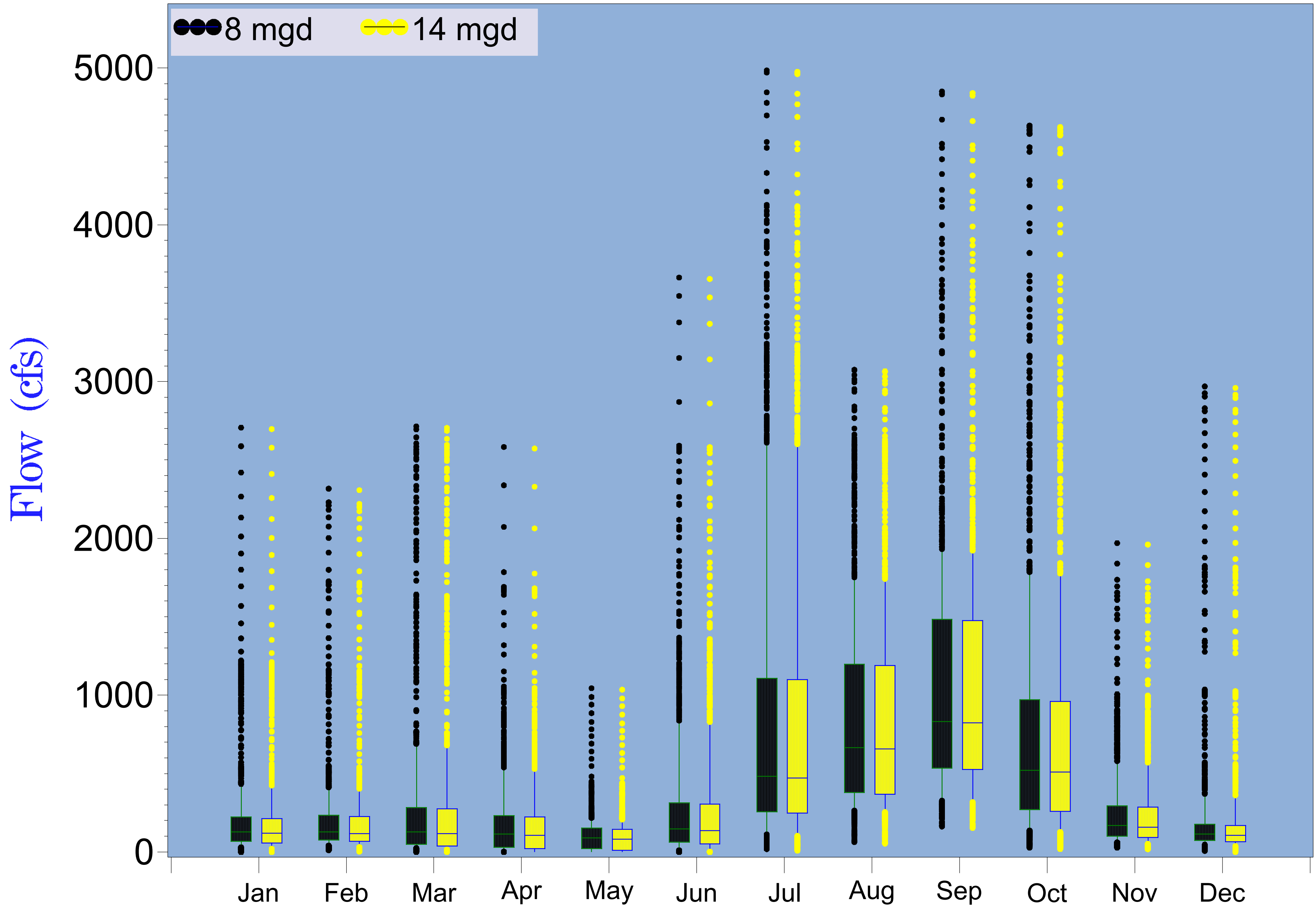


Figure 4.2.27 Monthly differences in average 15-day Shell Creek flow between 8 and 14 mgd withdrawals (1972-2004)

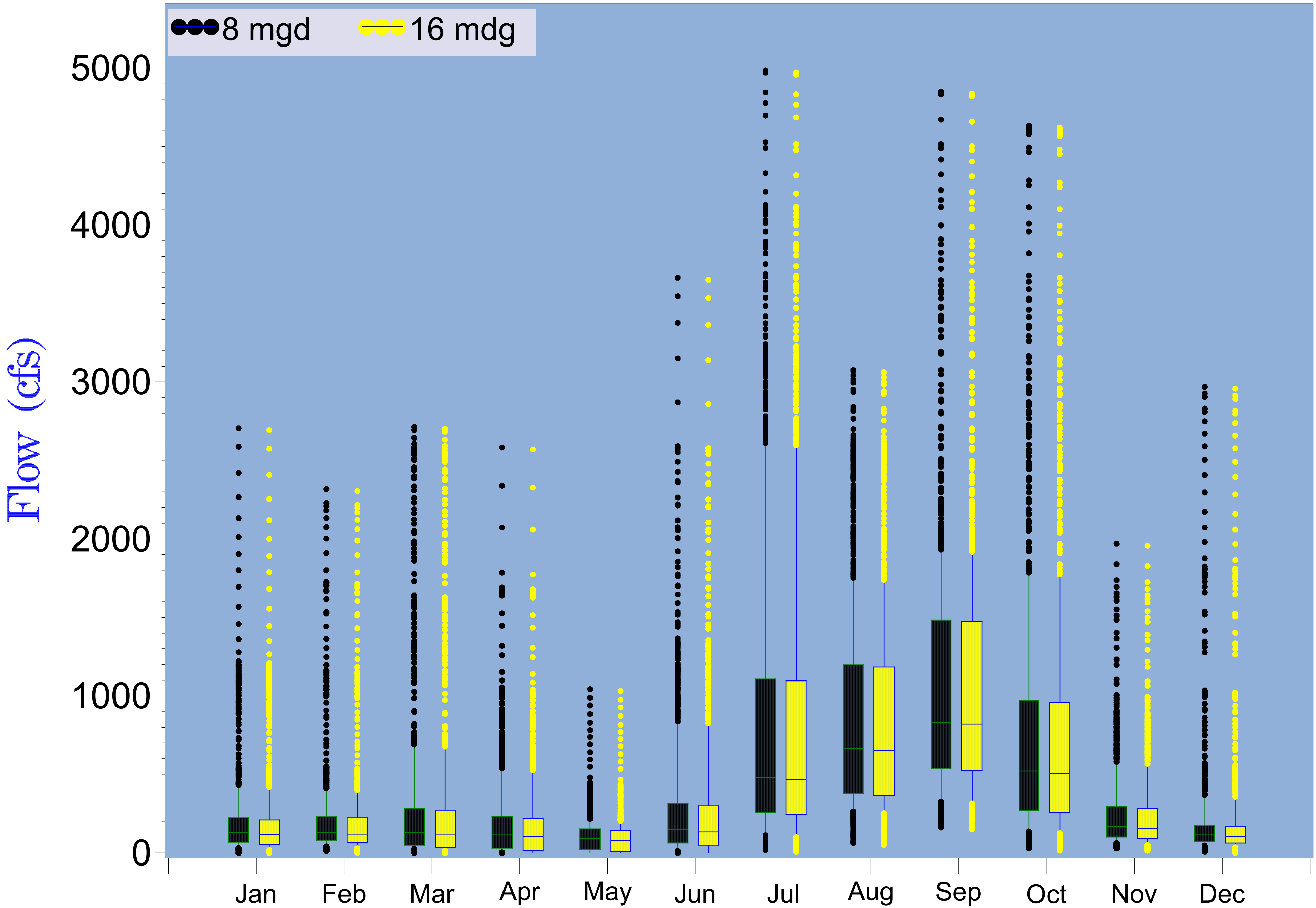


Figure 4.2.28 Monthly differences in average 15-day Shell Creek flow between 8 and 16 mgd withdrawals (1972-2004)

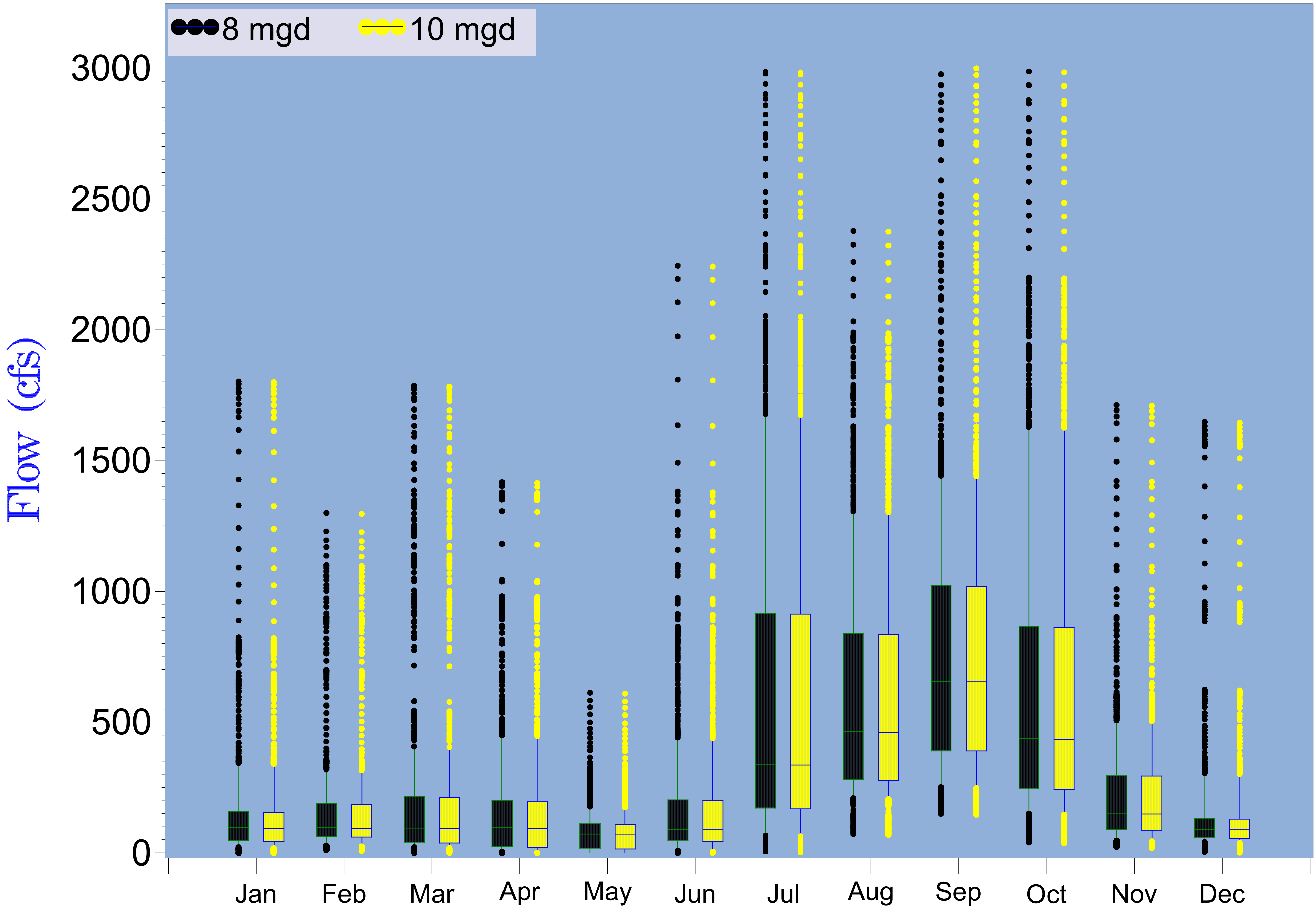


Figure 4.2.29 Monthly differences in average 30-day Shell Creek flow between 8 and 10 mgd withdrawals (1972-2004)

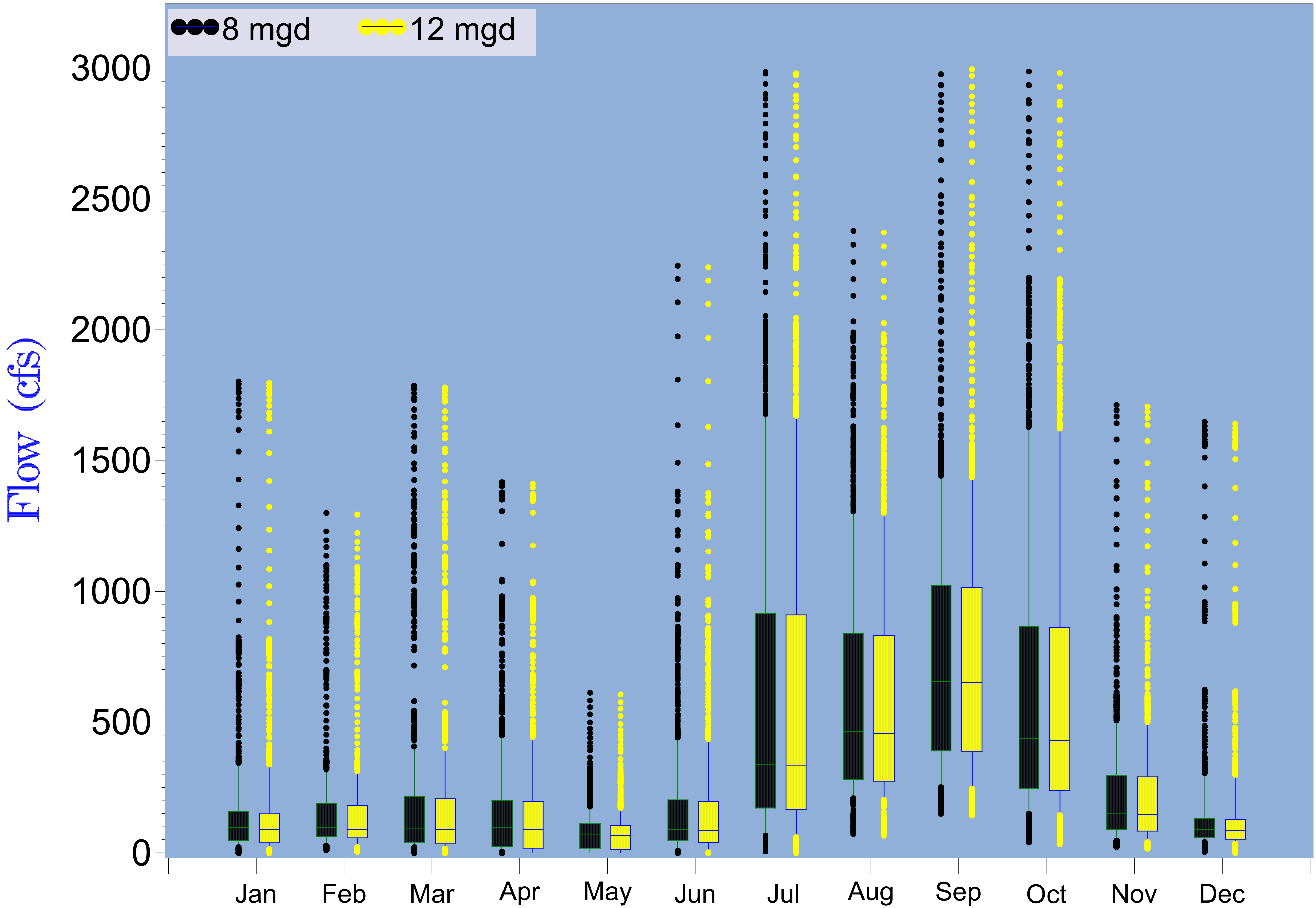


Figure 4.2.30 Monthly differences in average 30-day Shell Creek flow between 8 and 12 mgd withdrawals (1972-2004)

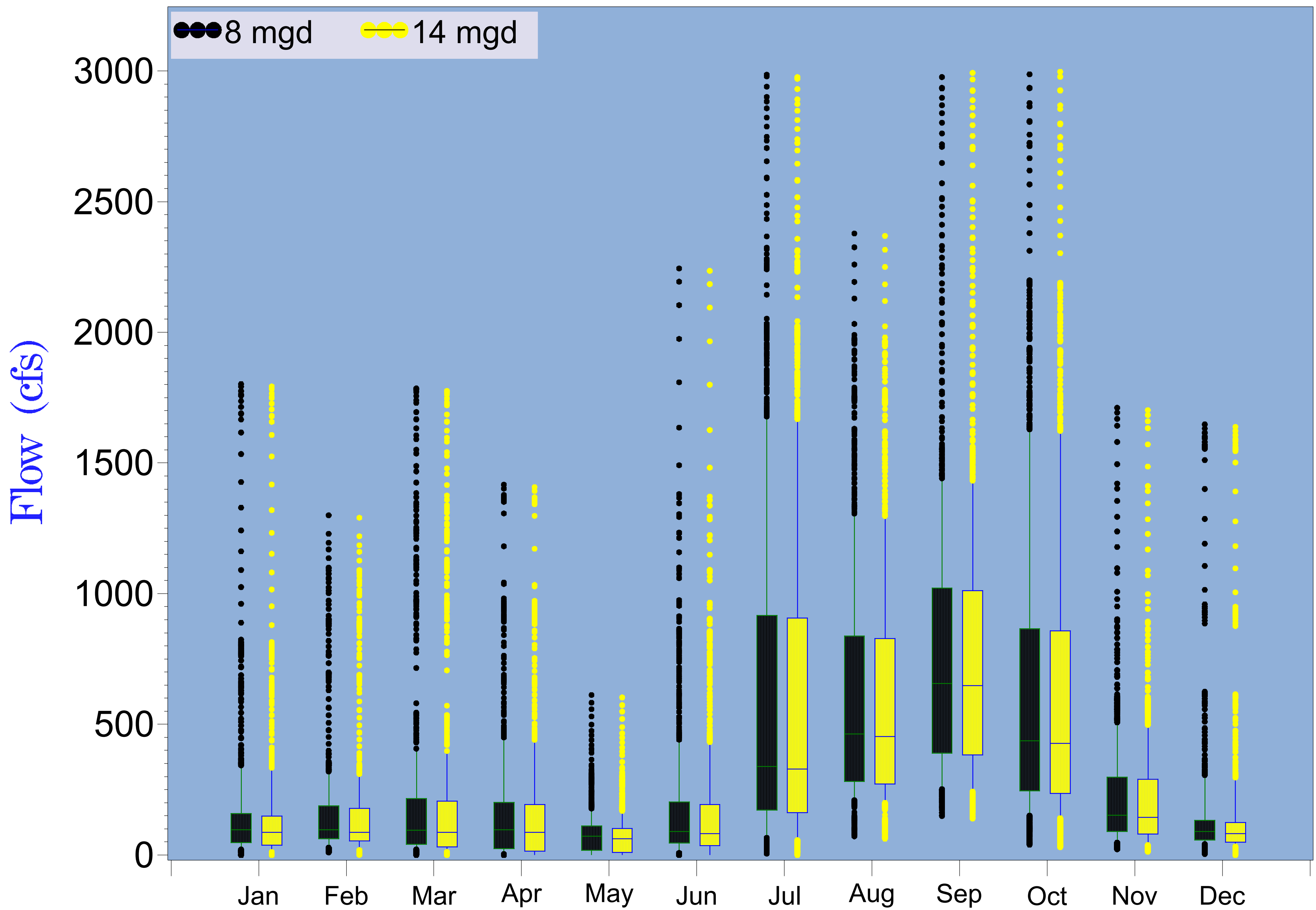


Figure 4.2.31 Monthly differences in average 30-day Shell Creek flow between 8 and 14 mgd withdrawals (1972-2004)

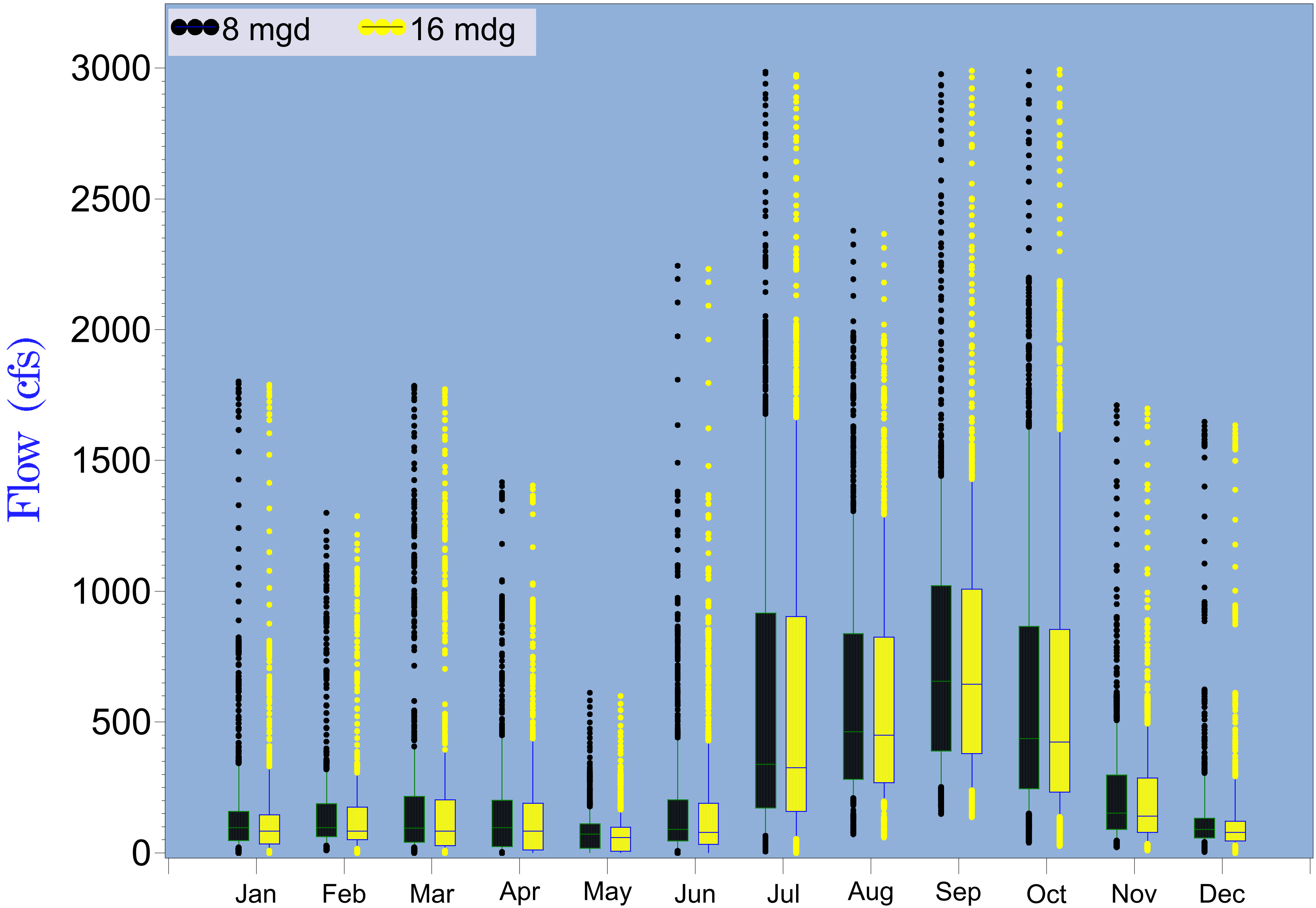


Figure 4.2.32 Monthly differences in average 30-day Shell Creek flow between 8 and 16 mgd withdrawals (1972-2004)

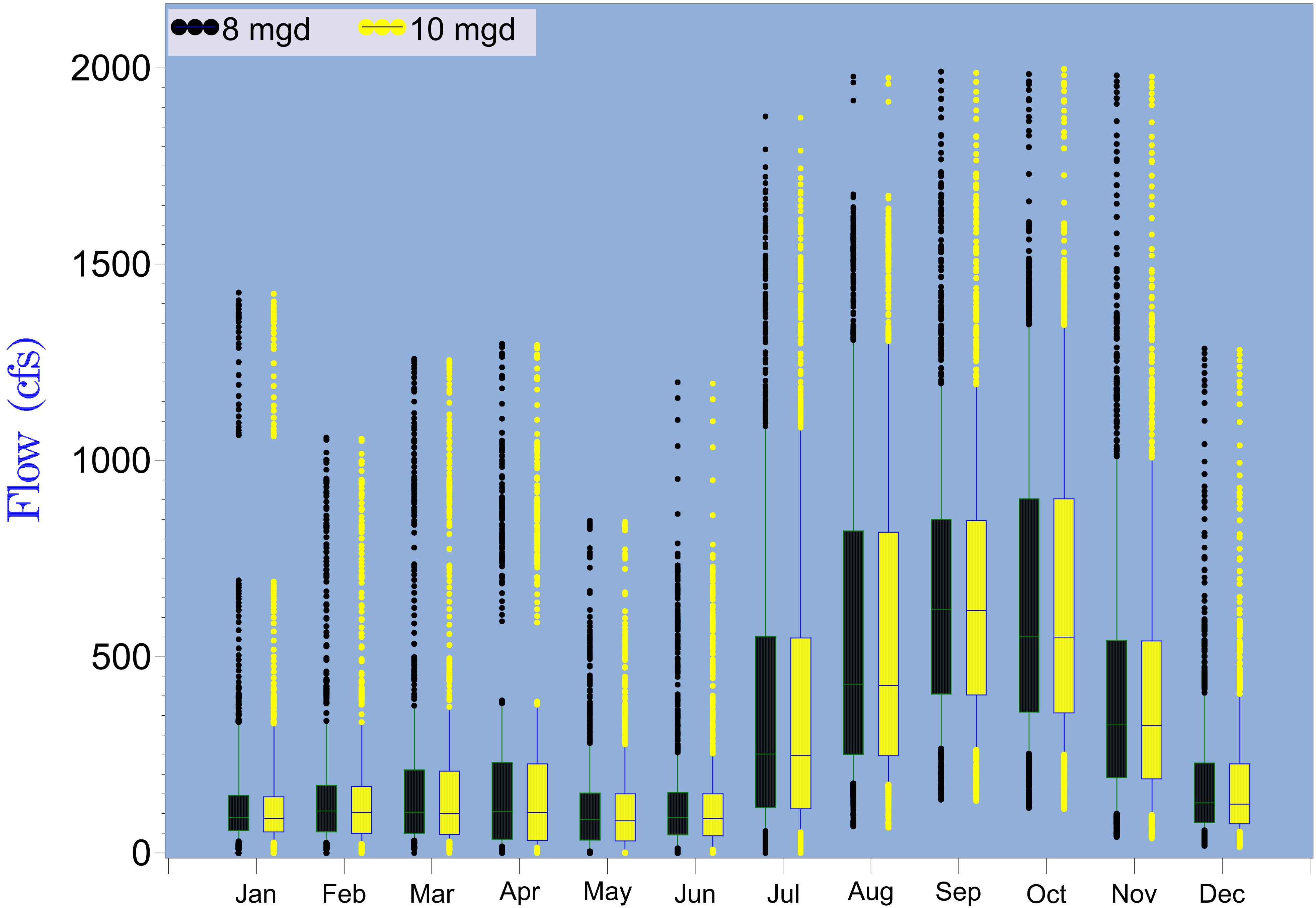


Figure 4.2.33 Monthly differences in average 60-day Shell Creek flow between 8 and 10 mgd withdrawals (1972-2004)

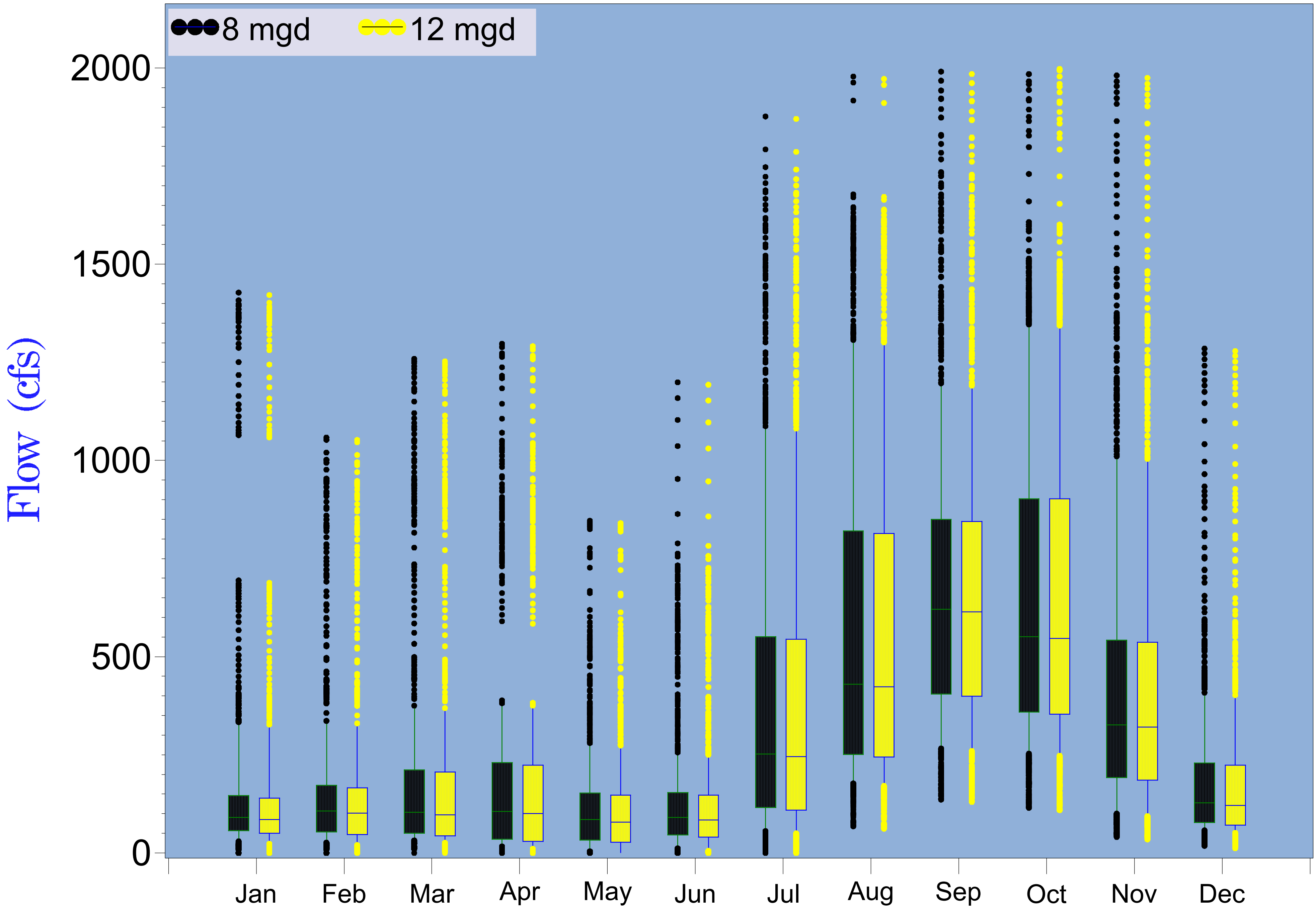
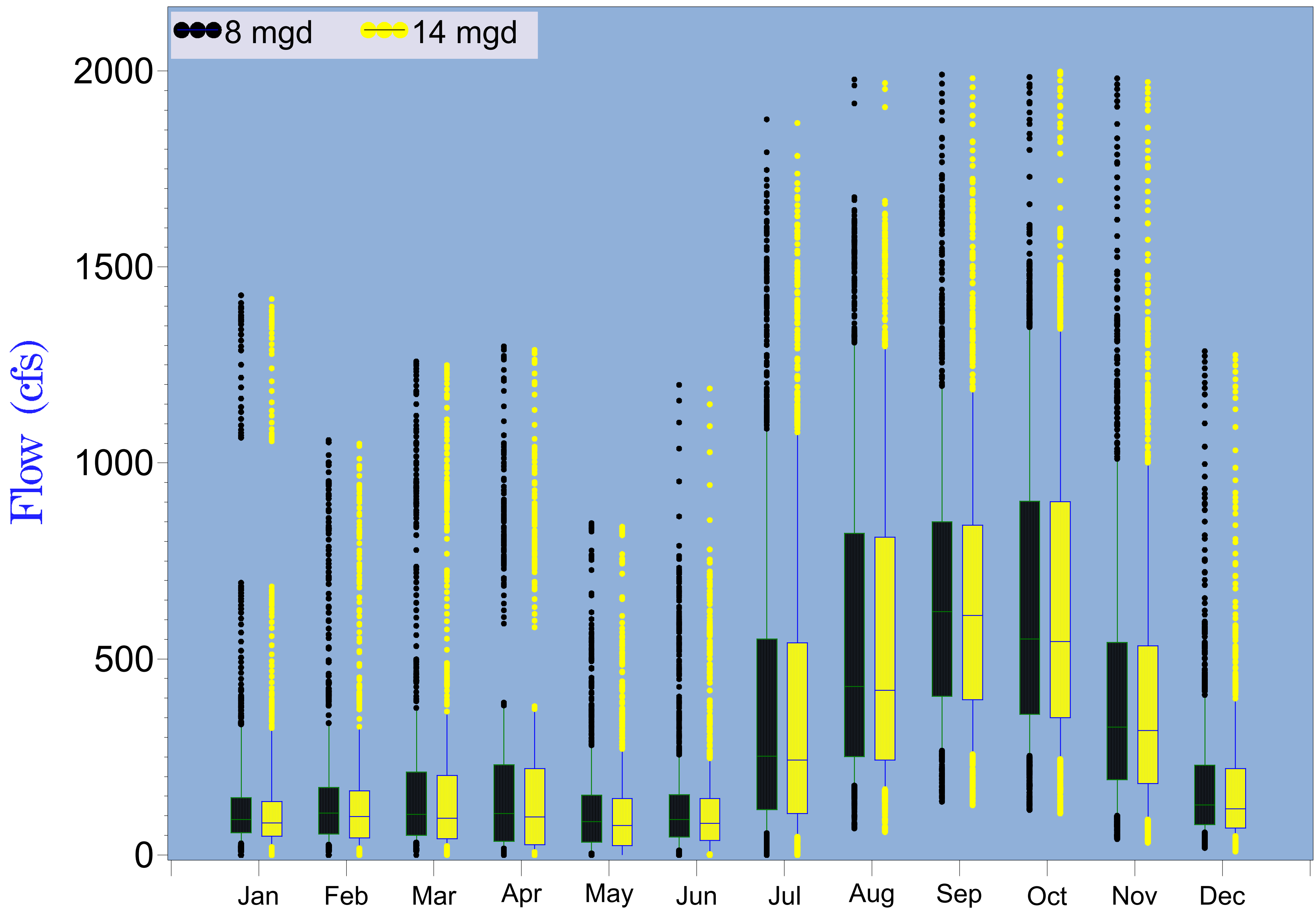


Figure 4.2.34 Monthly differences in average 60-day Shell Creek flow between 8 and 12 mgd withdrawals (1972-2004)



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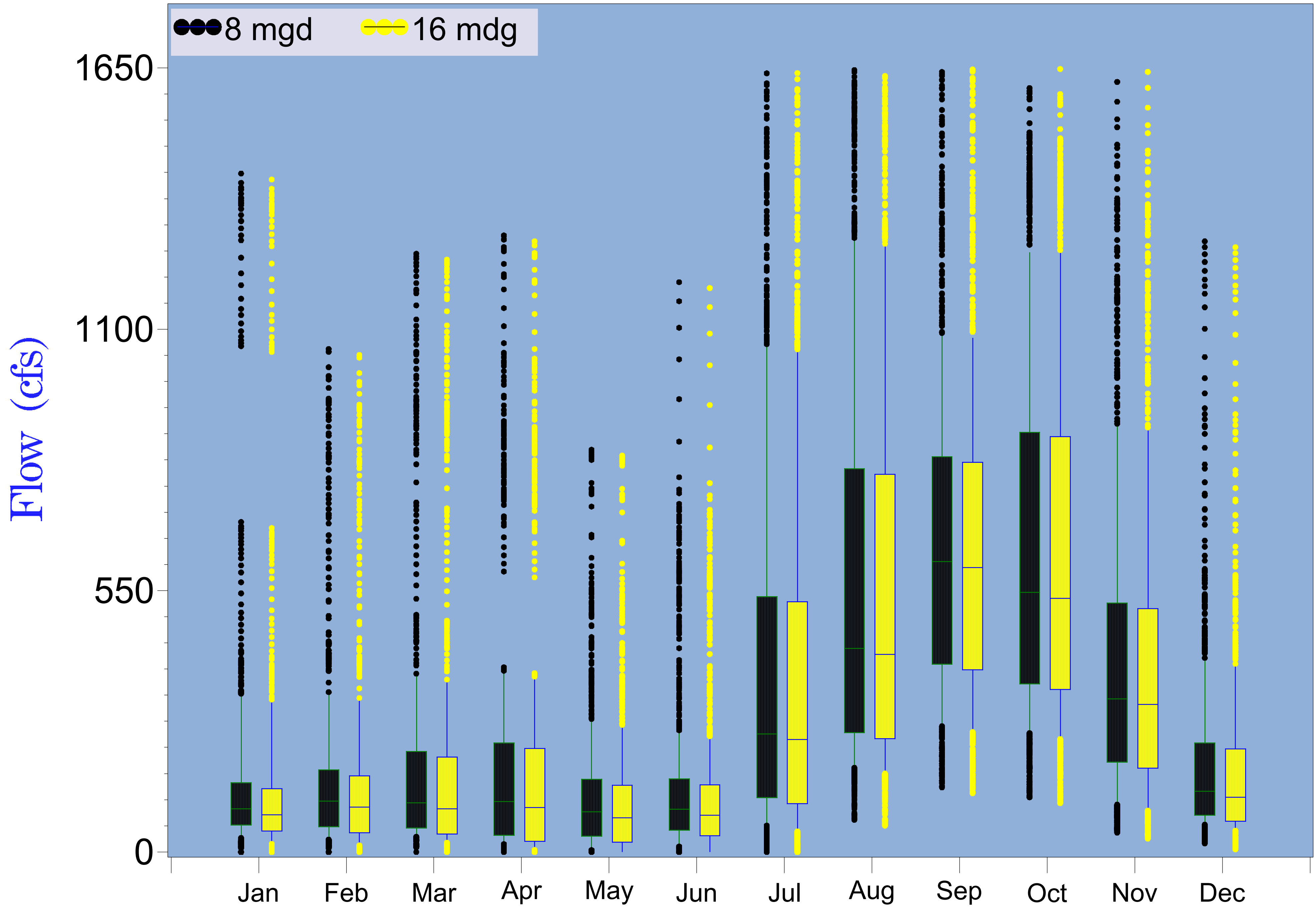


Figure 4.2.36 Monthly differences in average 60-day Shell Creek flow between 8 and 16 mgd withdrawals (1972-2004)

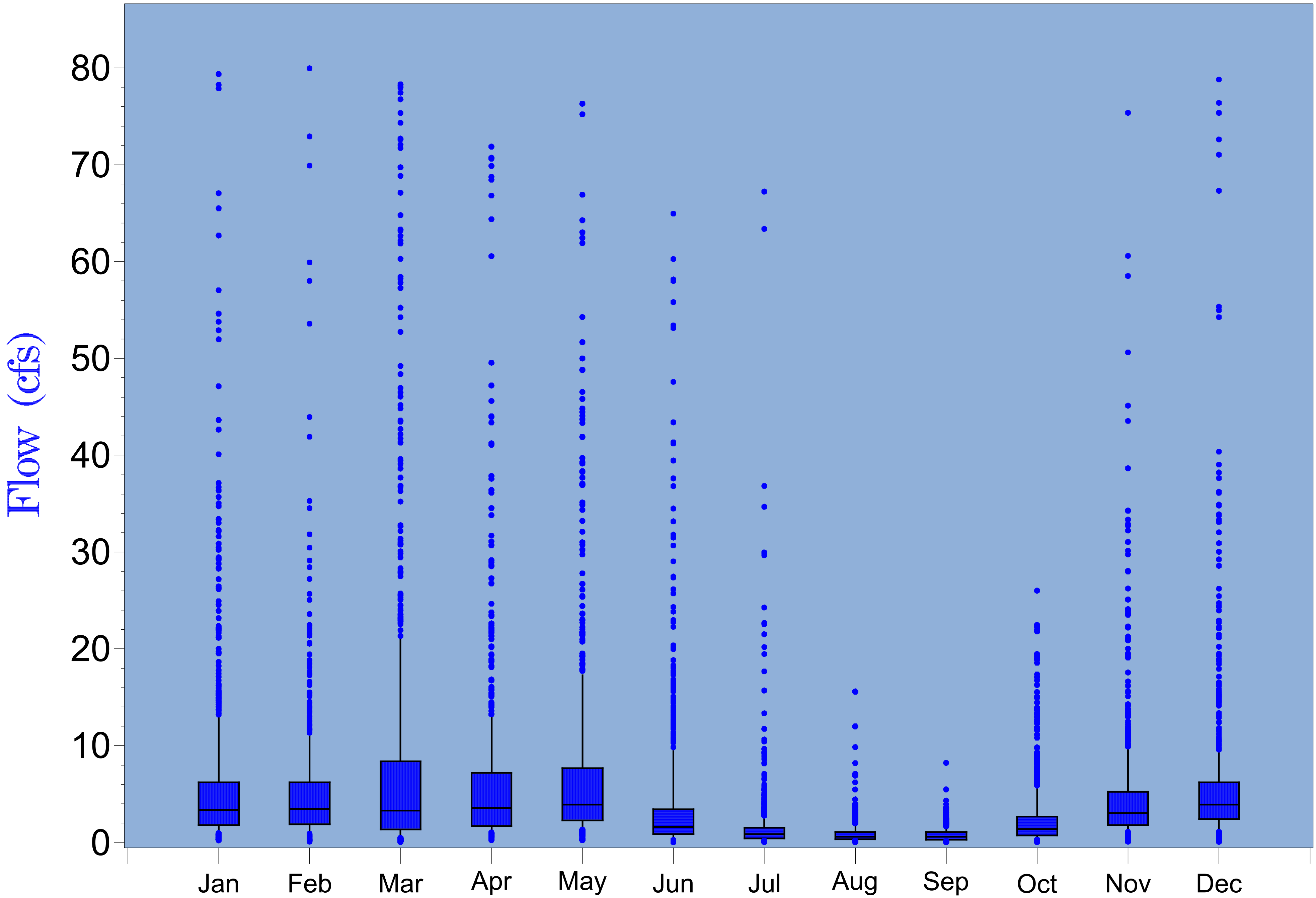


Figure 4.2.37 Monthly percent change in between 8 and 10 mgd withdrawals (1972-2004)

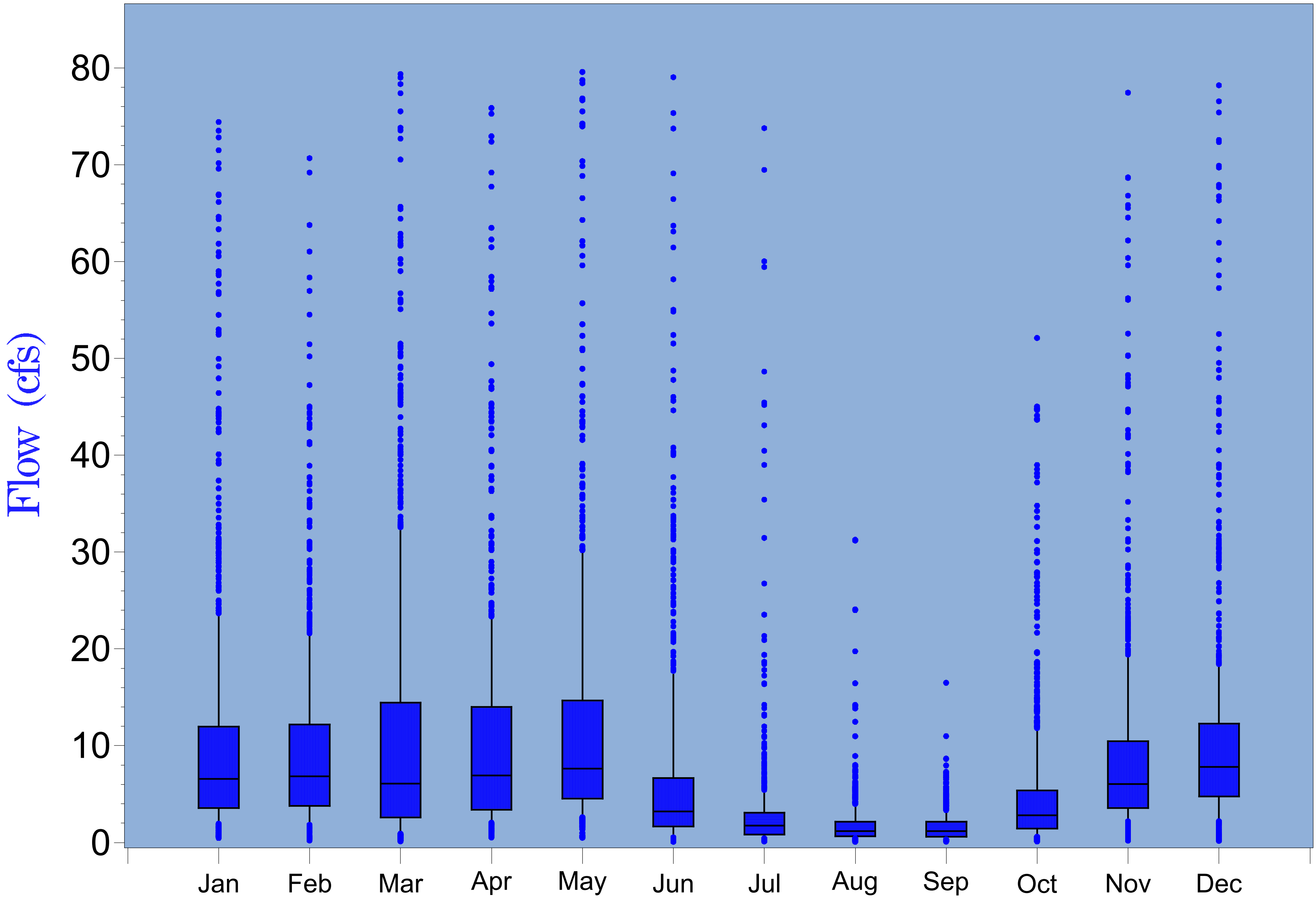


Figure 4.2.38 Monthly percent change in between 8 and 12 mgd withdrawals (1972-2004)

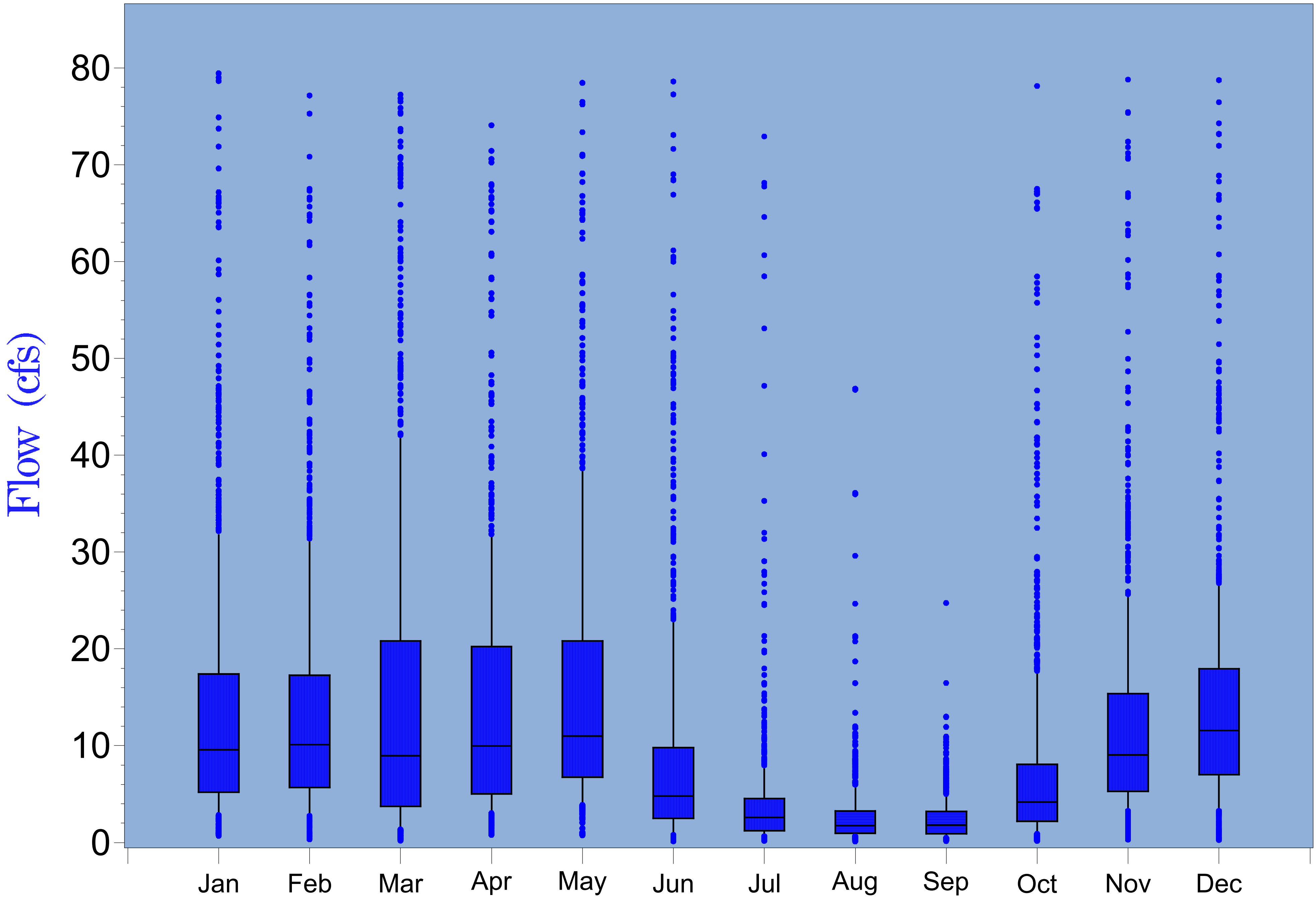


Figure 4.2.39 Monthly percent change in between 8 and 14 mgd withdrawals (1972-2004)

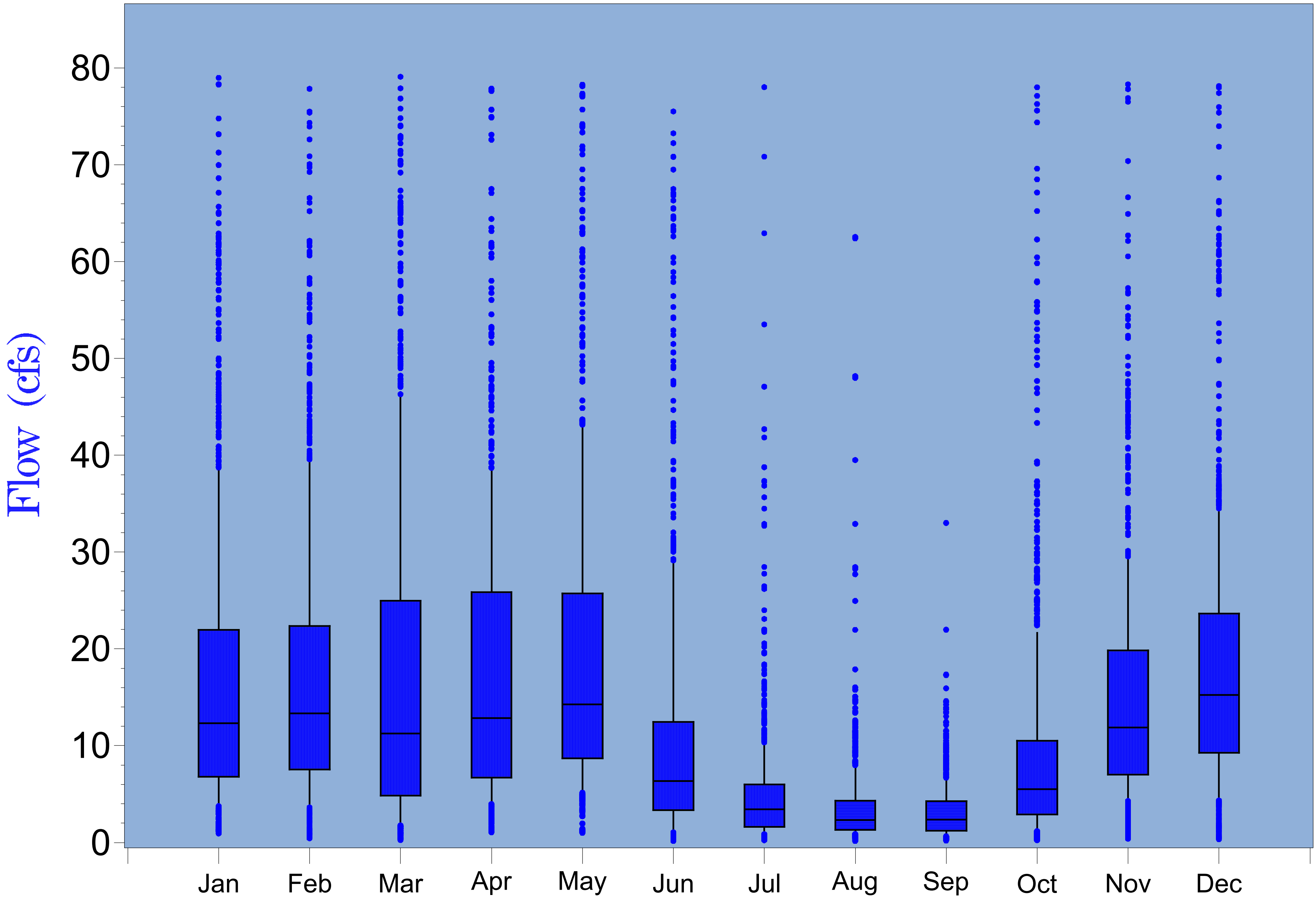


Figure 4.2.40 Monthly percent change in between 8 and 16 mgd withdrawals (1972-2004)

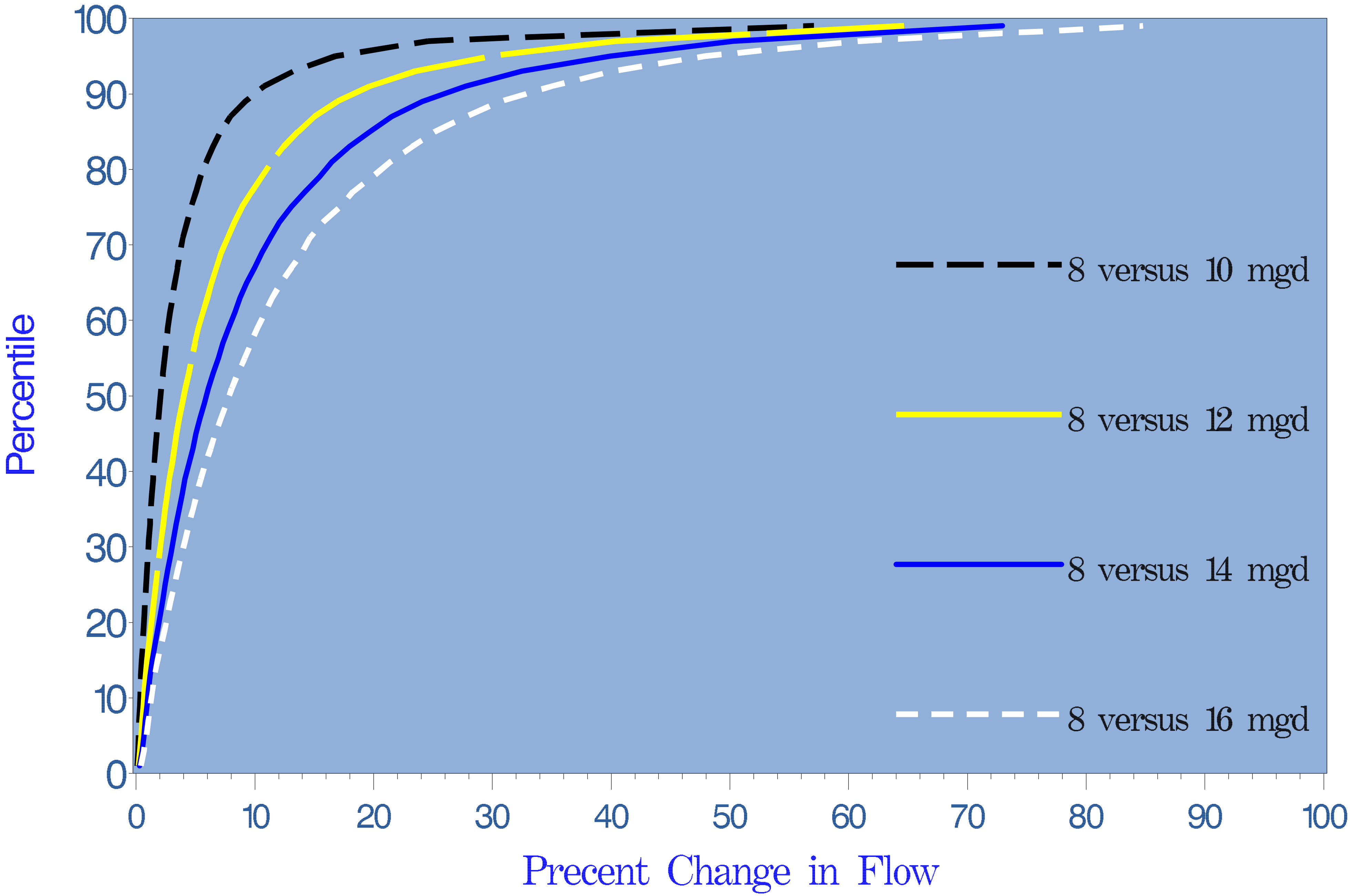


Figure 4.2.41 CDF of predicted percent change in flow due to different increased withdrawals

Appendix C

Influences of Flow on Selected Parameters

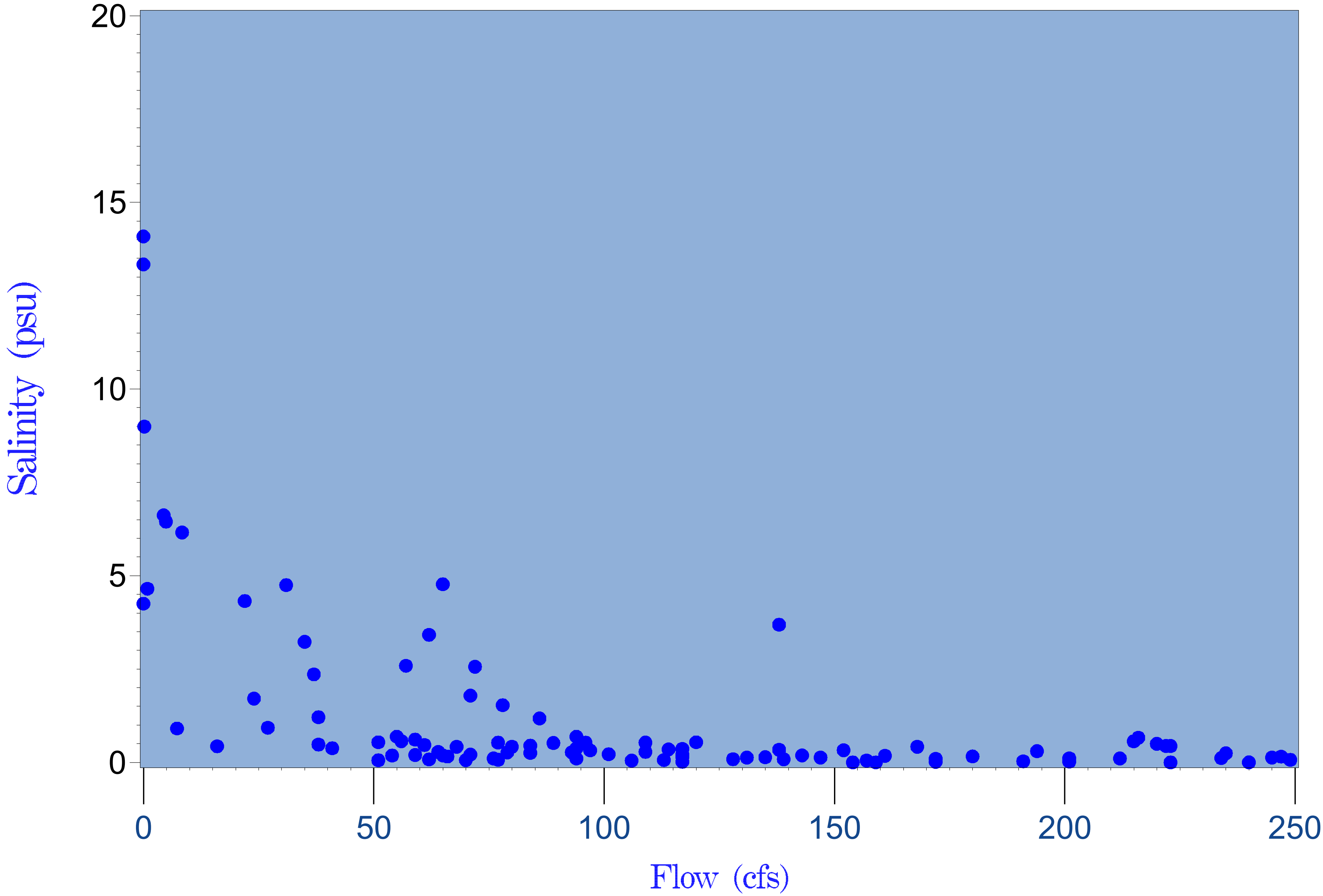


Figure 4.3.1 Surface salinity versus flow at Station #11 (River Kilometer 9.90), 1991-2004

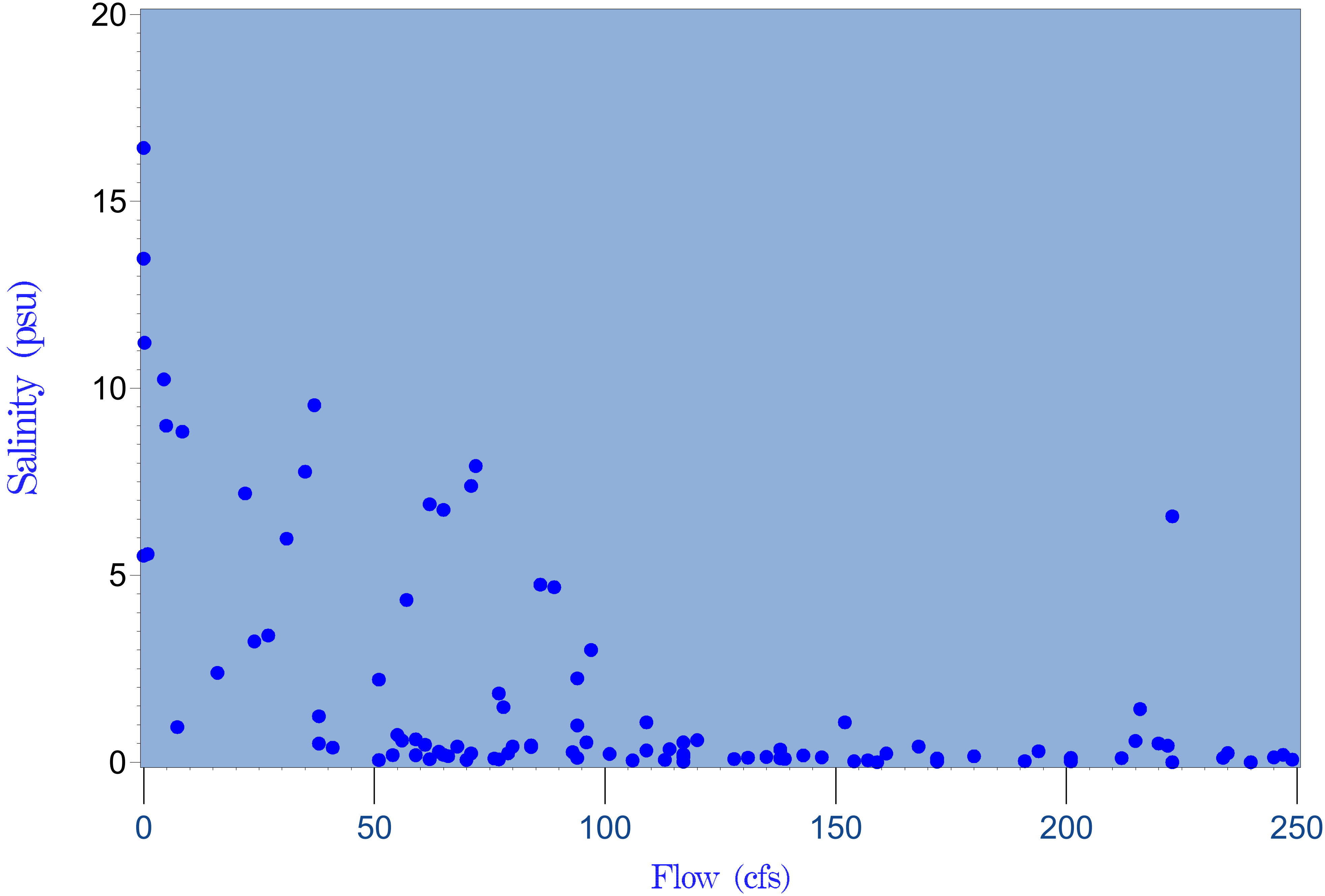


Figure 4.3.2 Bottom salinity versus flow at Station #11 (River Kilometer 9.90), 1991-2004

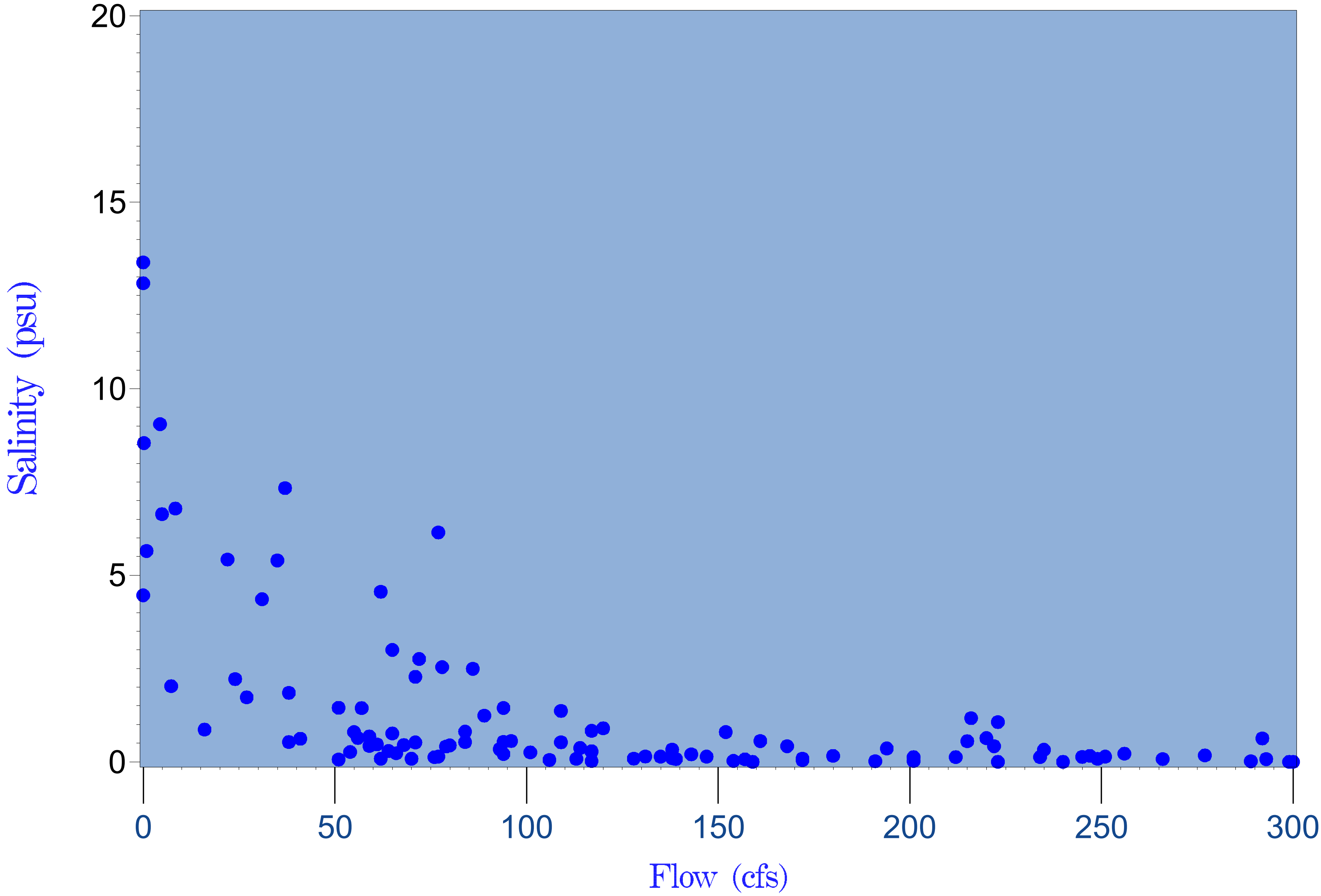


Figure 4.3.3 Surface salinity versus flow at Station #4 (River Kilometer 8.74), 1991-2004

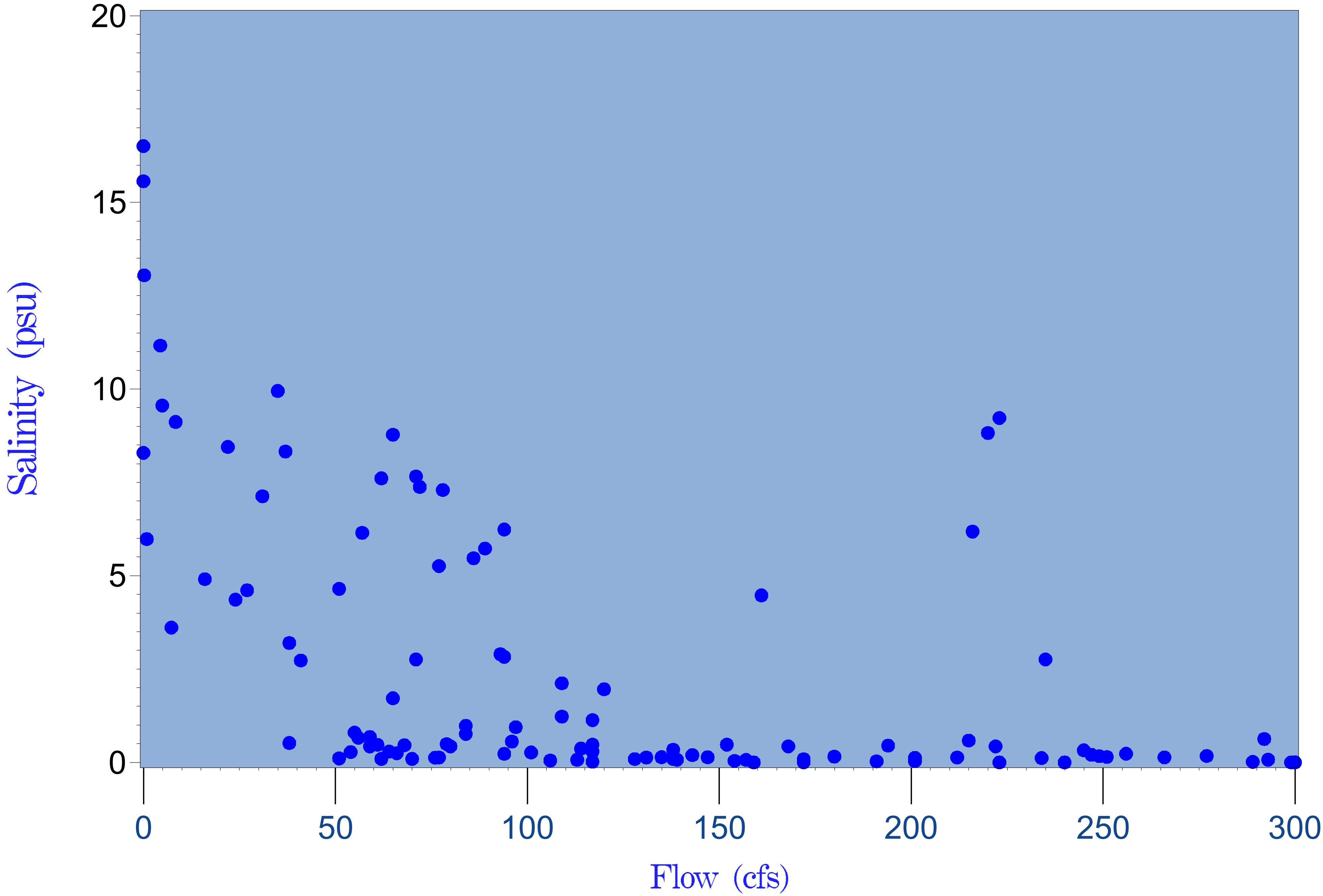


Figure 4.3.4 Bottom salinity versus flow at Station #4 (River Kilometer 8.74), 1991-2004

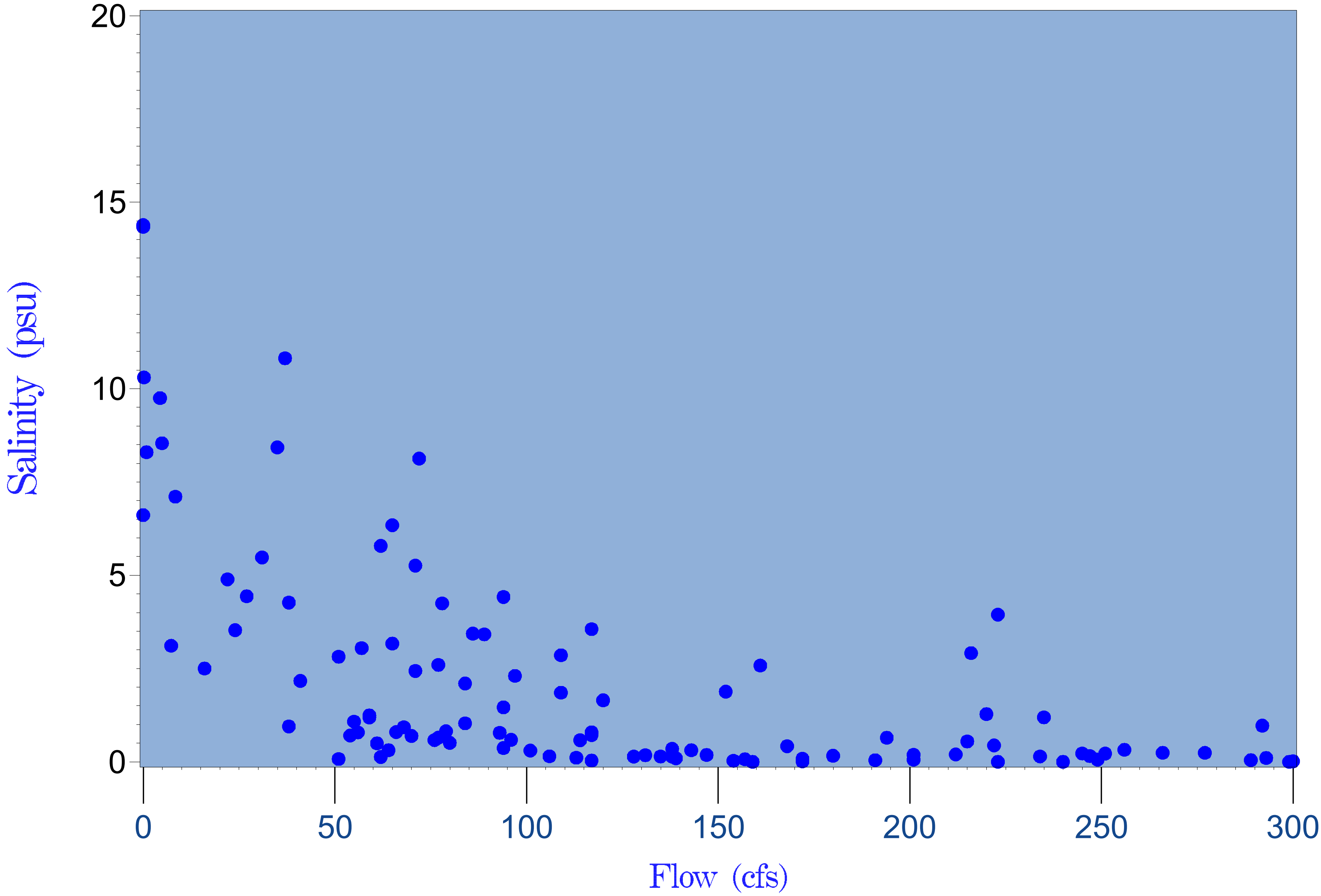


Figure 4.3.5 Surface salinity versus flow at Station #5 (River Kilometer 6.72), 1991-2004

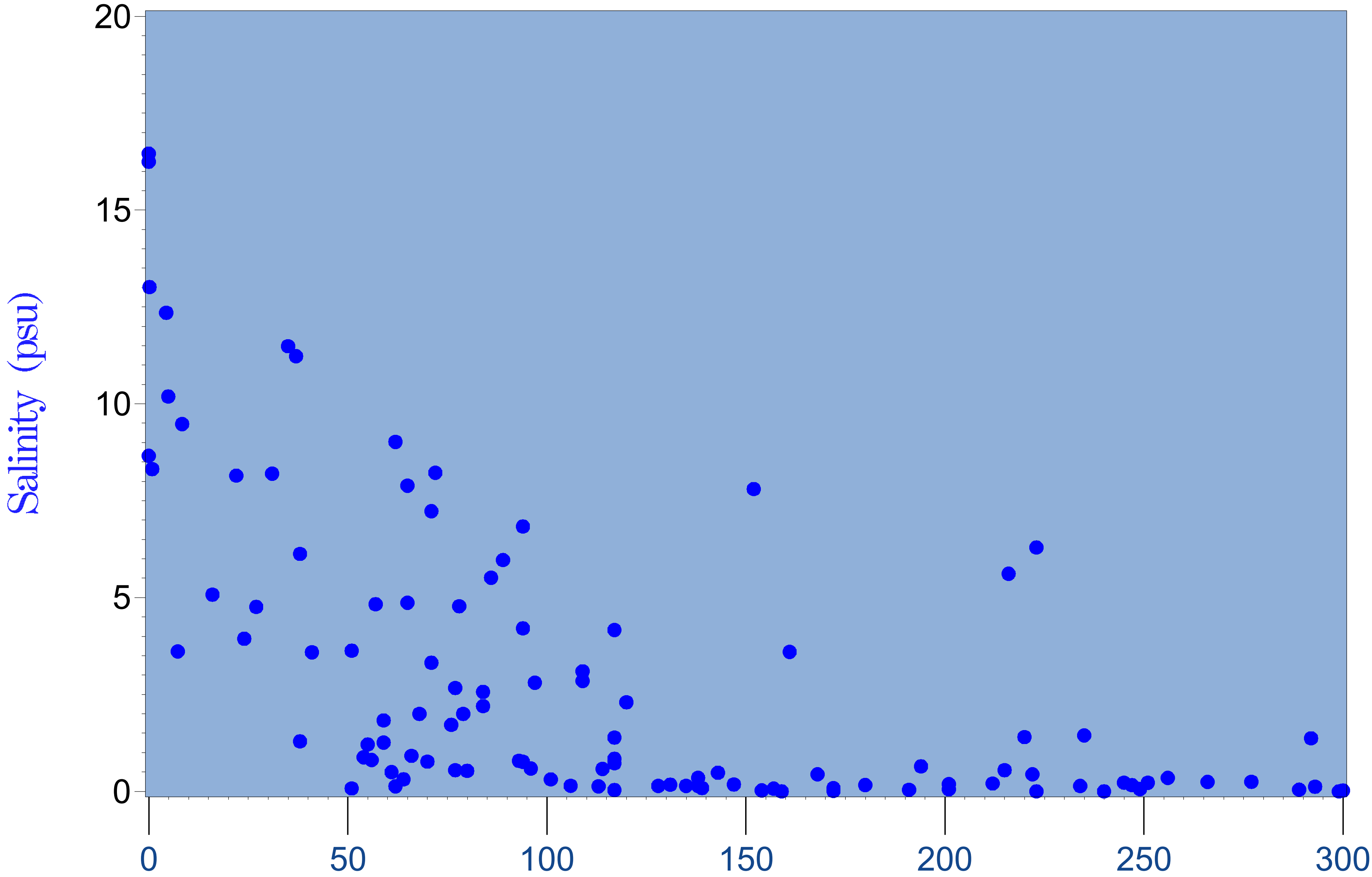


Figure 4.3.6 Bottom salinity versus flow at Station #5 (River Kilometer 6.72), 1991-2004

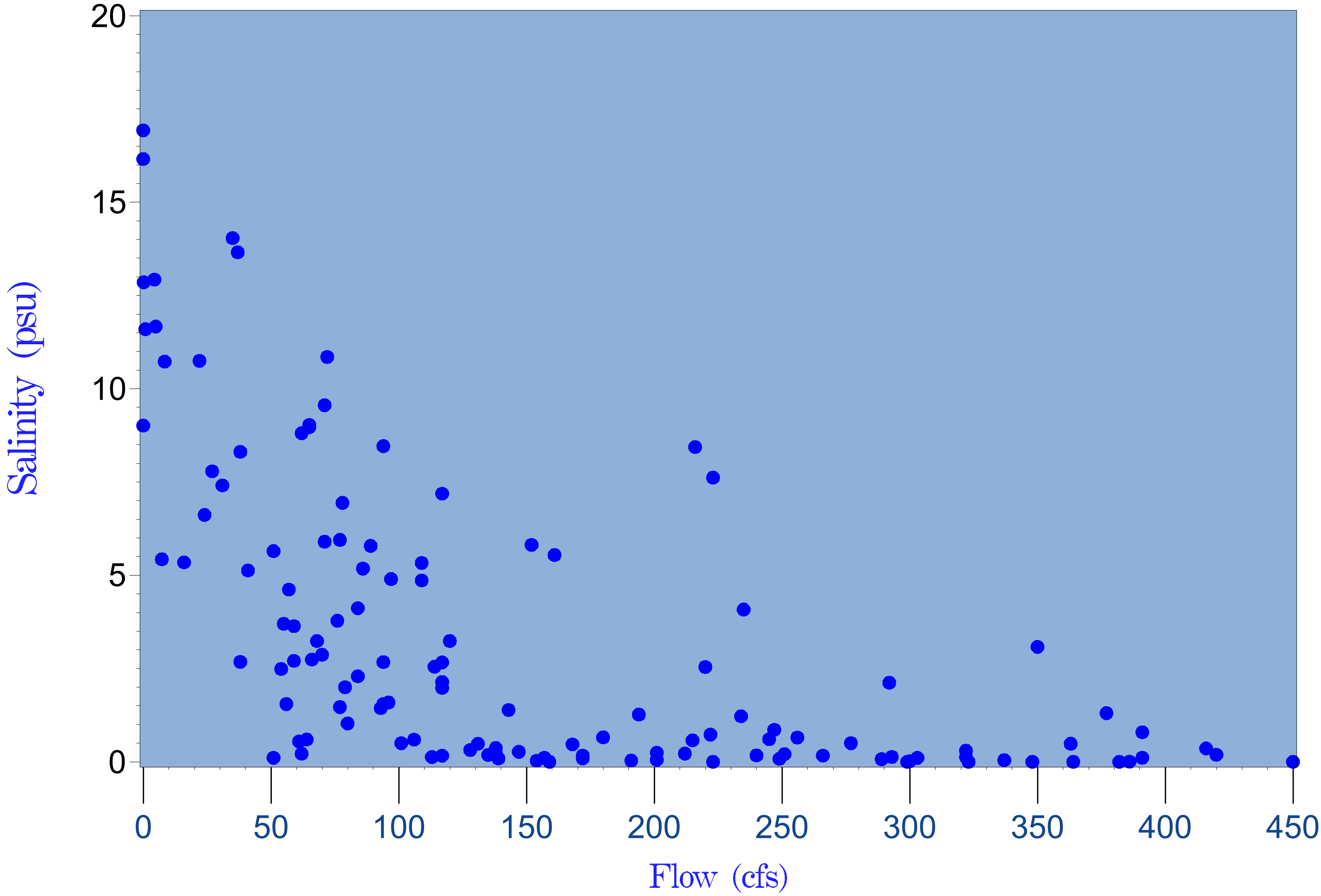


Figure 4.3.7 Surface salinity versus flow at Station #6 (River Kilometer 4.61), 1991-2004

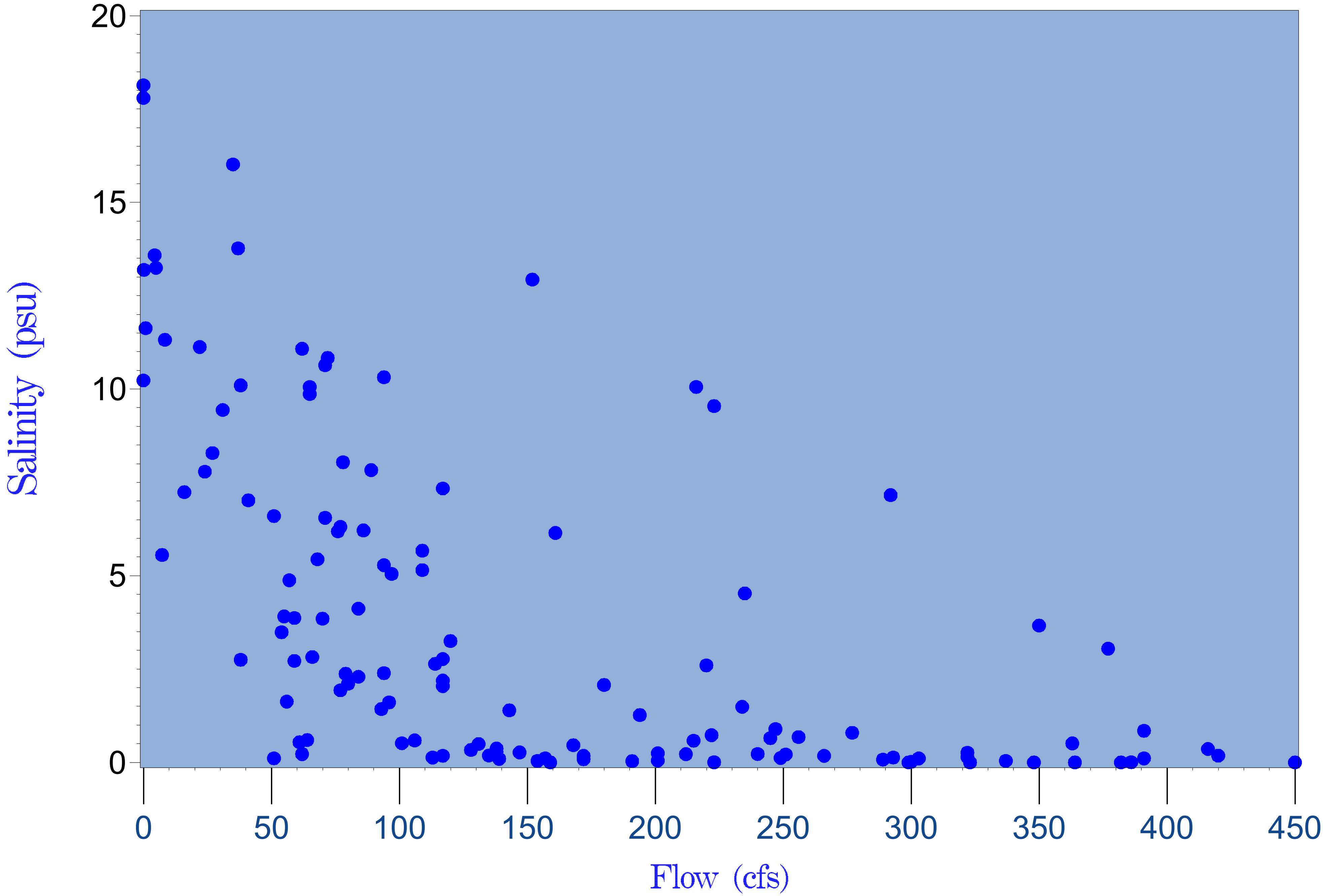


Figure 4.3.8 Bottom salinity versus flow at Station #6 (River Kilometer 4.61), 1991-2004

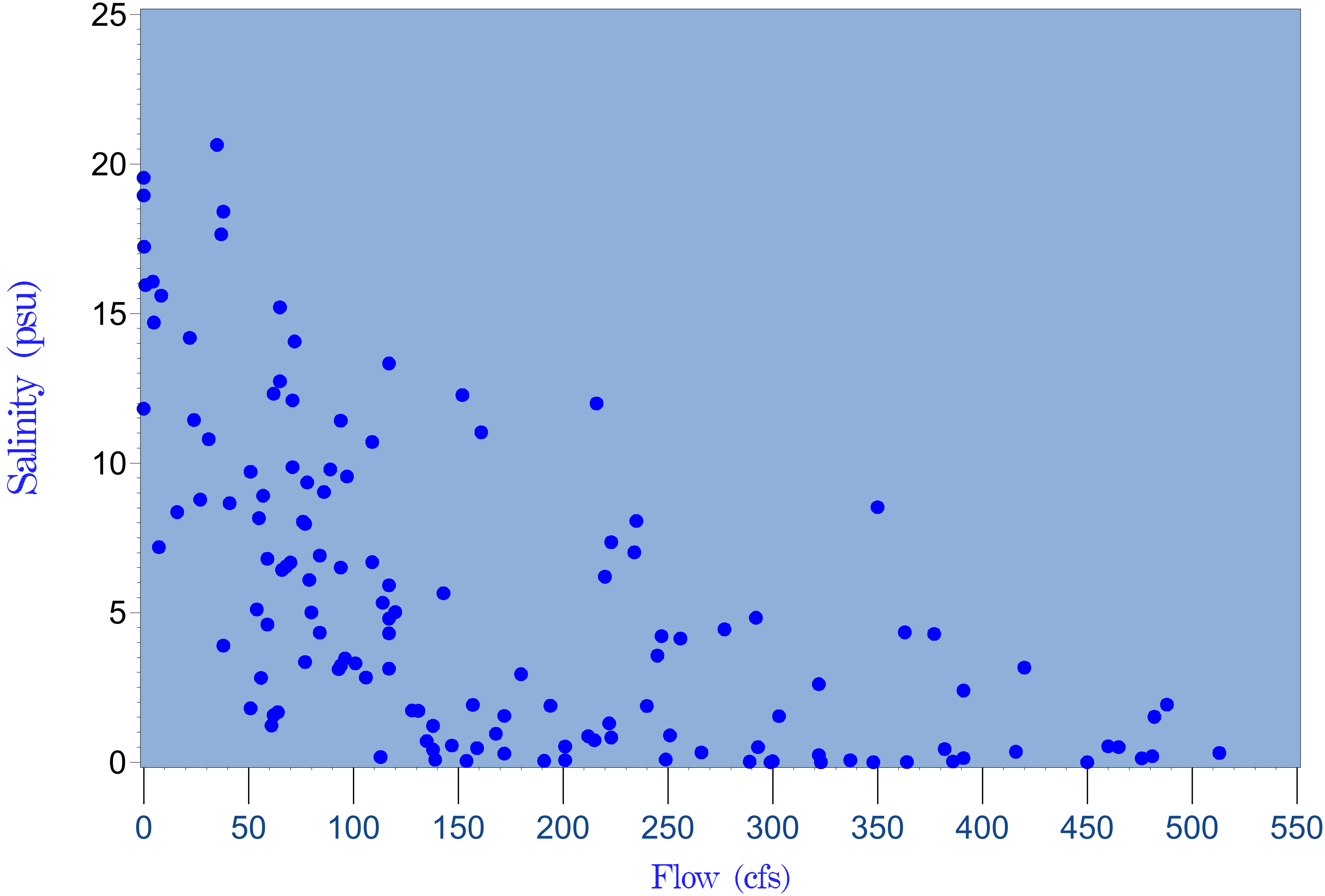


Figure 4.3.9 Surface salinity versus flow at Station #7 (River Kilometer 2.35), 1991-2004

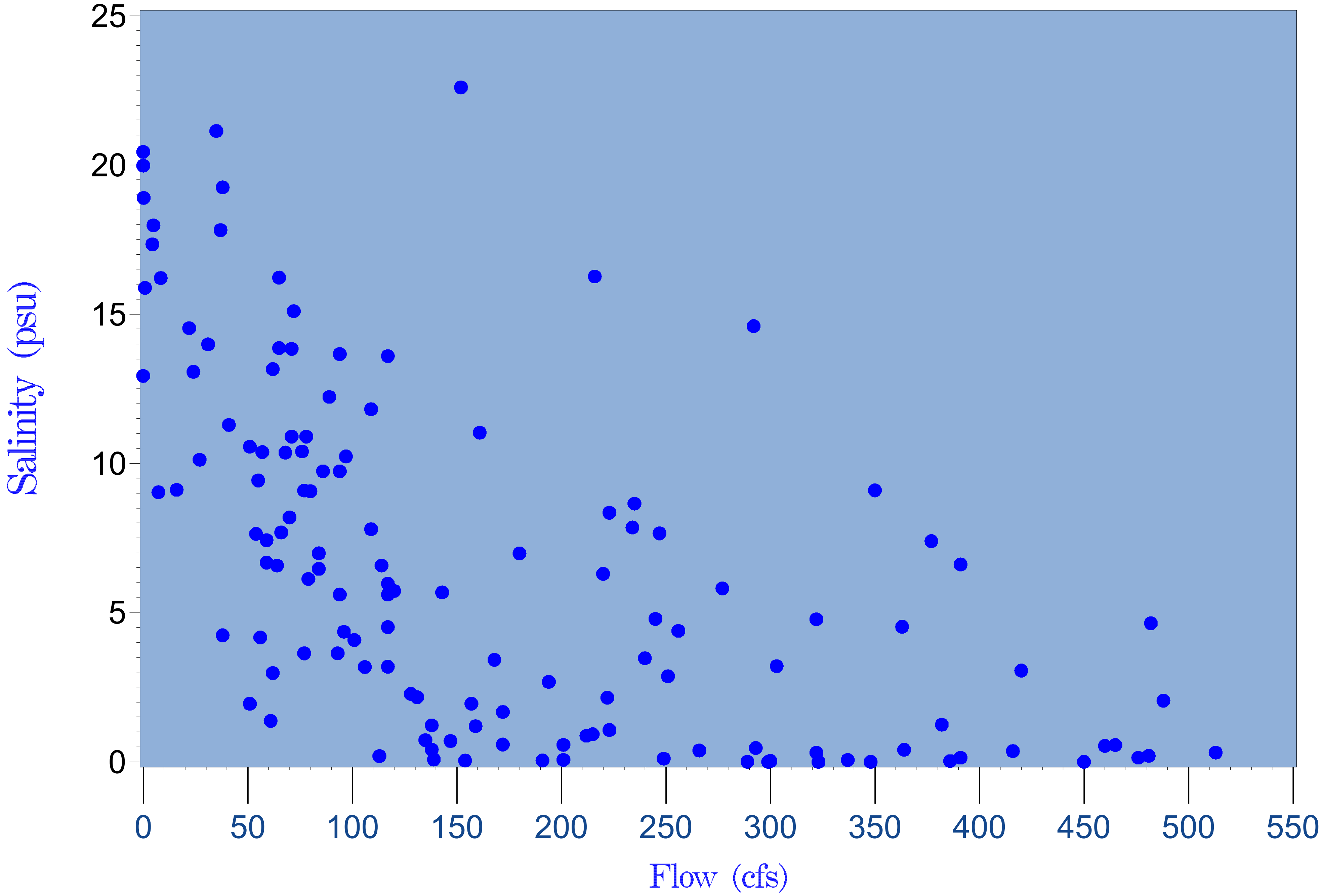


Figure 4.3.10 Bottom salinity versus flow at Station #7 (River Kilometer 2.35), 1991-2004

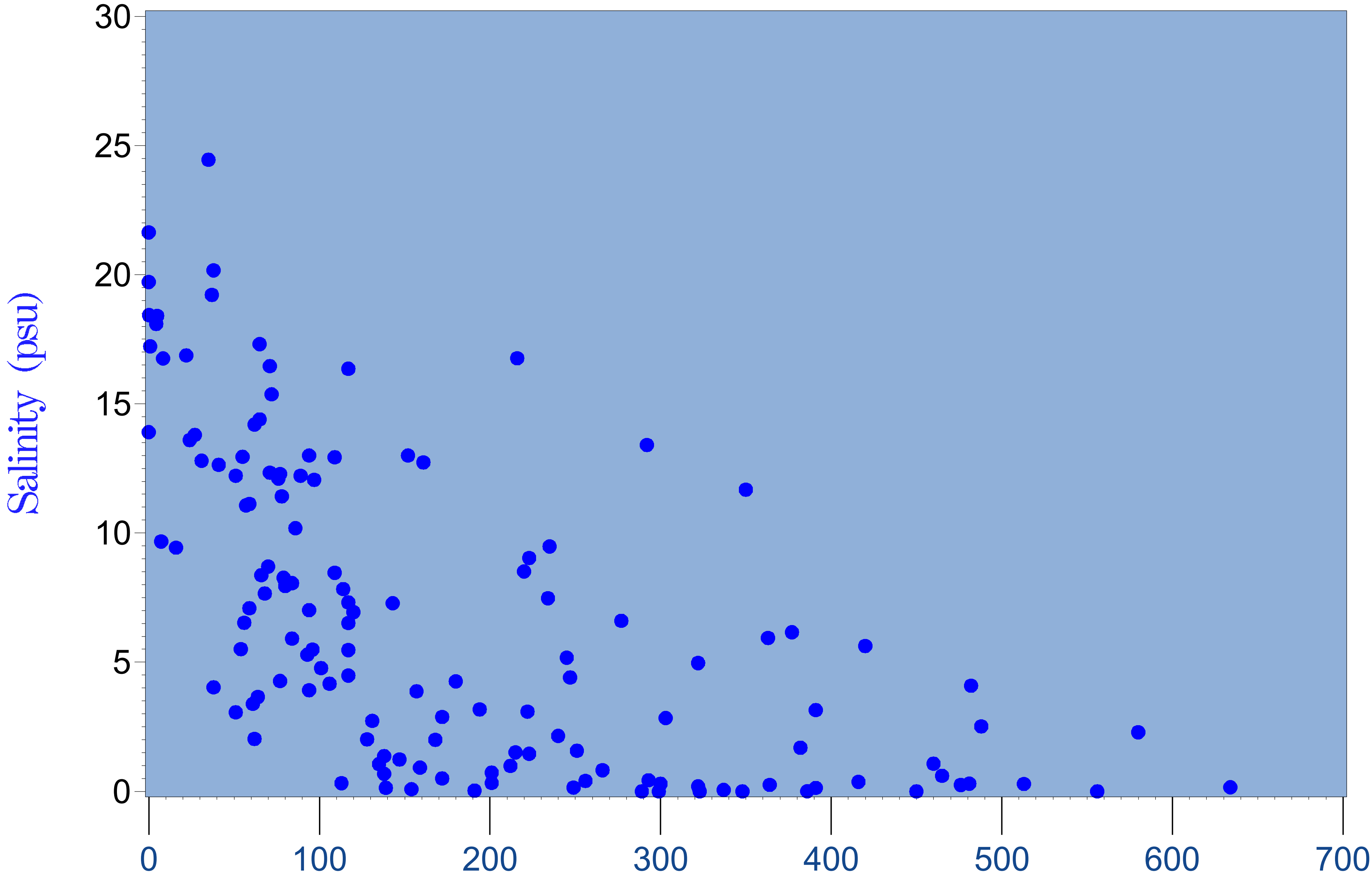


Figure 4.3.11 Surface salinity versus flow at Station #16 (River Kilometer 1.26), 1991-2004

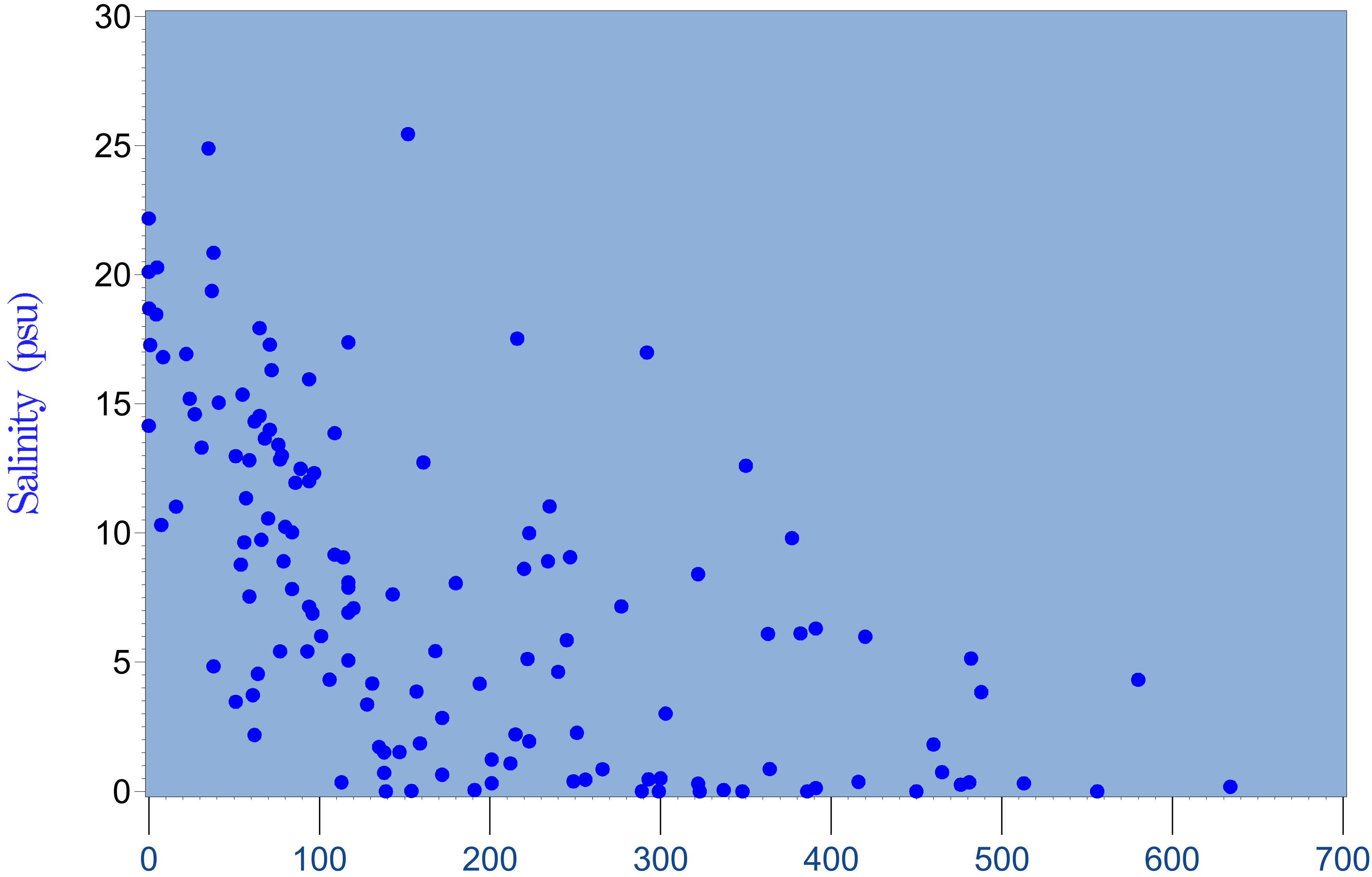


Figure 4.3.12 Bottom salinity versus flow at Station #16 (River Kilometer 1.26), 1991-2004

Shell Creek GAP 2006

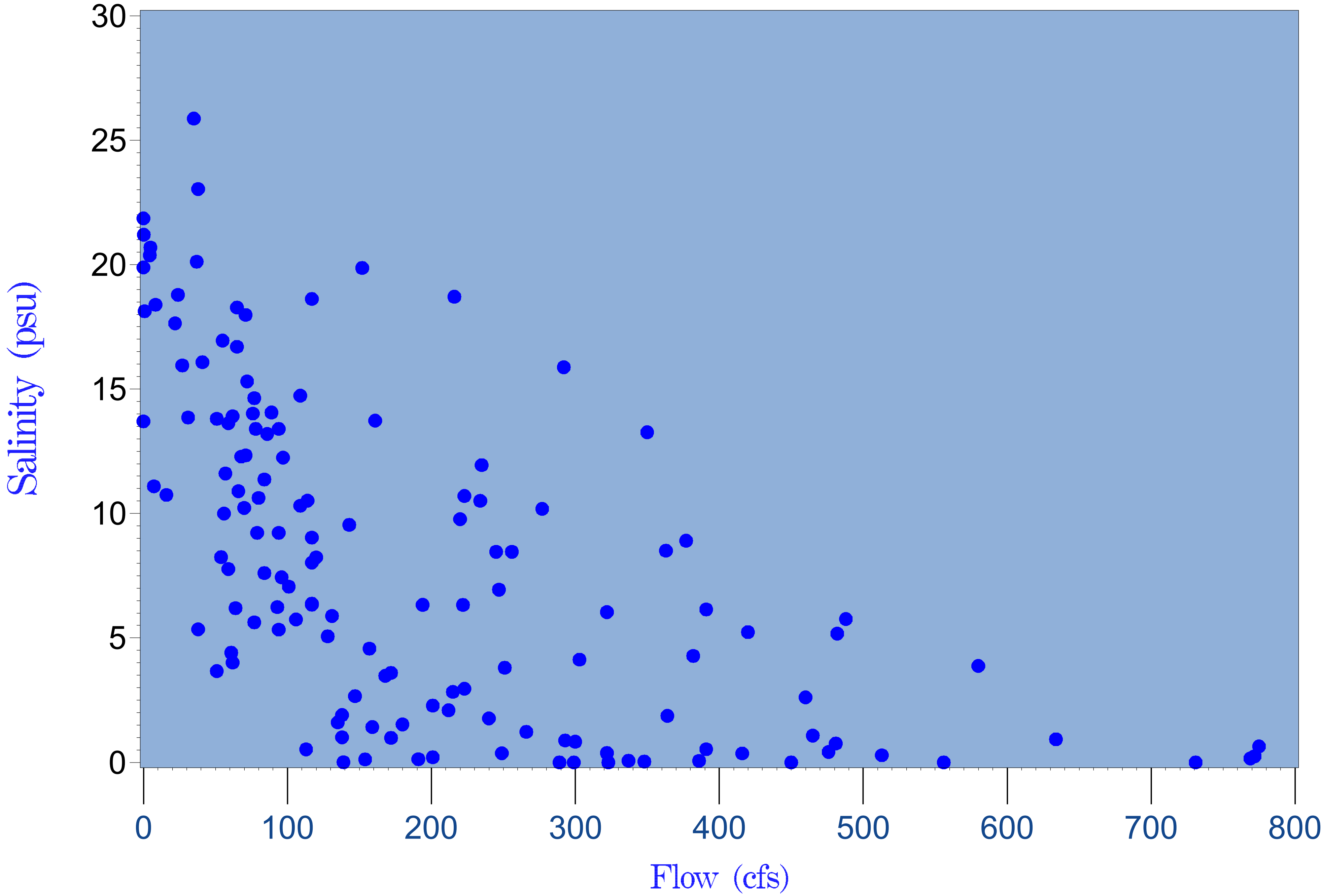


Figure 4.3.13 Surface salinity versus flow at Station #17 (River Kilometer 0.43), 1991-2004

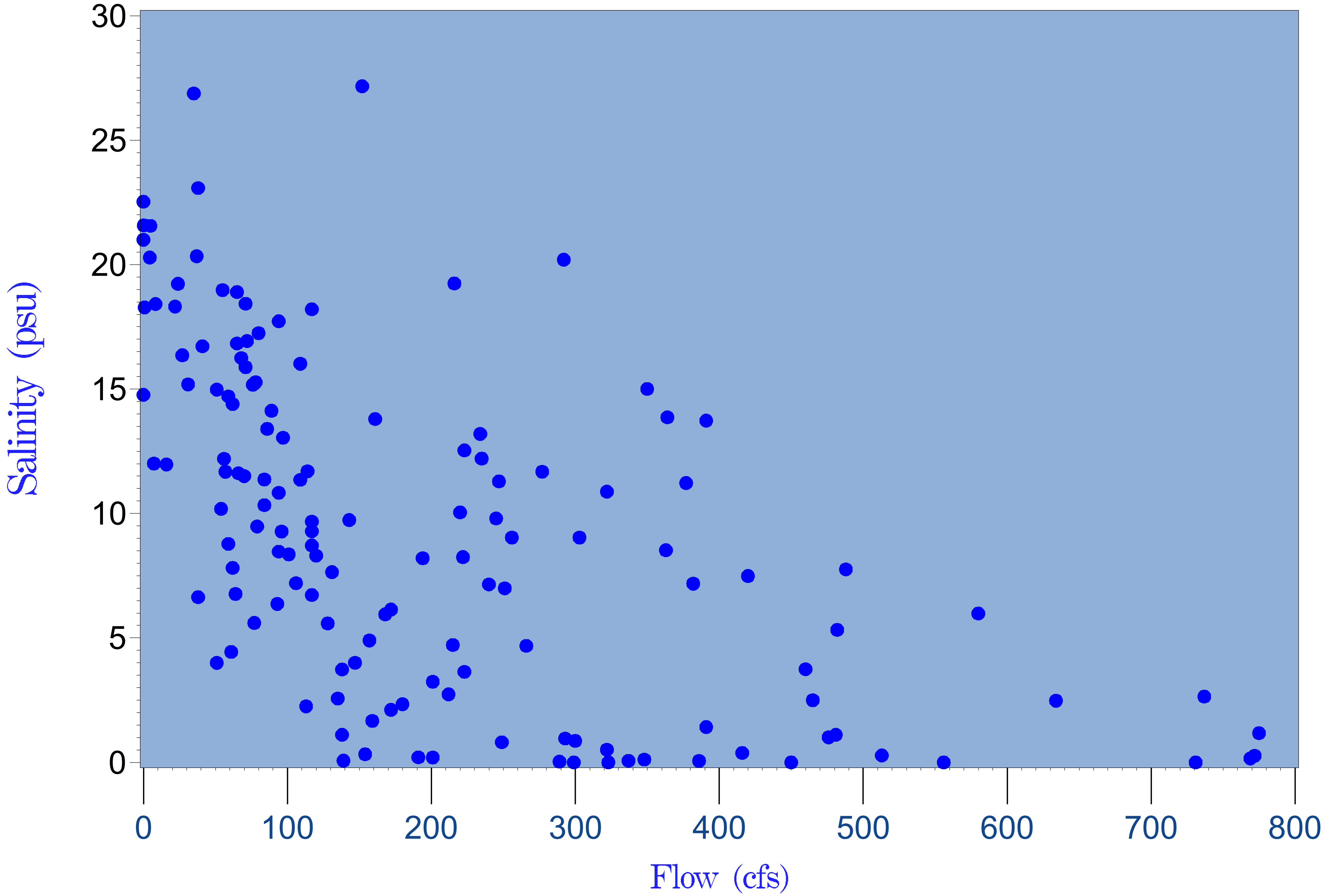


Figure 4.3.14 Bottom salinity versus flow at Station #17 (River Kilometer 0.43), 1991-2004

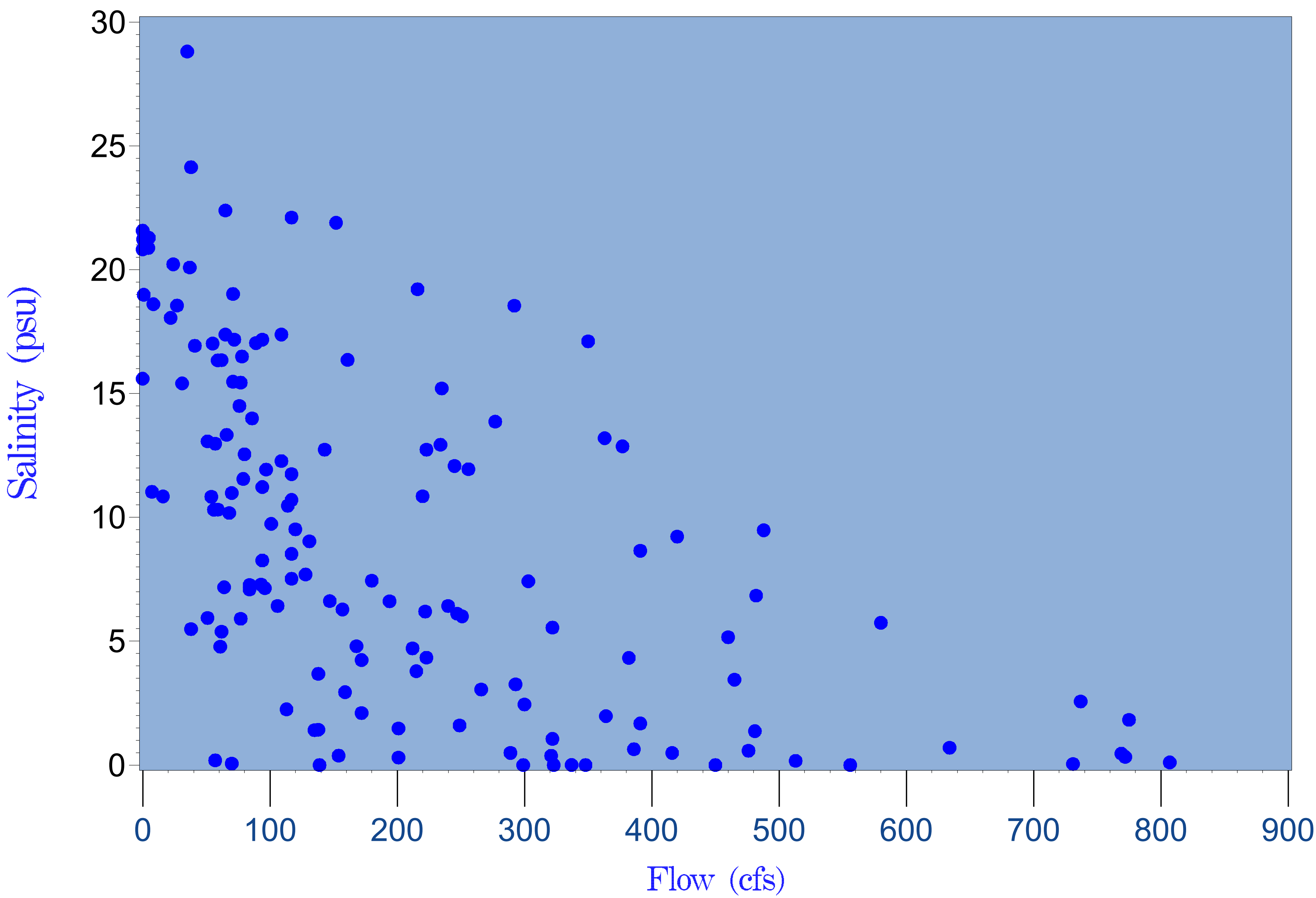


Figure 4.3.15 Surface salinity versus flow at Station #9 (River Kilometer -0.37), 1991-2004

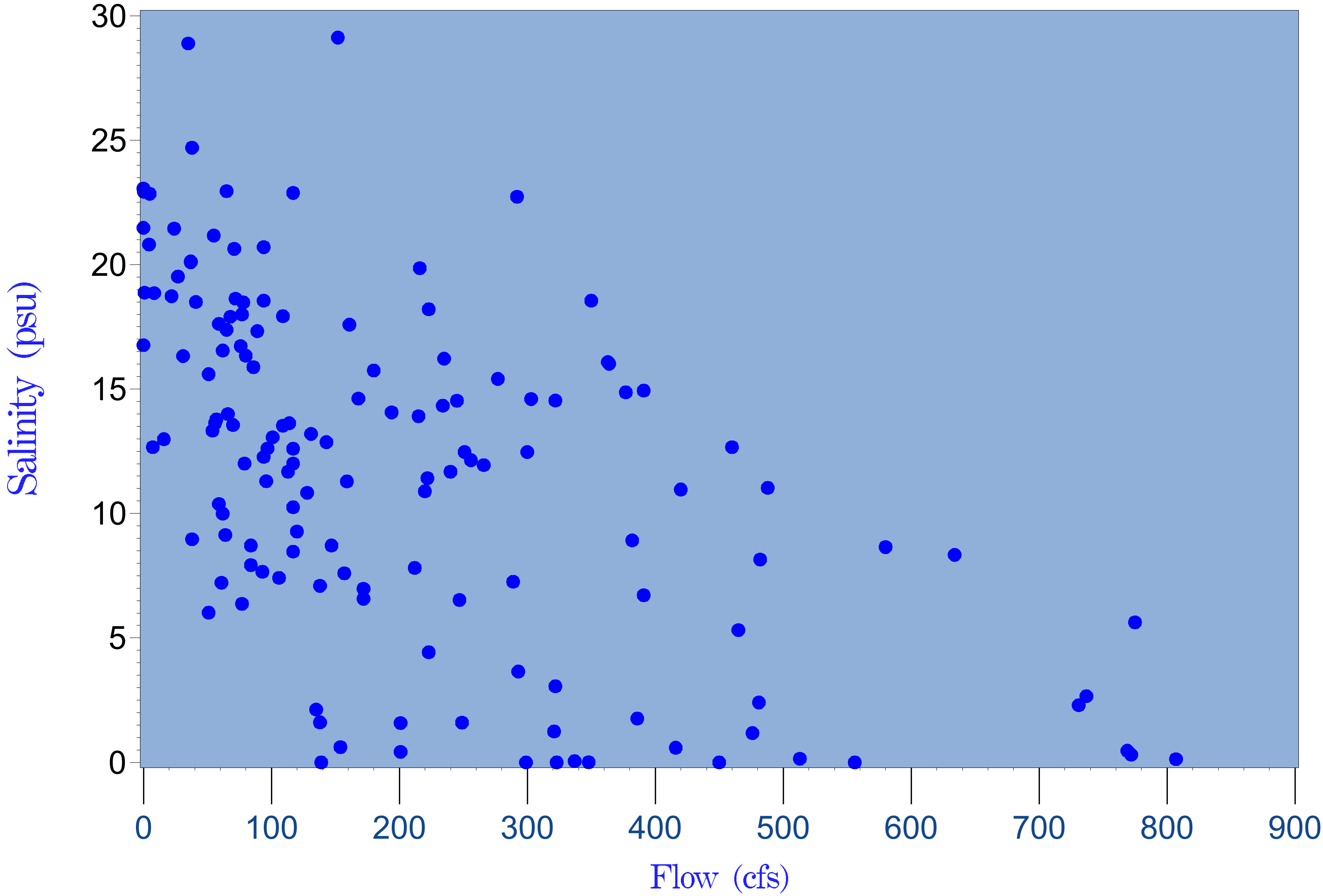


Figure 4.3.16 Bottom salinity versus flow at Station #9 (River Kilometer -0.37), 1991-2004

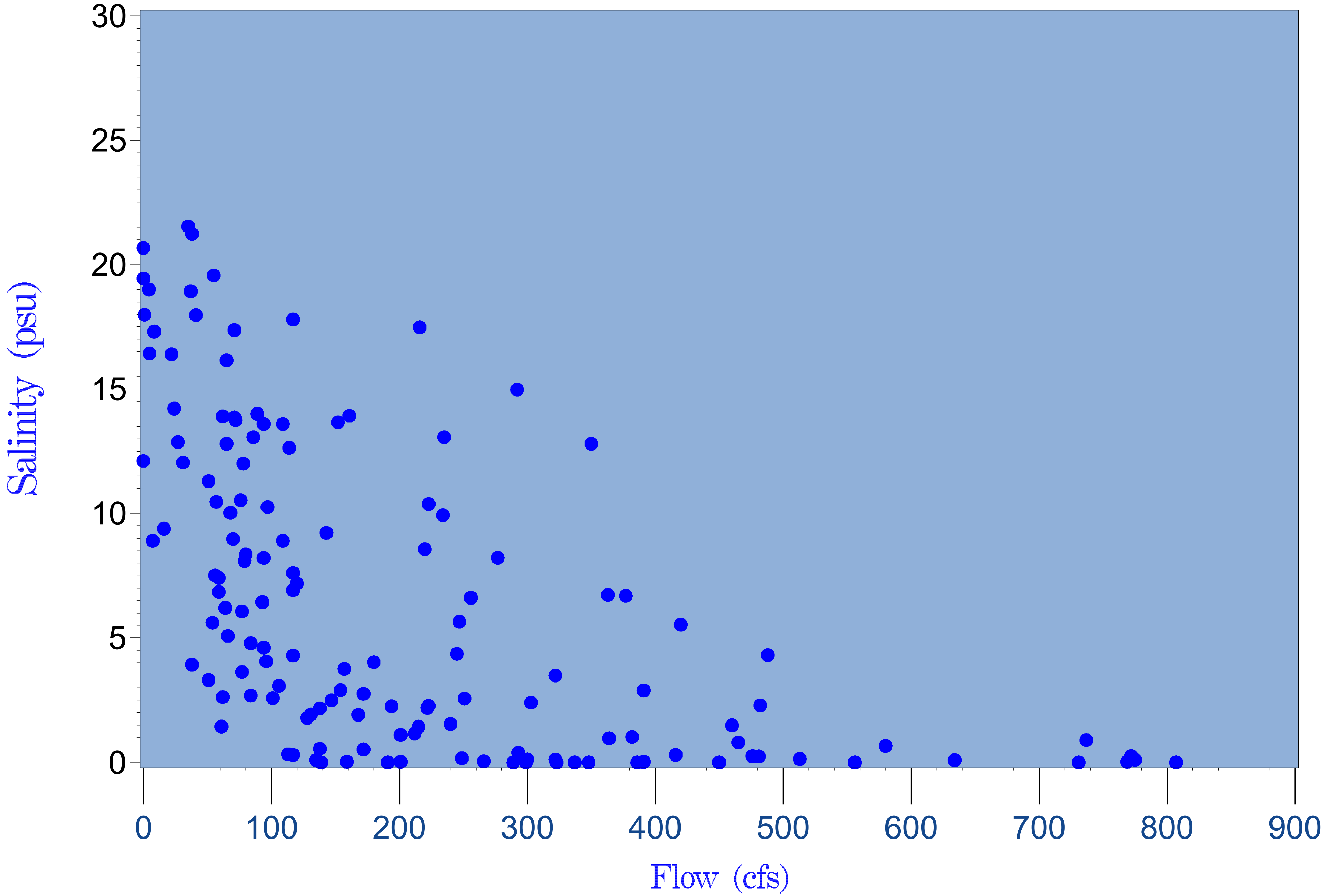


Figure 4.3.17 Surface salinity versus flow at Station #8 (Lower Peace River), 1991-2004

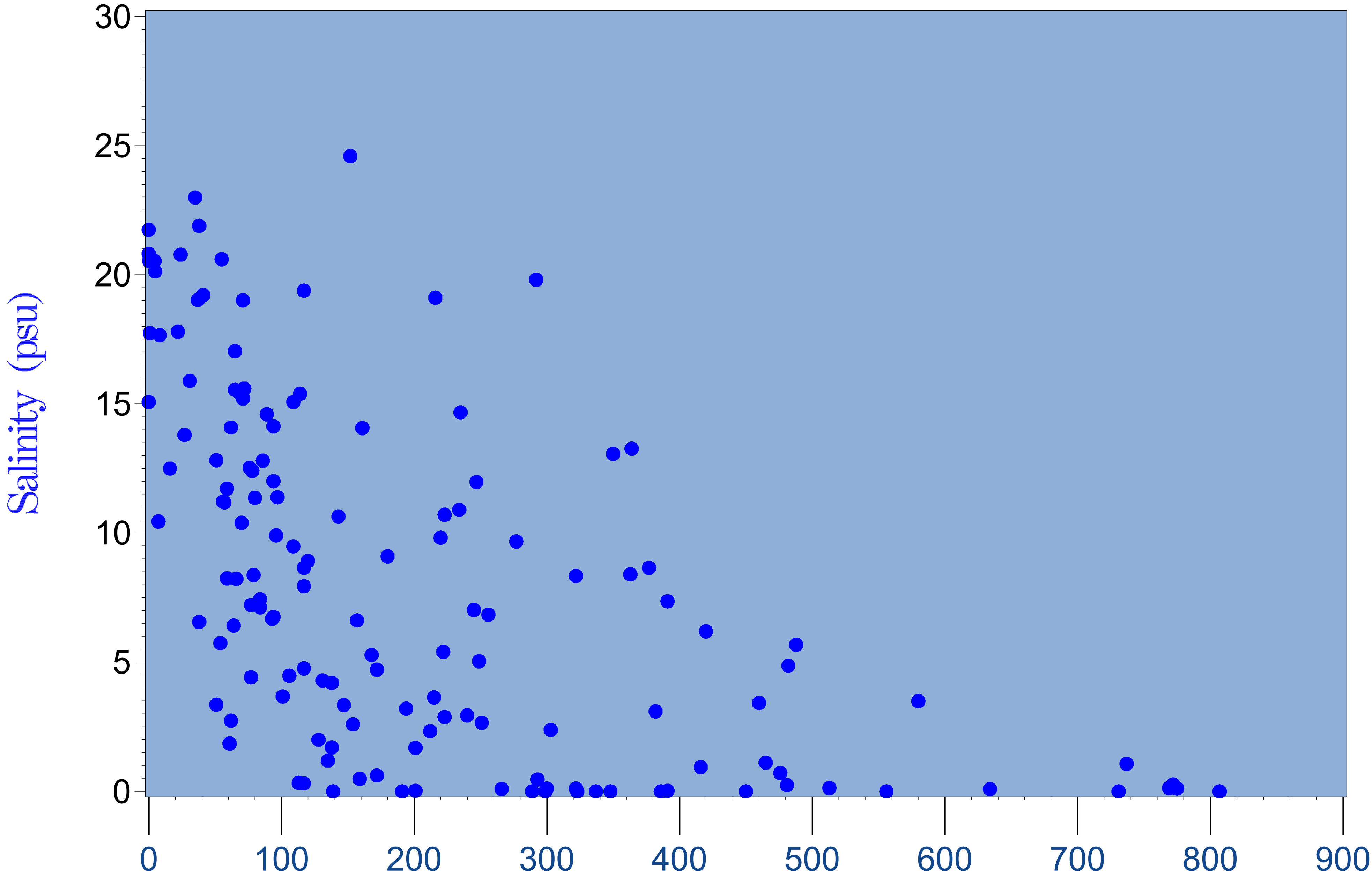


Figure 4.3.18 Bottom salinity versus flow at Station #8 (Lower Peace River), 1991-2004

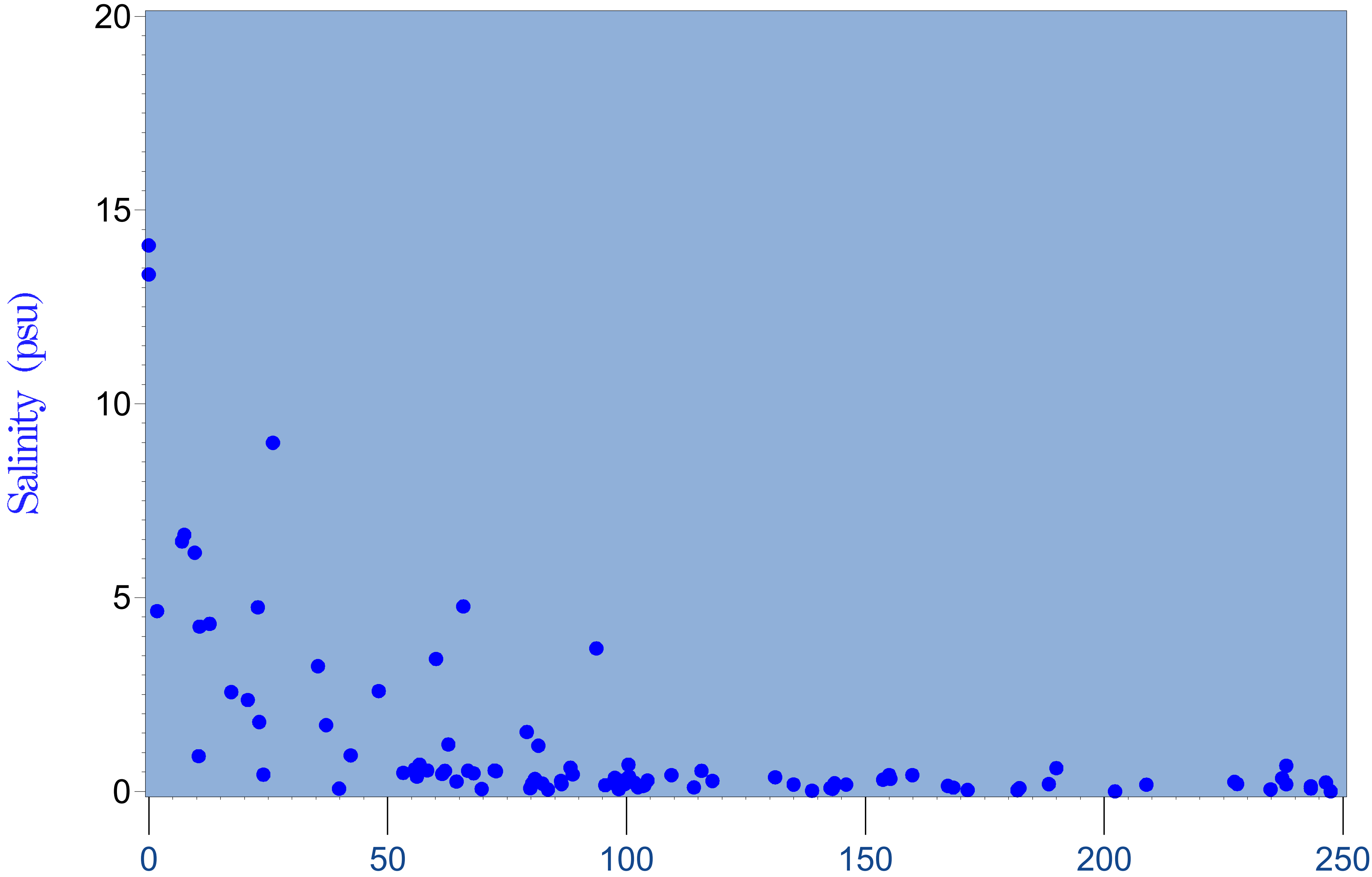


Figure 4.3.19 Surface salinity versus 7-day average flow at Station #11 (River Kilometer 9.90), 1991-2004

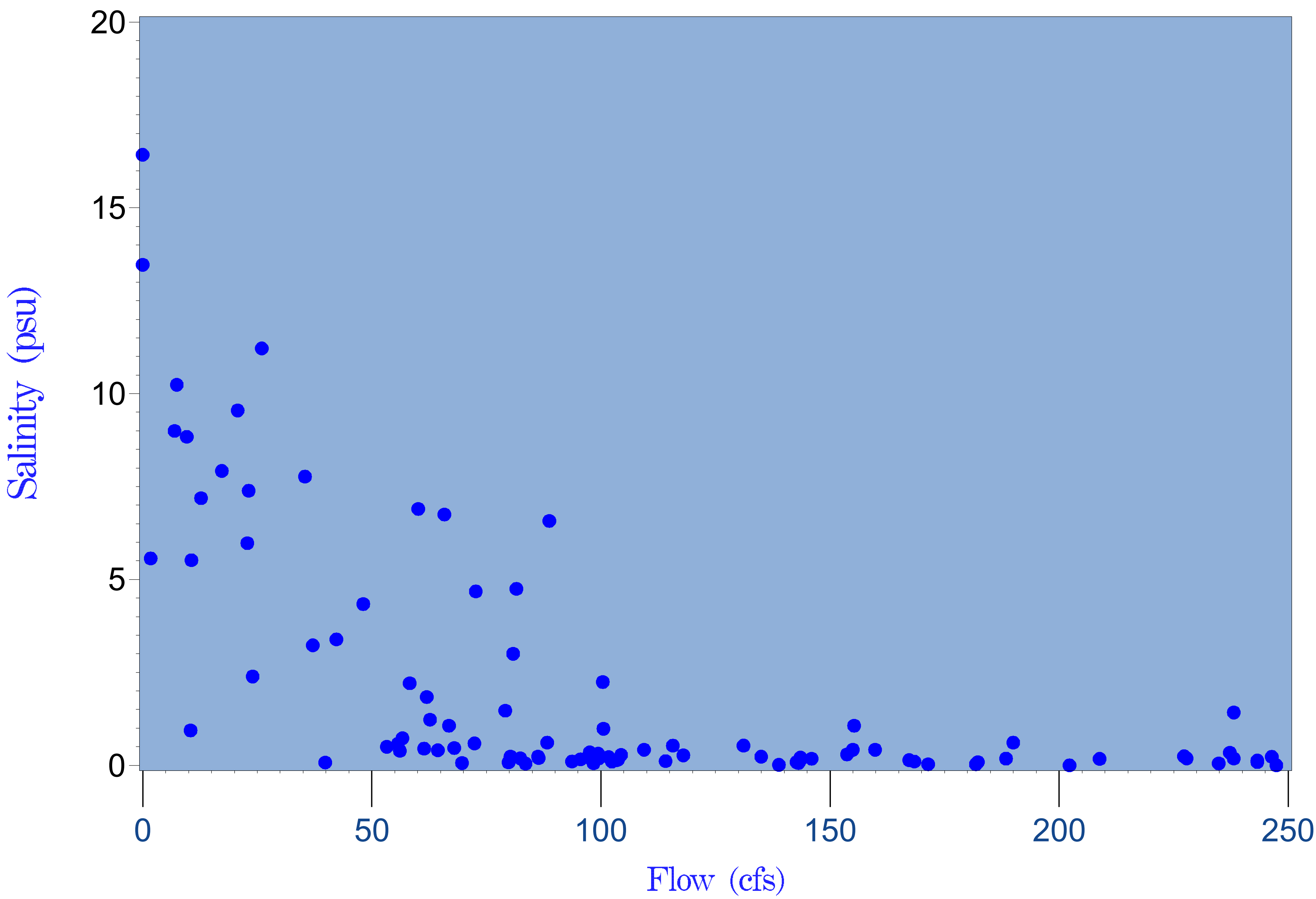


Figure 4.3.20 Bottom salinity versus 7-day average flow at Station #11 (River Kilometer 9.90), 1991-2004

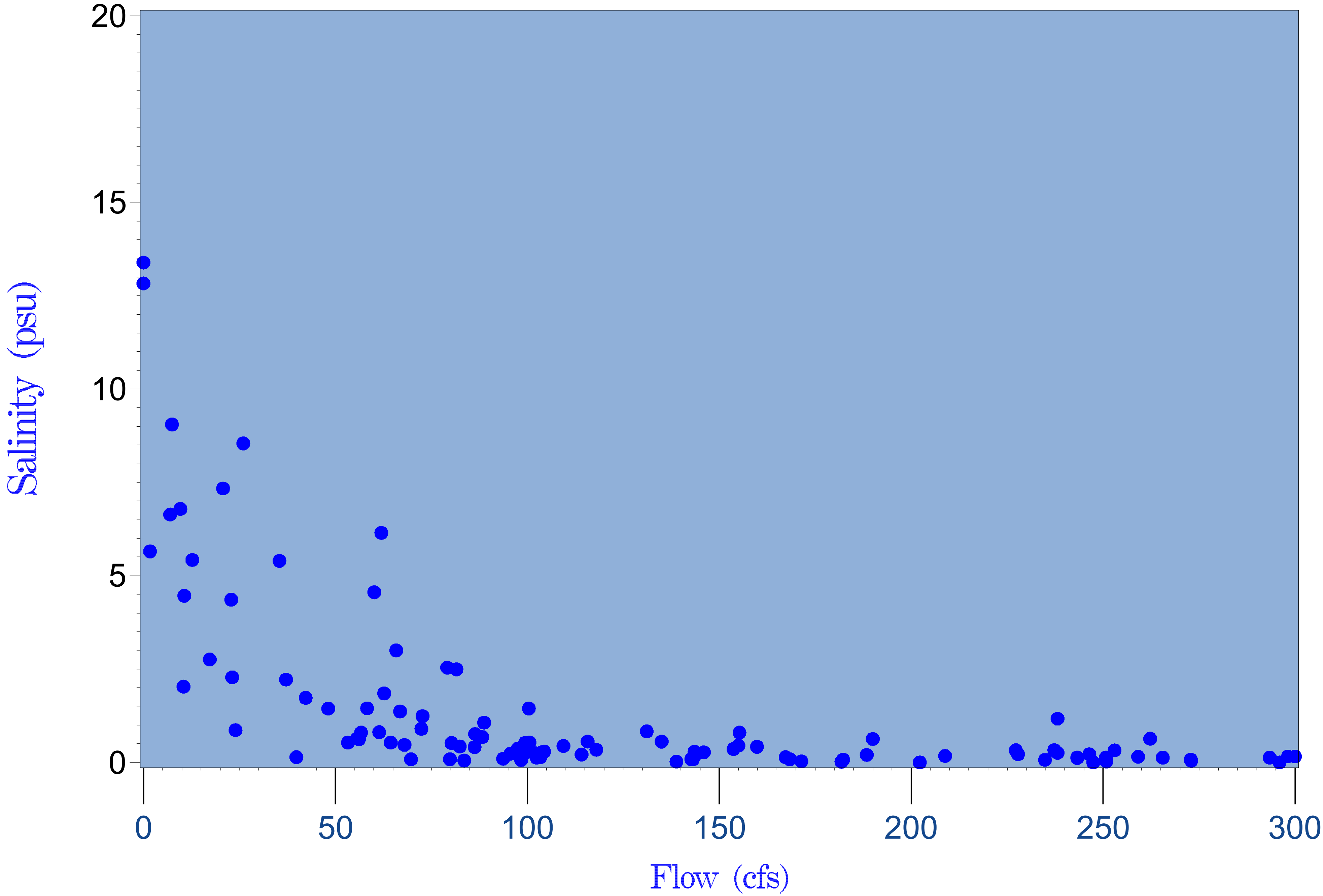


Figure 4.3.21 Surface salinity versus 7-day average flow at Station #4 (River Kilometer 8.74), 1991-2004

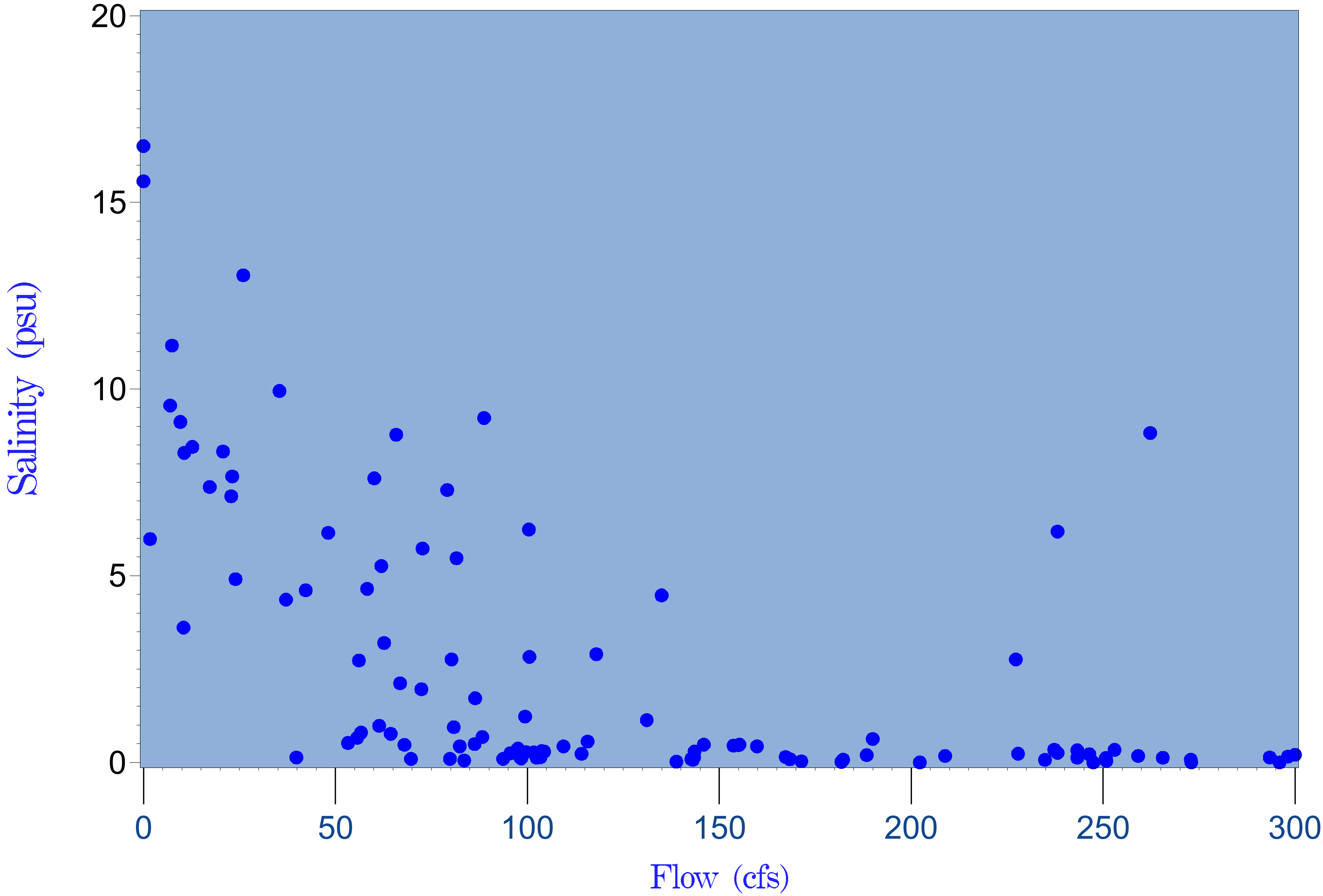


Figure 4.3.22 Bottom salinity versus 7-day average flow at Station #4 (River Kilometer 8.74), 1991-2004

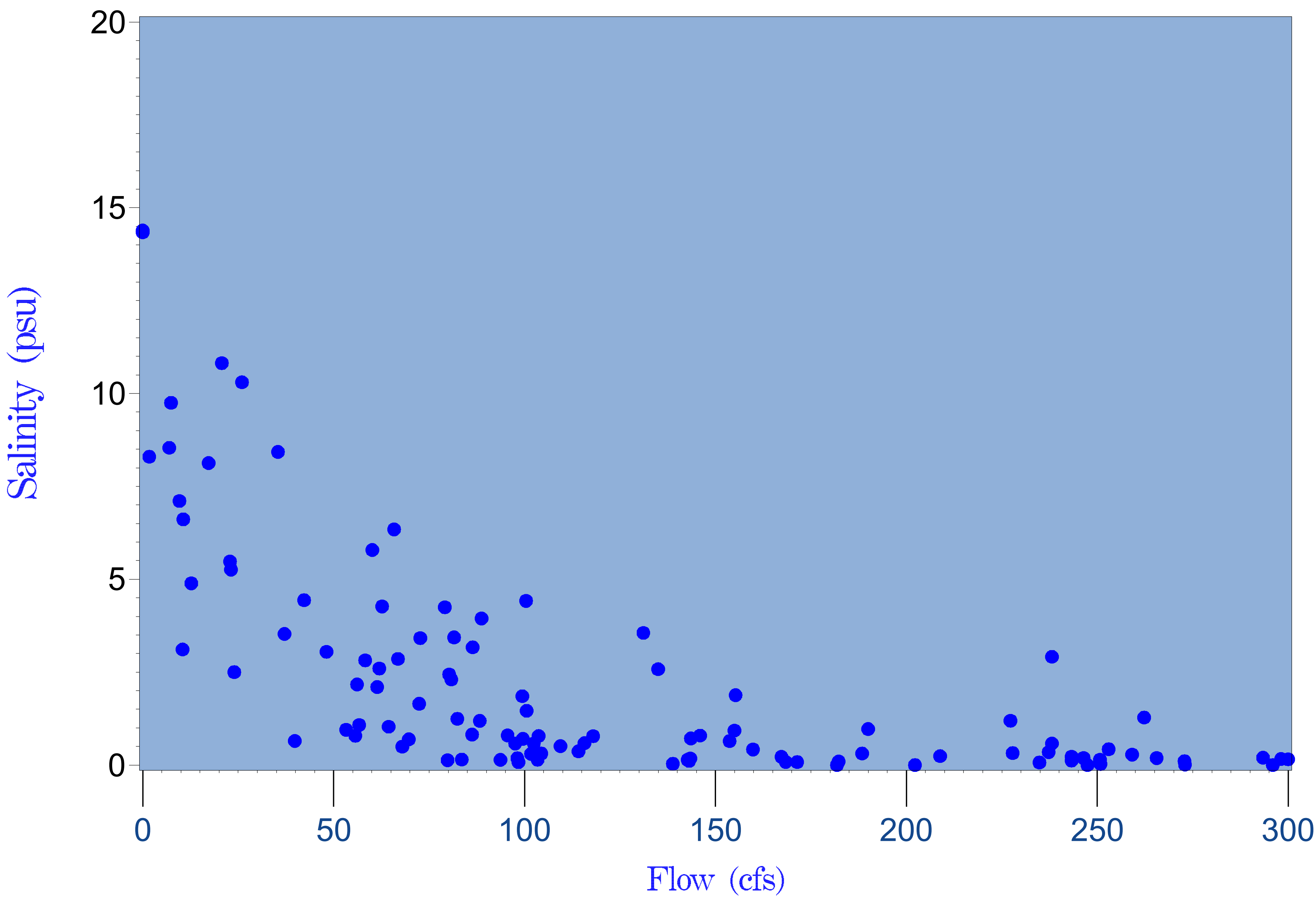


Figure 4.3.23 Surface salinity versus 7-day average flow at Station #5 (River Kilometer 6.72), 1991-2004

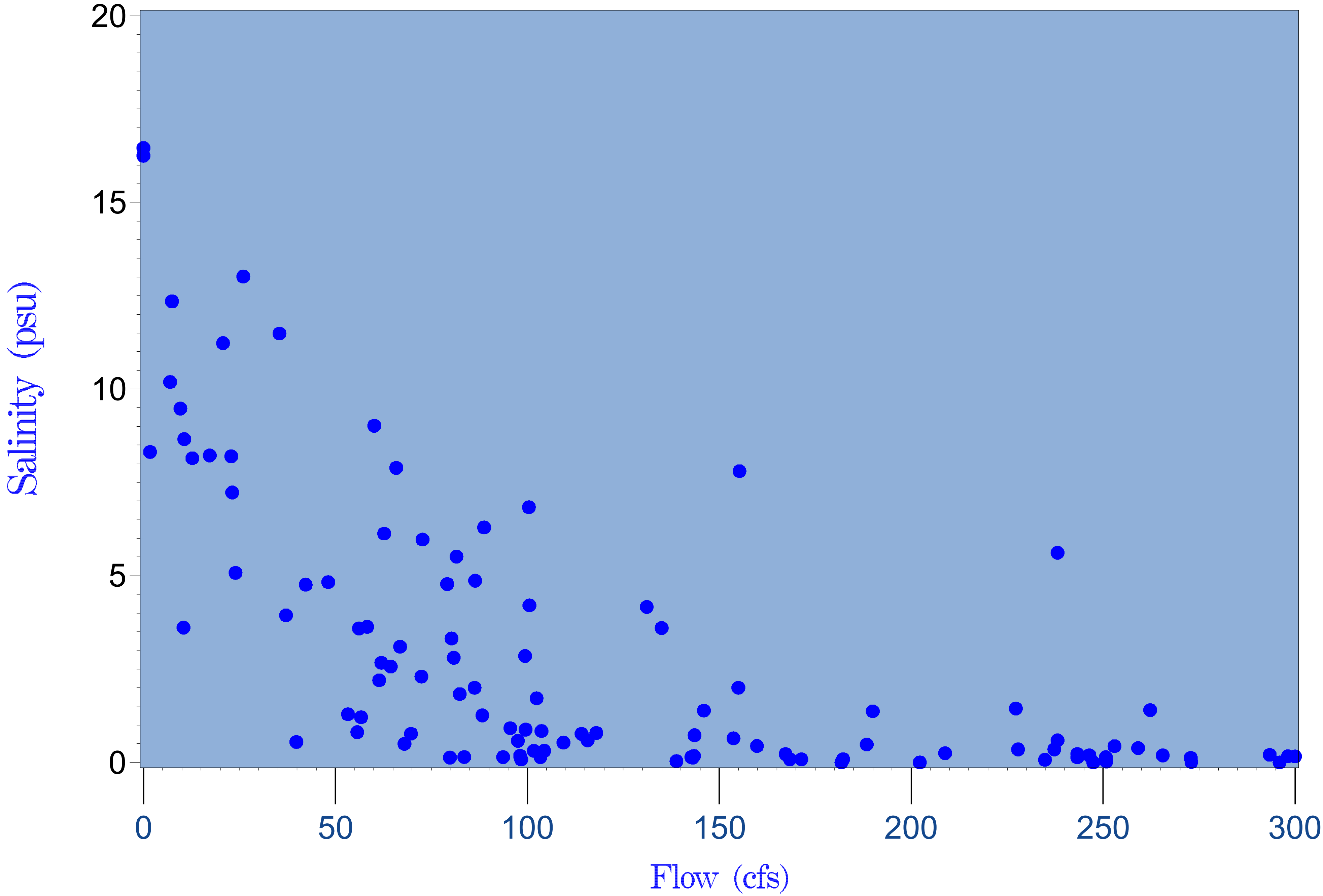


Figure 4.3.24 Bottom salinity versus 7-day average flow at Station #5 (River Kilometer 6.72), 1991-2004

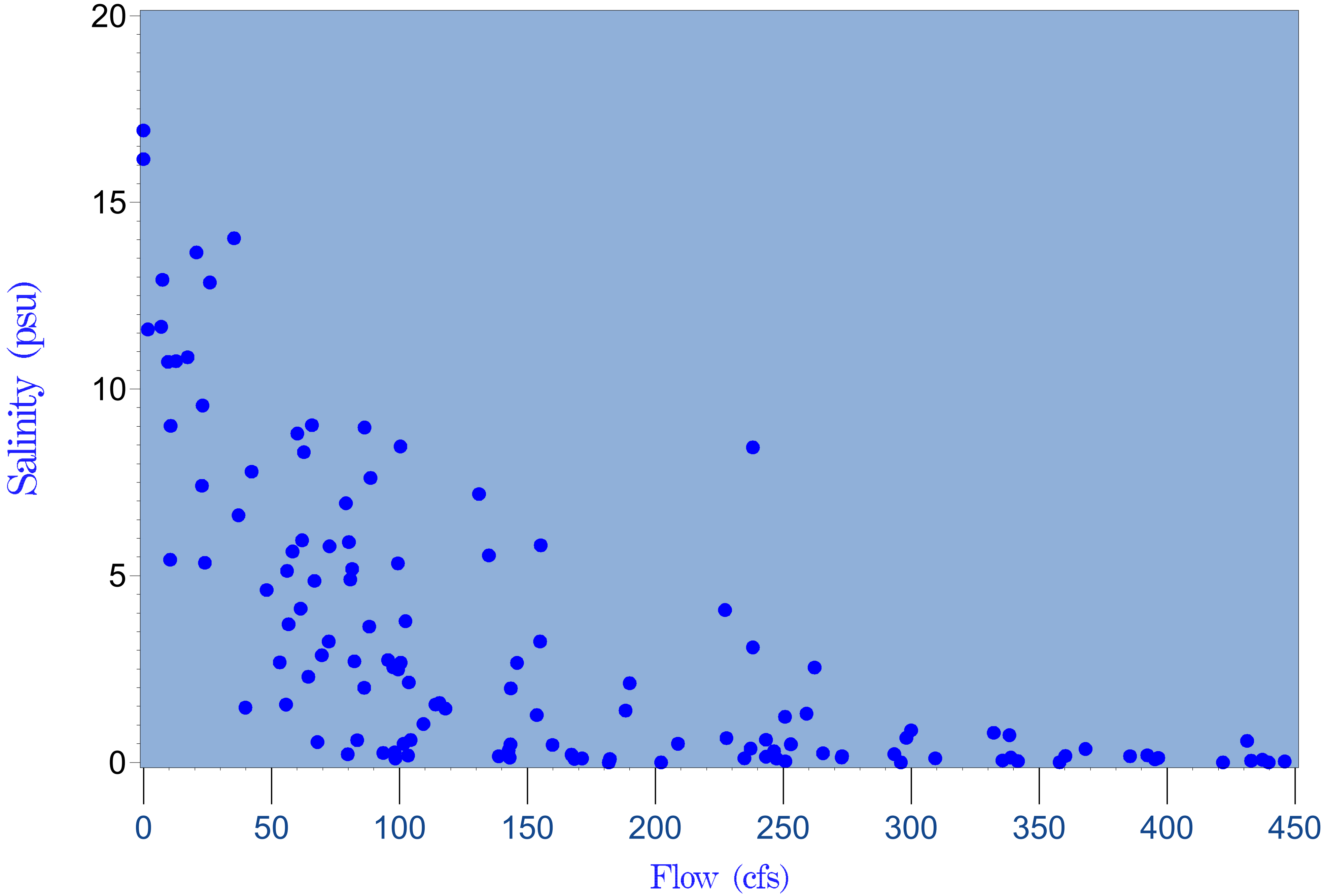


Figure 4.3.25 Surface salinity versus 7-day average flow at Station #6 (River Kilometer 4.61), 1991-2004

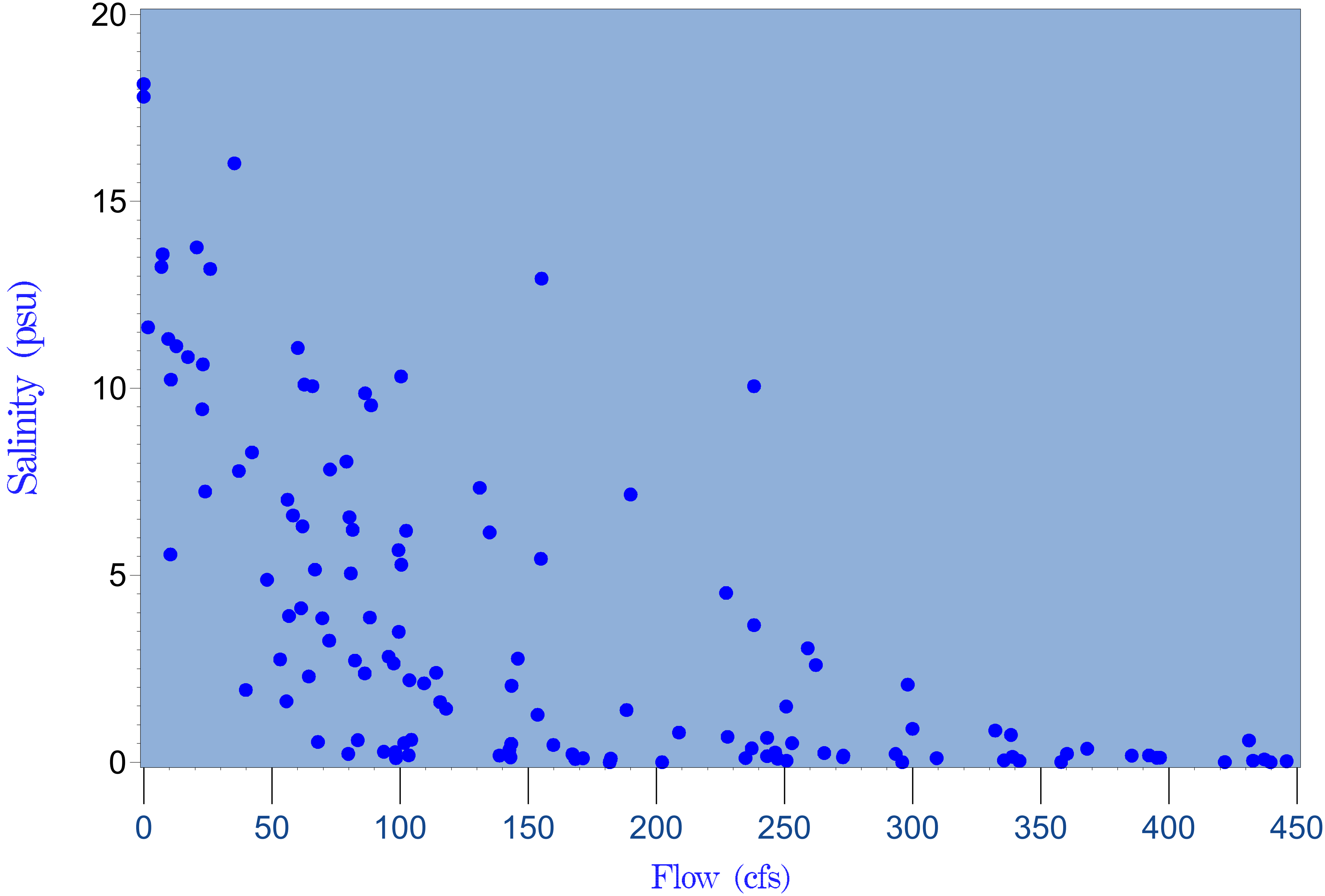


Figure 4.3.26 Bottom salinity versus 7-day average flow at Station #6 (River Kilometer 4.61), 1991-2004

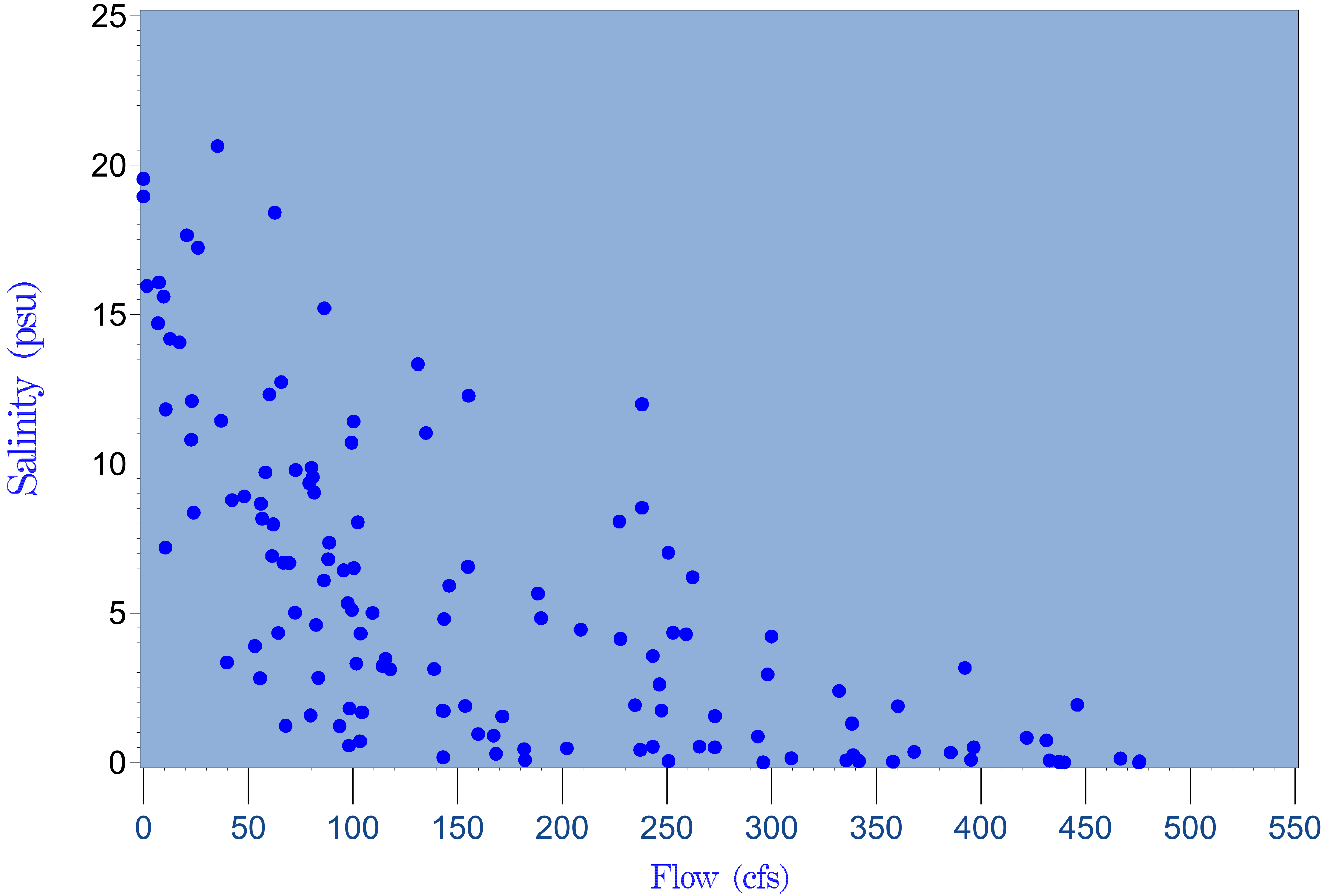


Figure 4.3.27 Surface salinity versus 7-day average flow at Station #7 (River Kilometer 2.35), 1991-2004

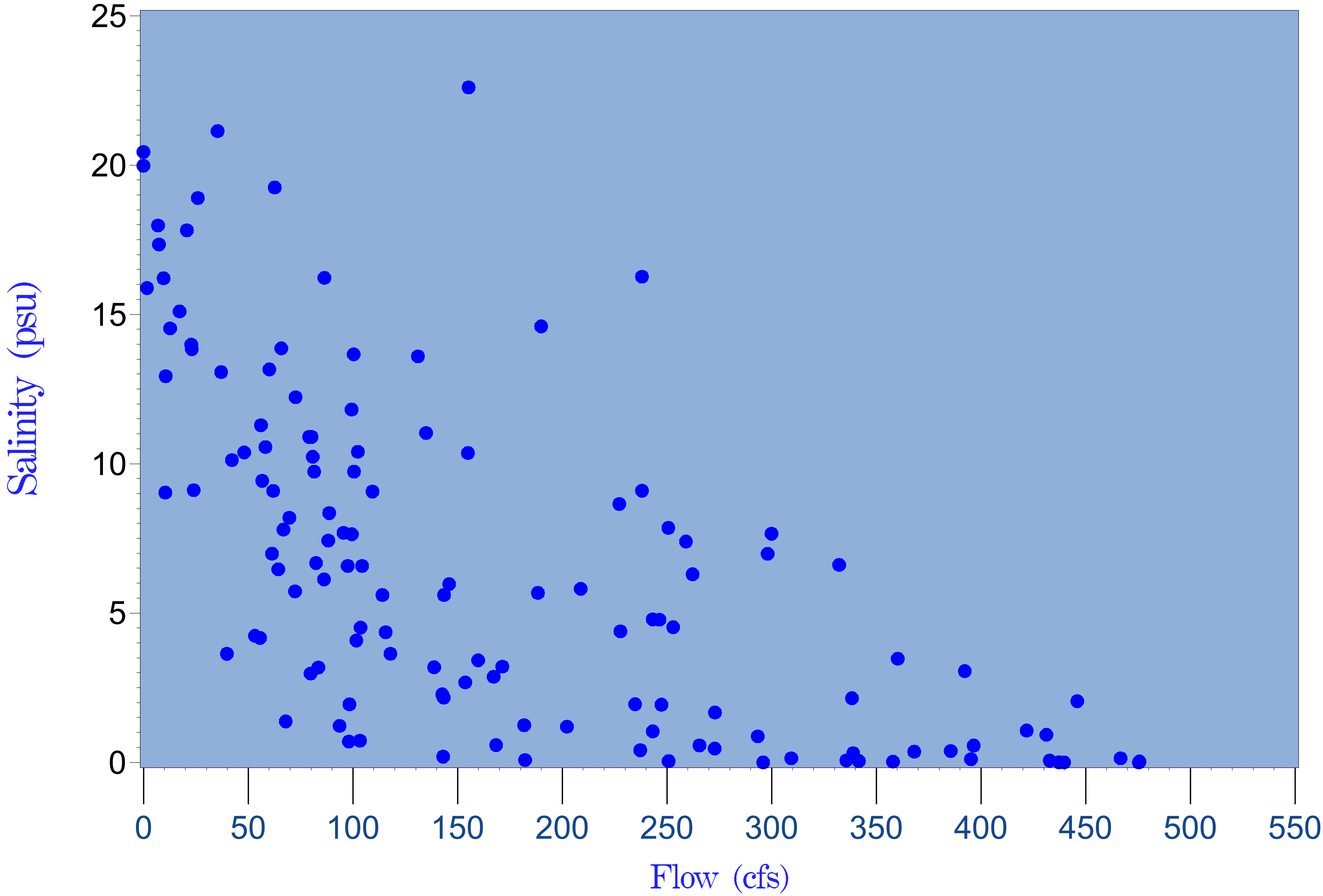


Figure 4.3.28 Bottom salinity versus 7-day average flow at Station #7 (River Kilometer 2.35), 1991-2004

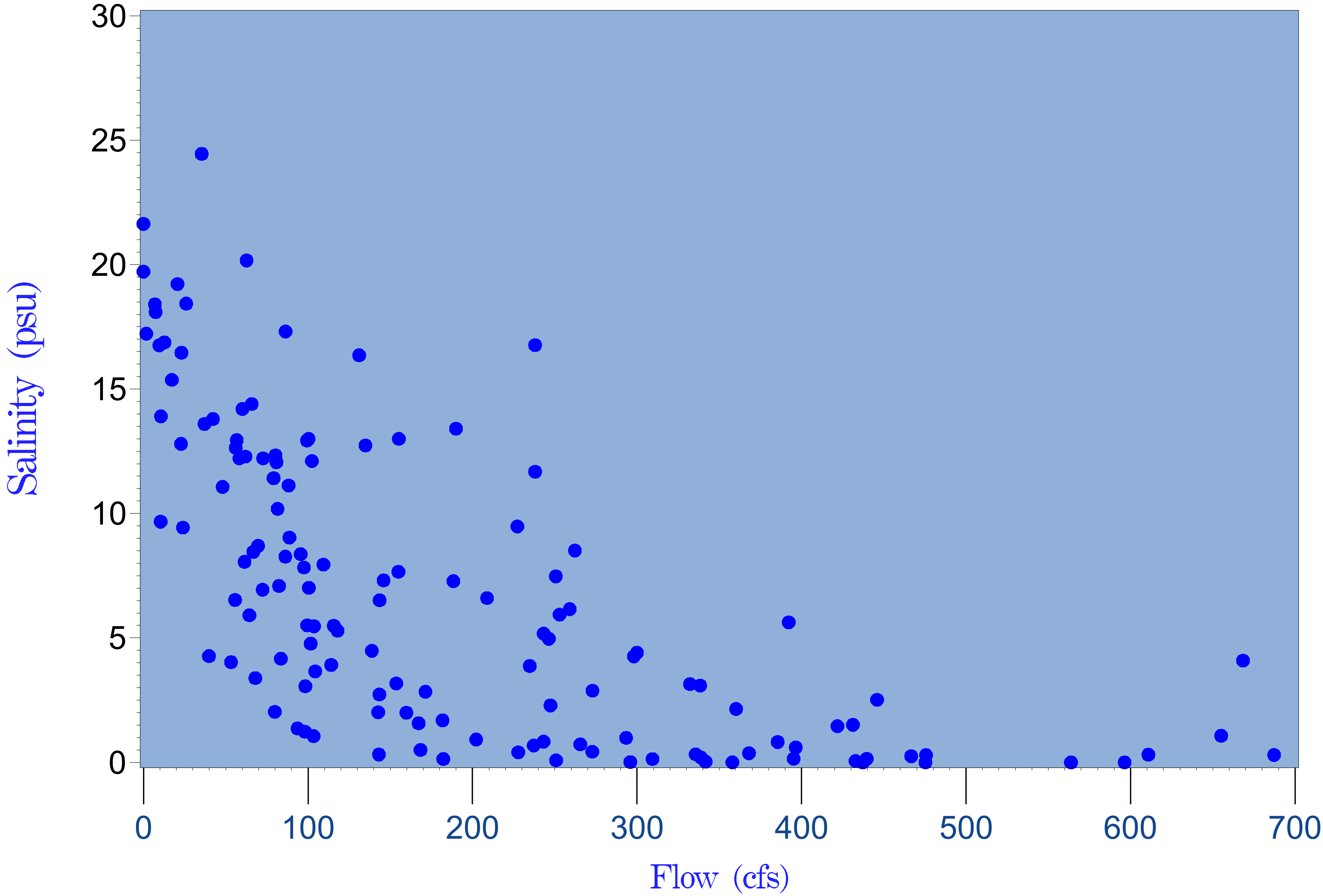


Figure 4.3.29 Surface salinity versus 7-day average flow at Station #16 (River Kilometer 1.26), 1991-2004

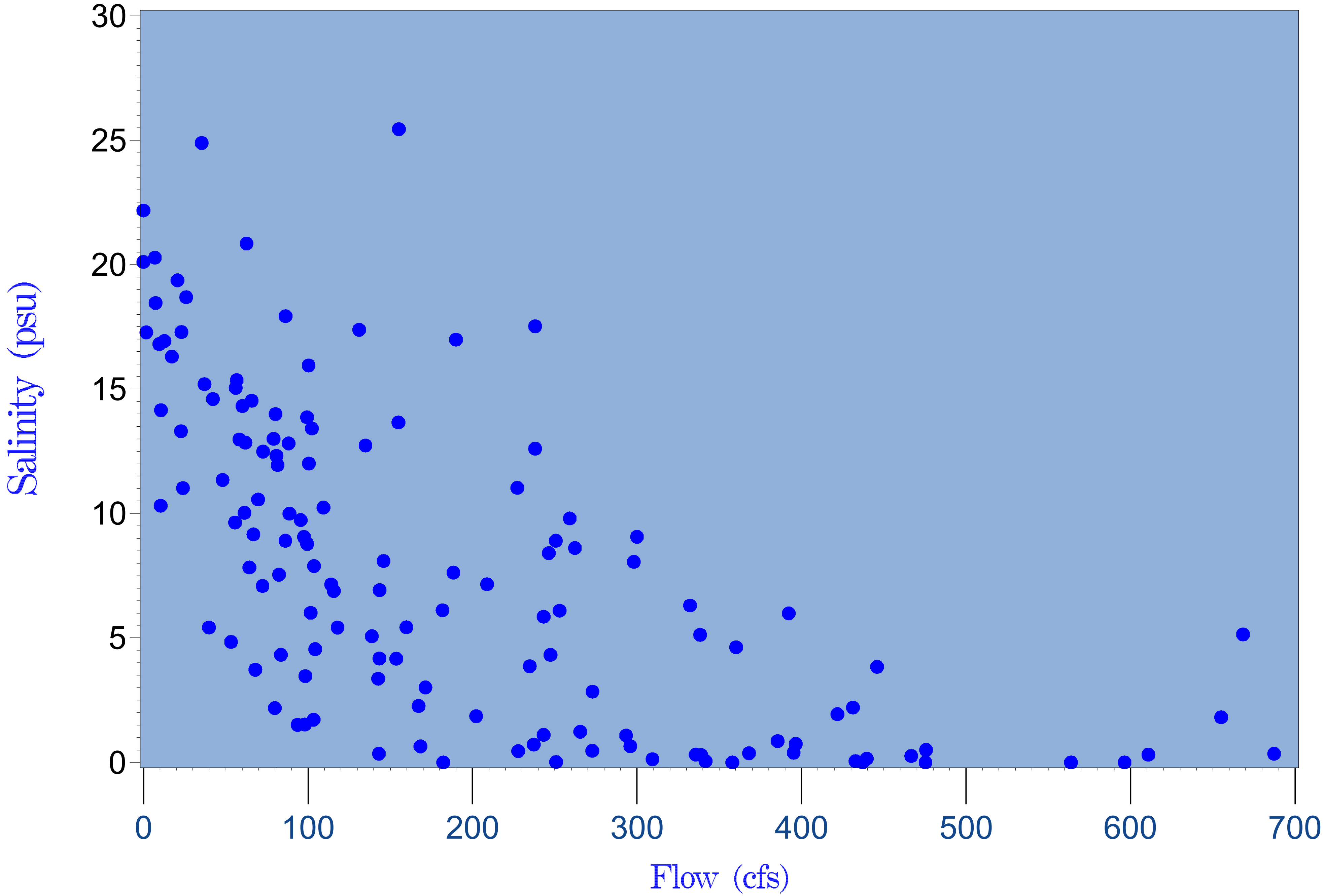


Figure 4.3.30 Bottom salinity versus 7-day average flow at Station #16 (River Kilometer 1.26), 1991-2004

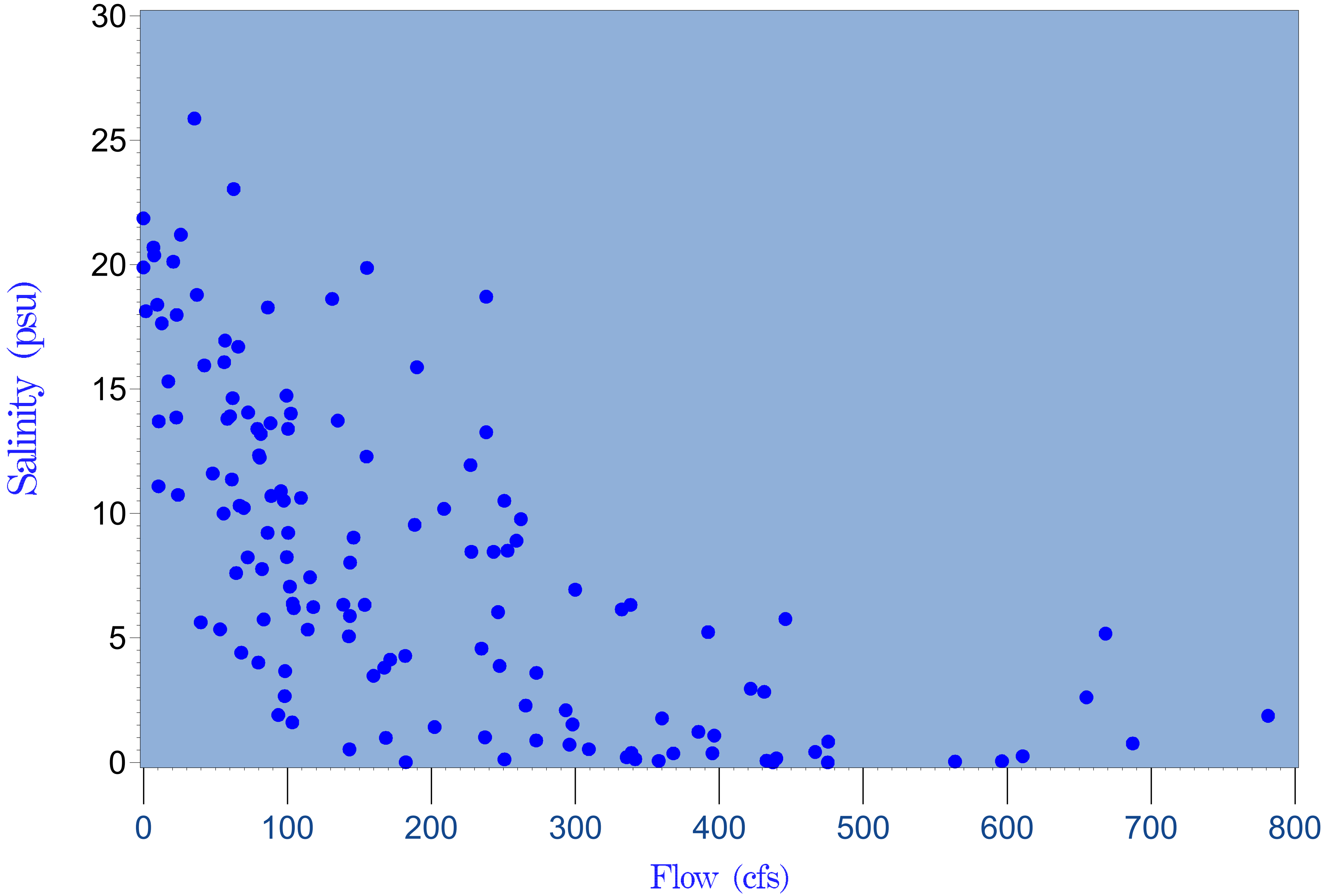


Figure 4.3.31 Surface salinity versus 7-day average flow at Station #17 (River Kilometer 0.43), 1991-2004

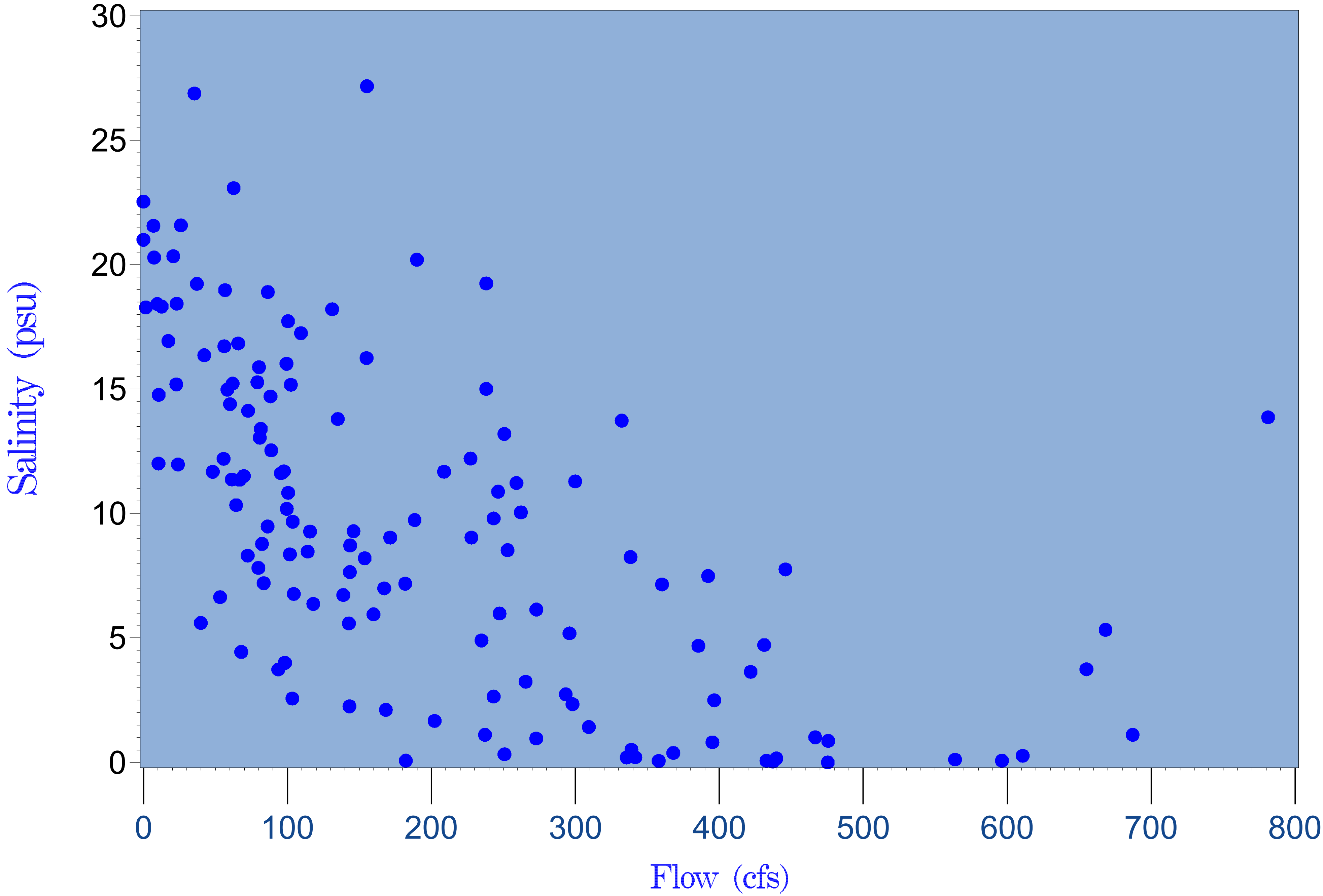


Figure 4.3.32 Bottom salinity versus 7-day average flow at Station #17 (River Kilometer 0.43), 1991-2004

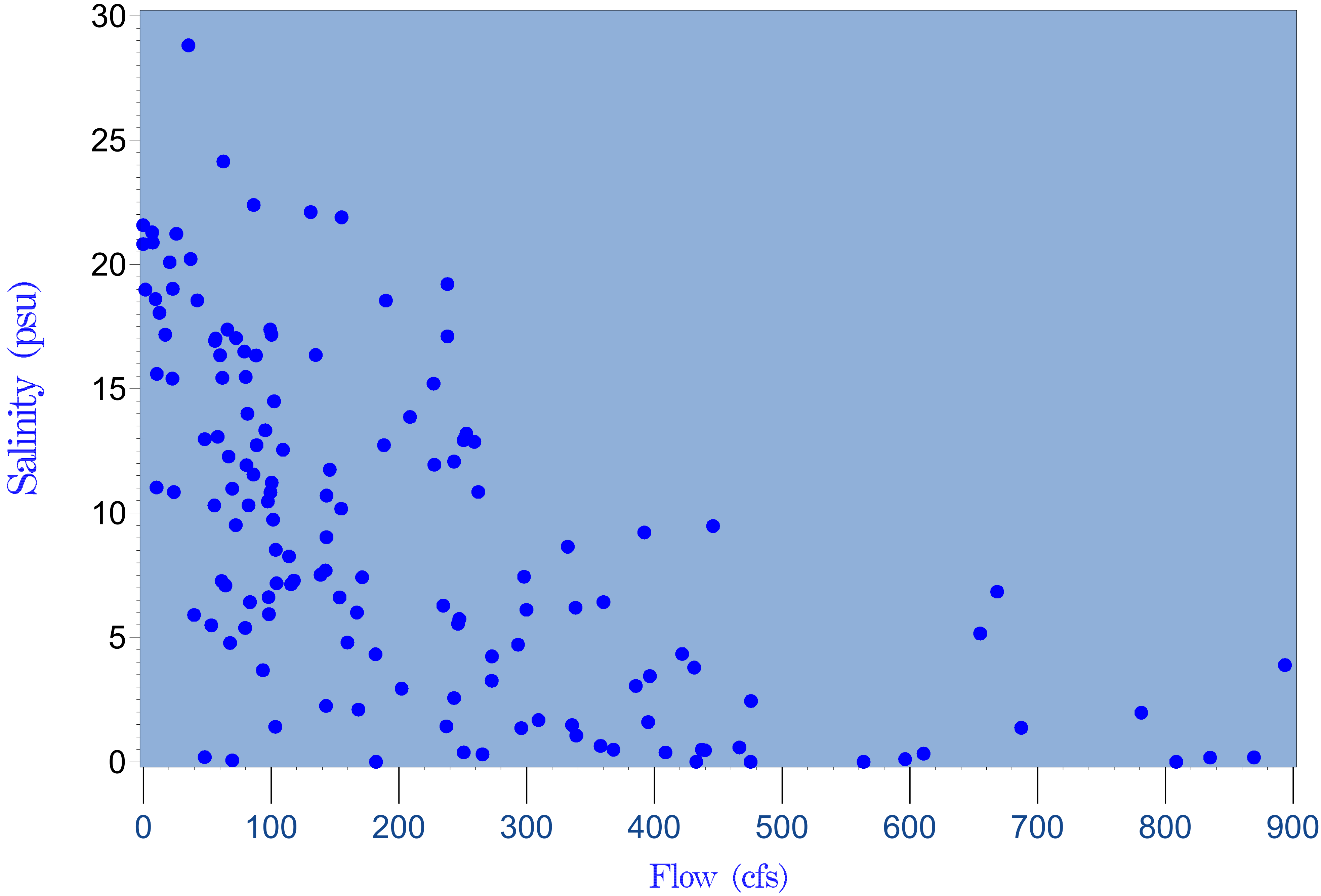


Figure 4.3.33 Surface salinity versus 7-day average flow at Station #9 (River Kilometer -0.37), 1991-2004

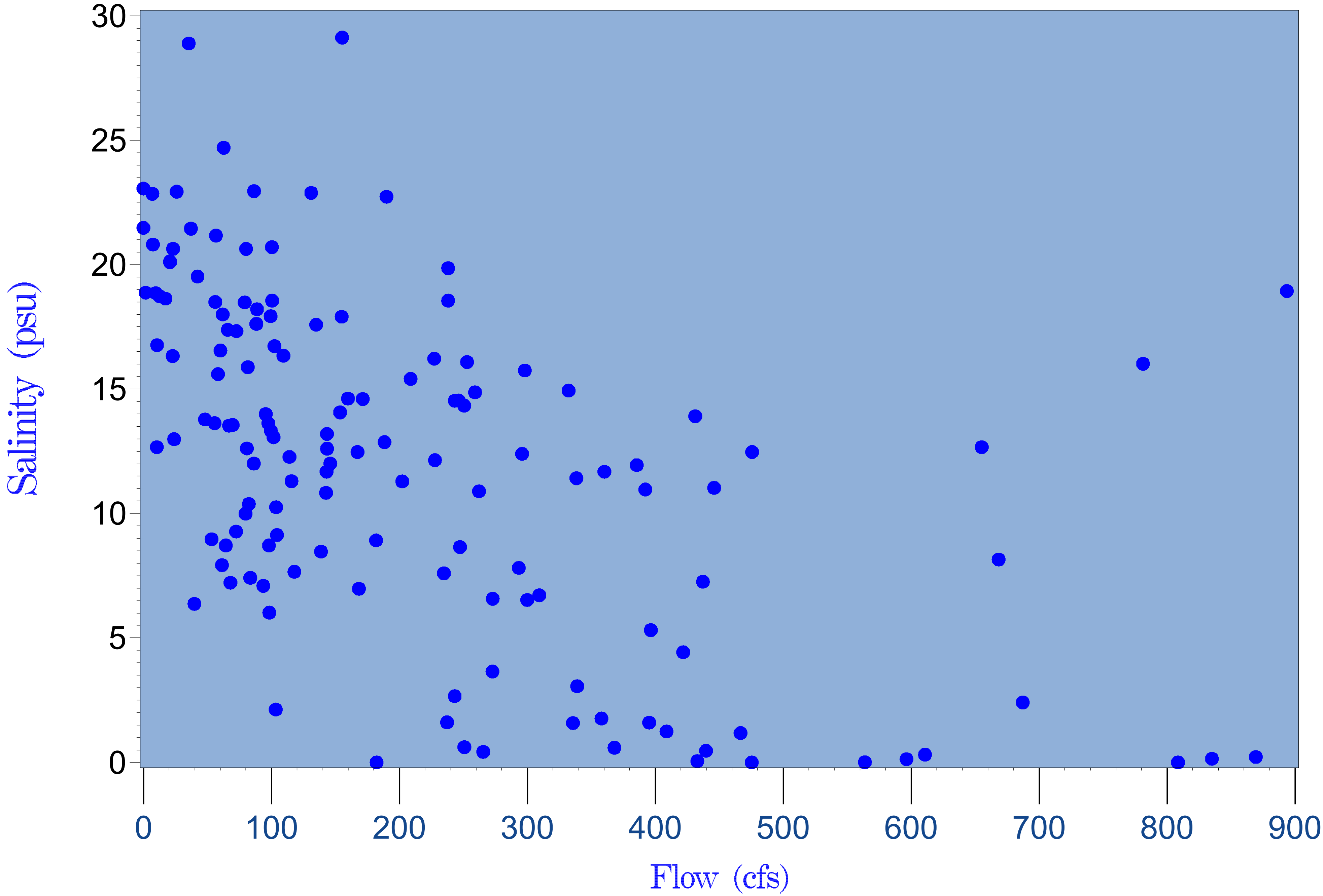


Figure 4.3.34 Bottom salinity versus 7-day average flow at Station #9 (River Kilometer -0.37), 1991-2004

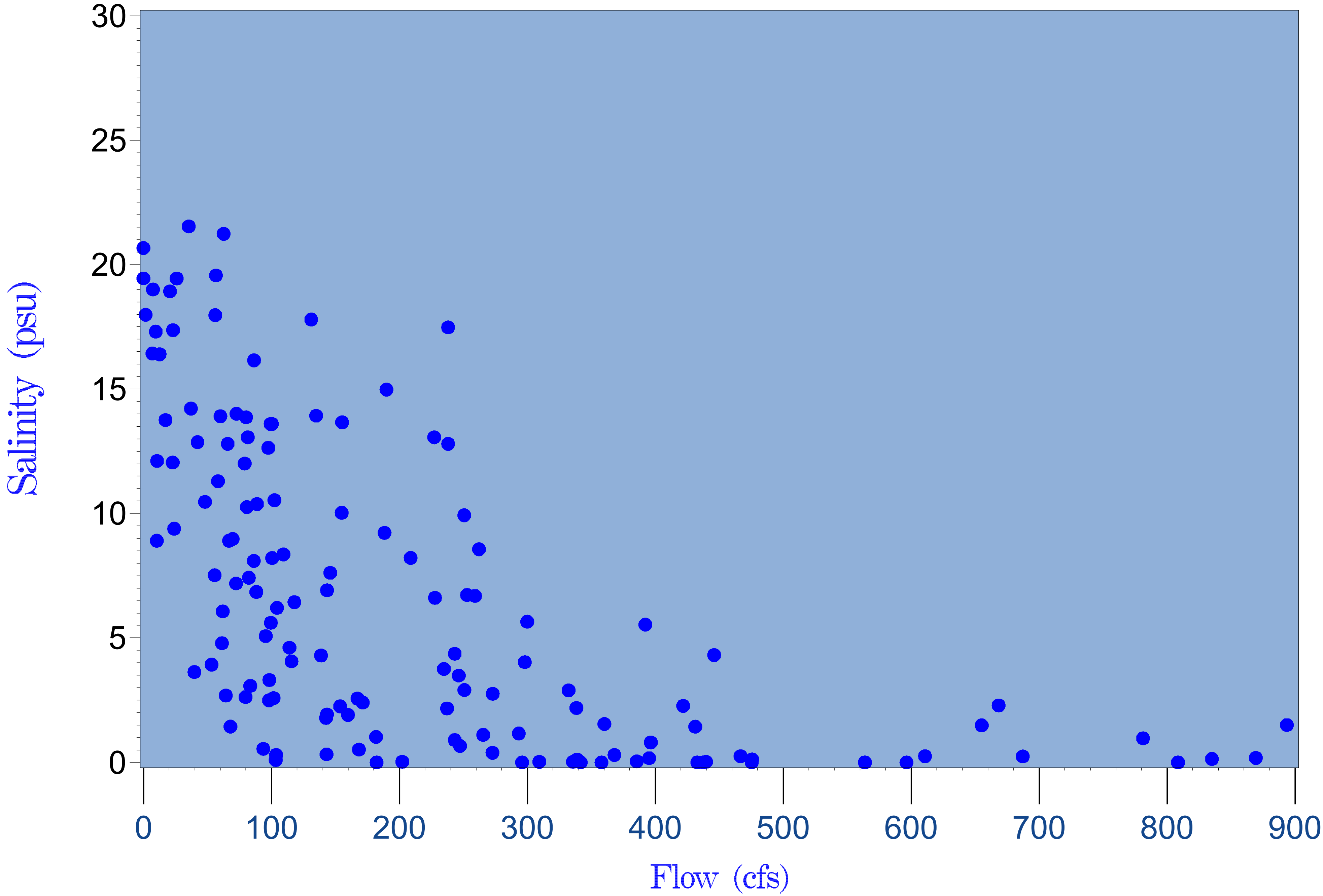


Figure 4.3.35 Surface salinity versus 7-day average flow at Station #8 (Lower Peace River), 1991-2004

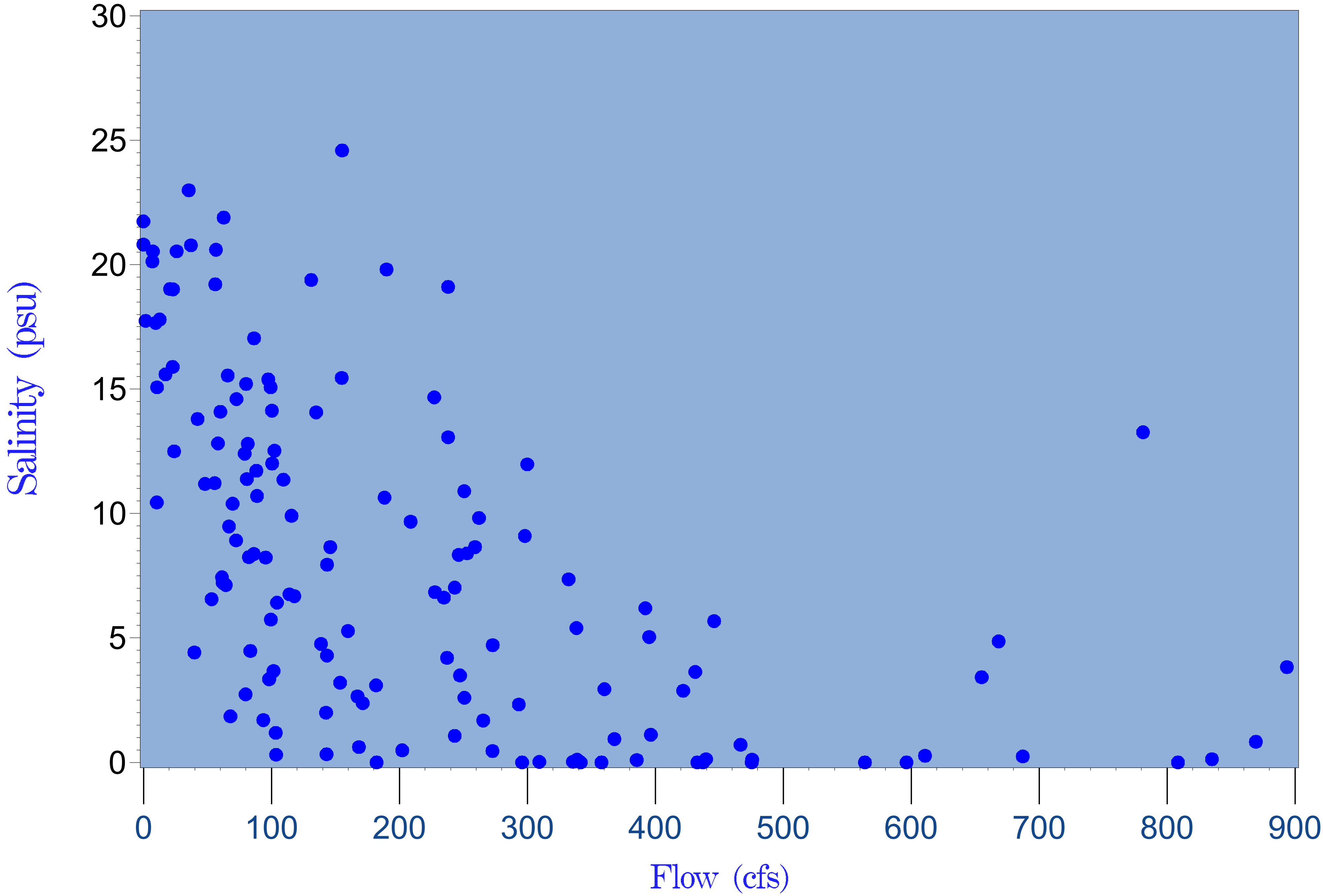


Figure 4.3.36 Bottom salinity versus 7-day average flow at Station #8 (Lower Peace River), 1991-2004

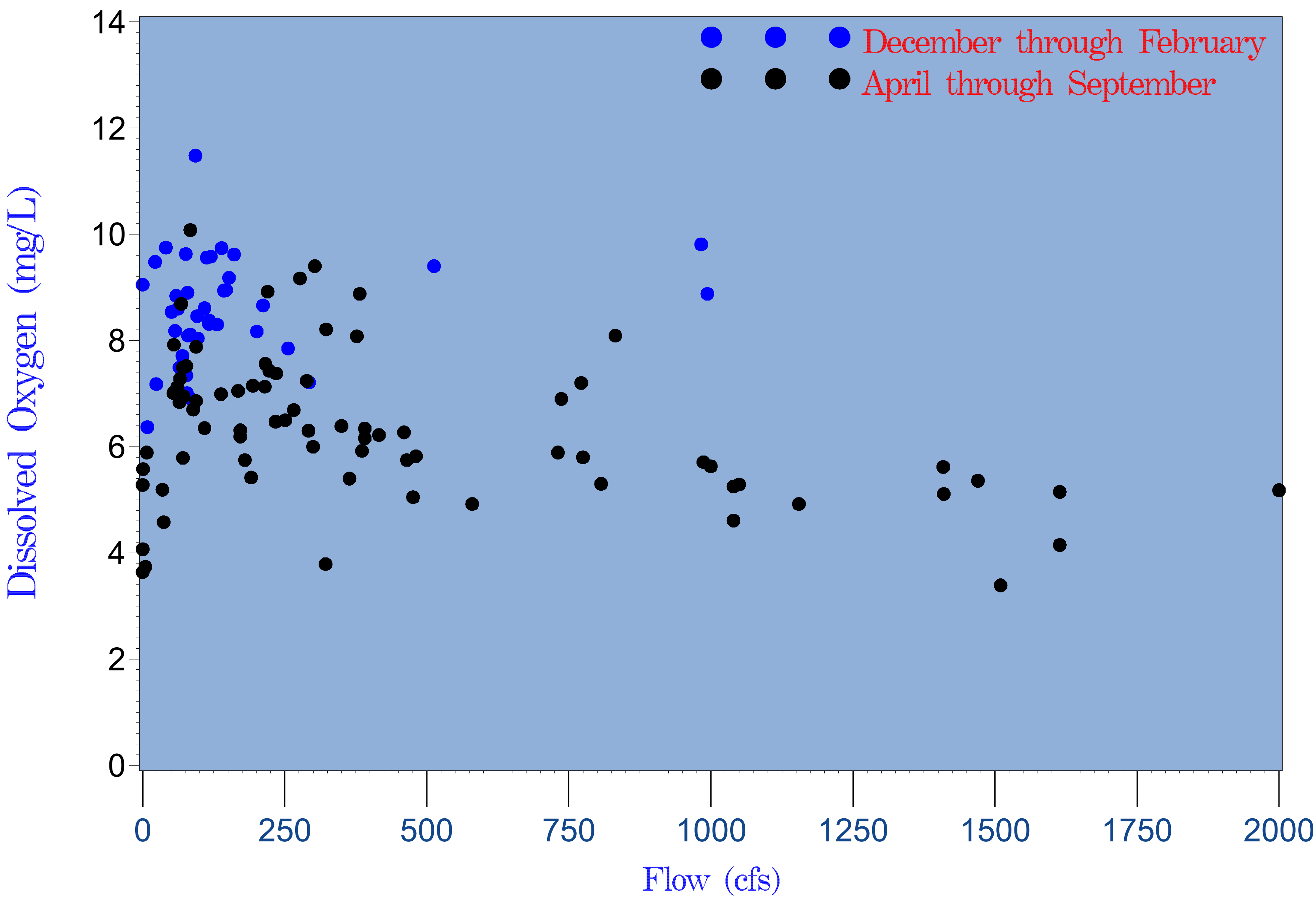


Figure 4.3.37 Surface D.O. versus flow at Station #11 (River Kilometer 9.90), 1991-2004

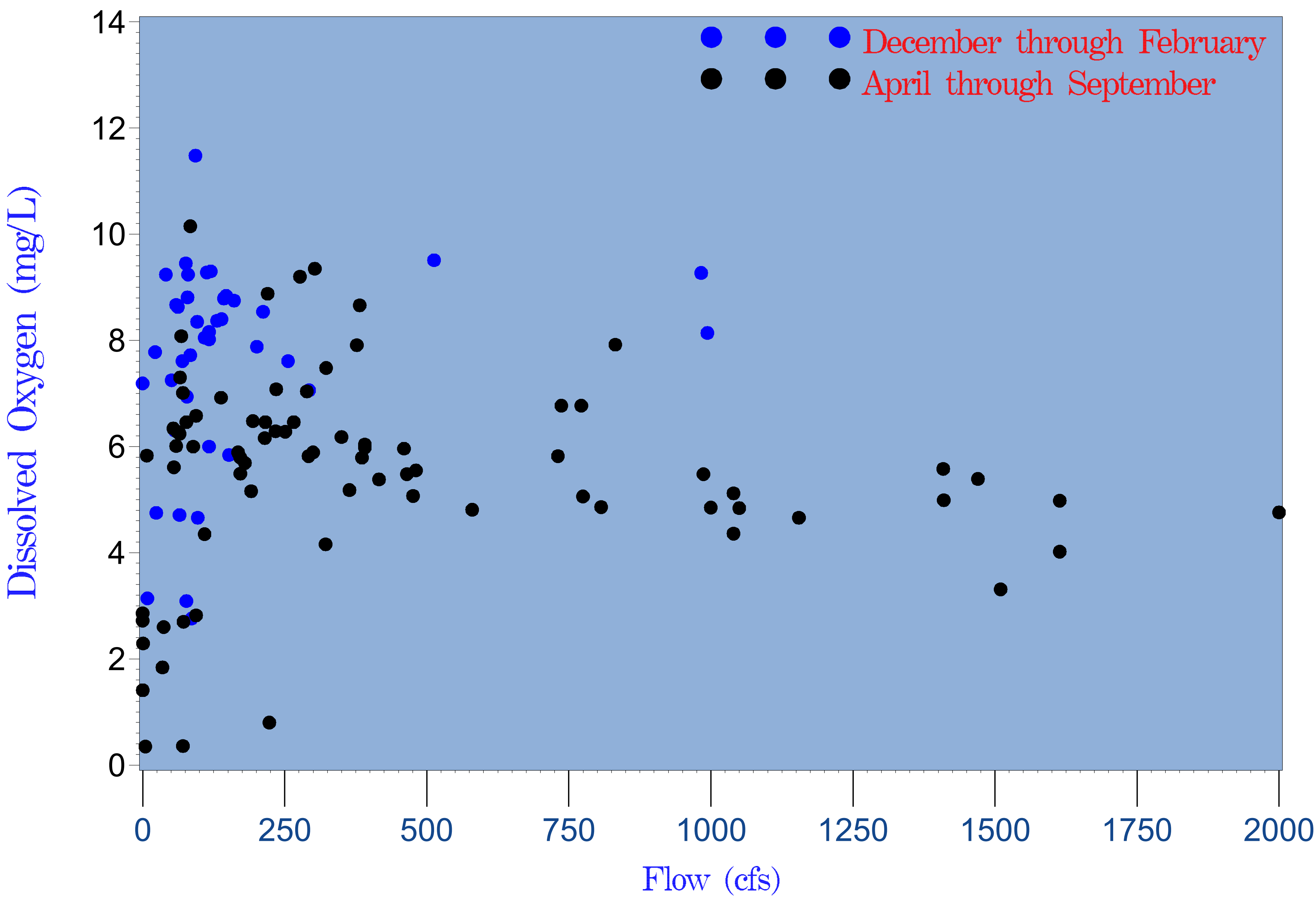


Figure 4.3.38 Bottom D.O. versus flow at Station #11 (River Kilometer 9.90), 1991-2004

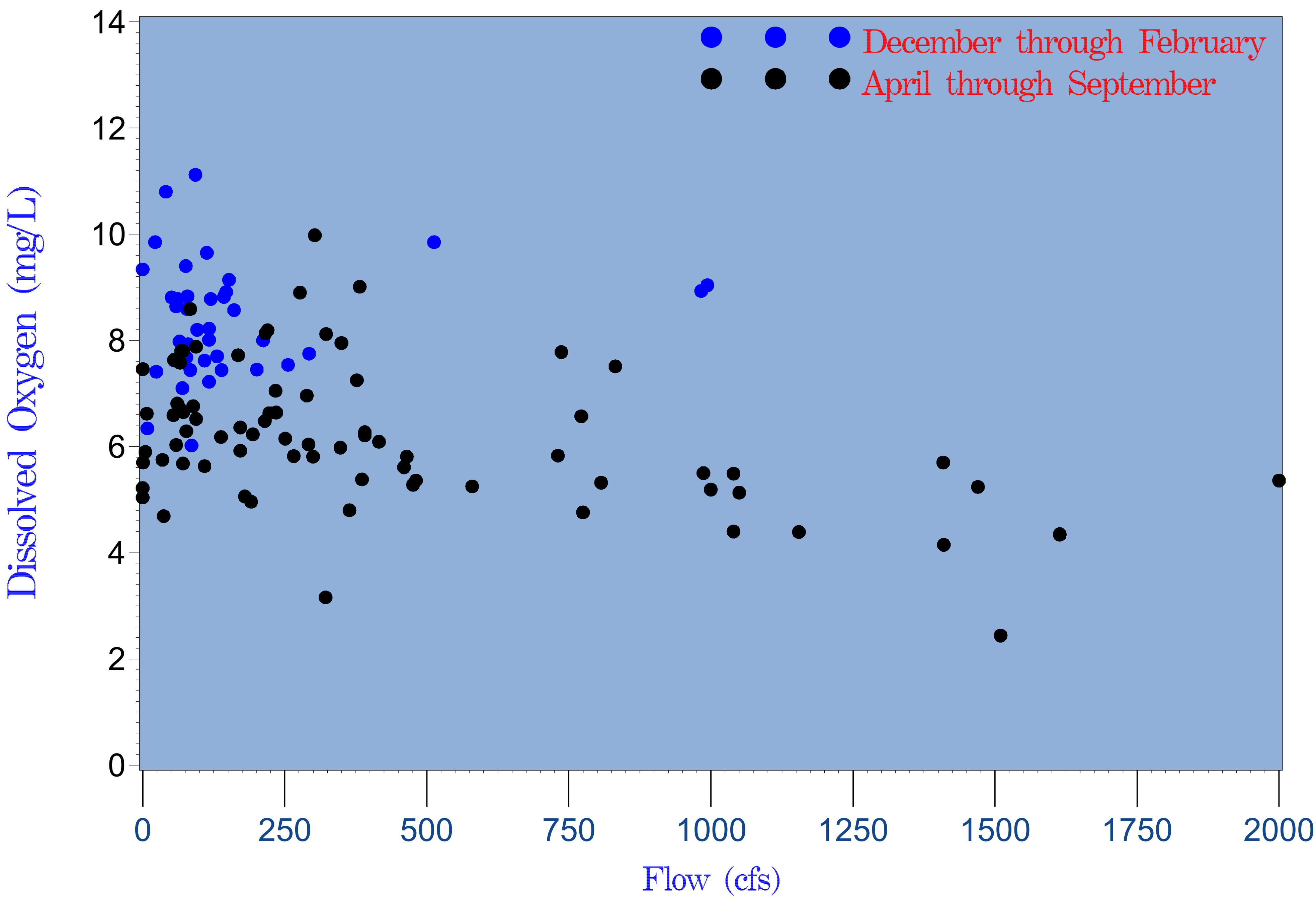


Figure 4.3.39 Surface D.O. versus flow at Station #4 (River Kilometer 8.74), 1991-2004

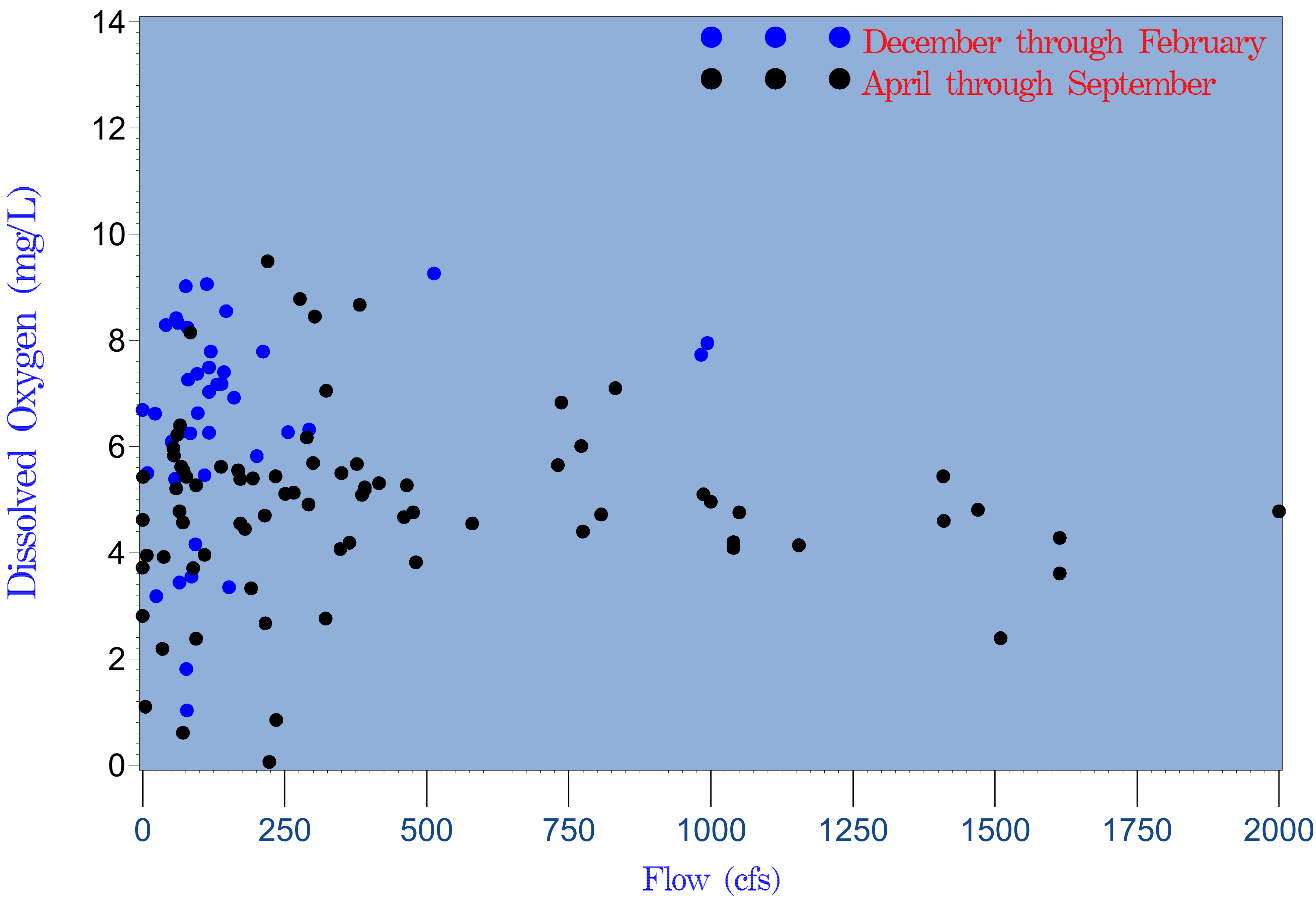


Figure 4.3.40 Bottom D.O. versus flow at Station #4 (River Kilometer 8.74), 1991-2004

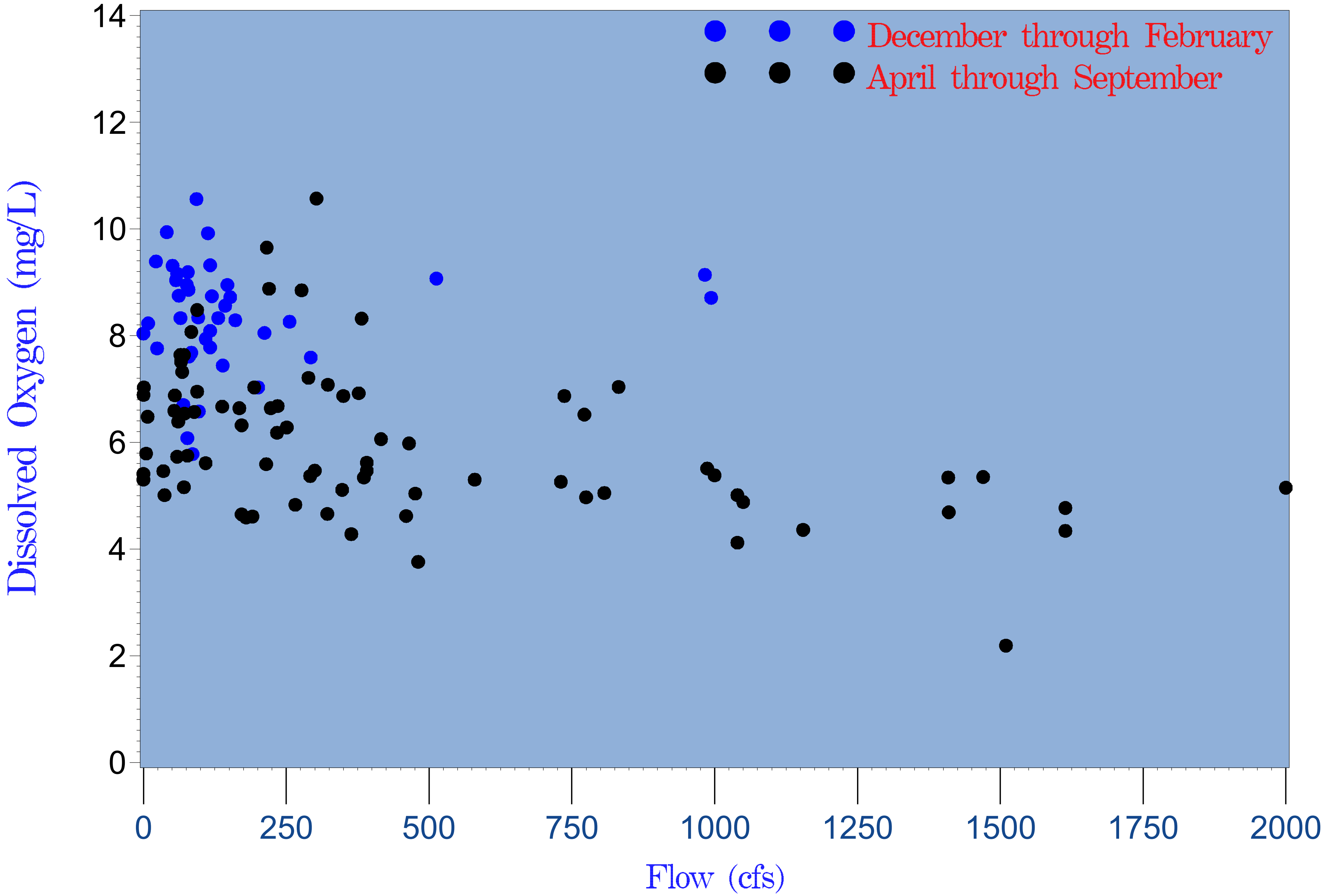


Figure 4.3.41 Surface D.O. versus flow at Station #5 (River Kilometer 6.72), 1991-2004

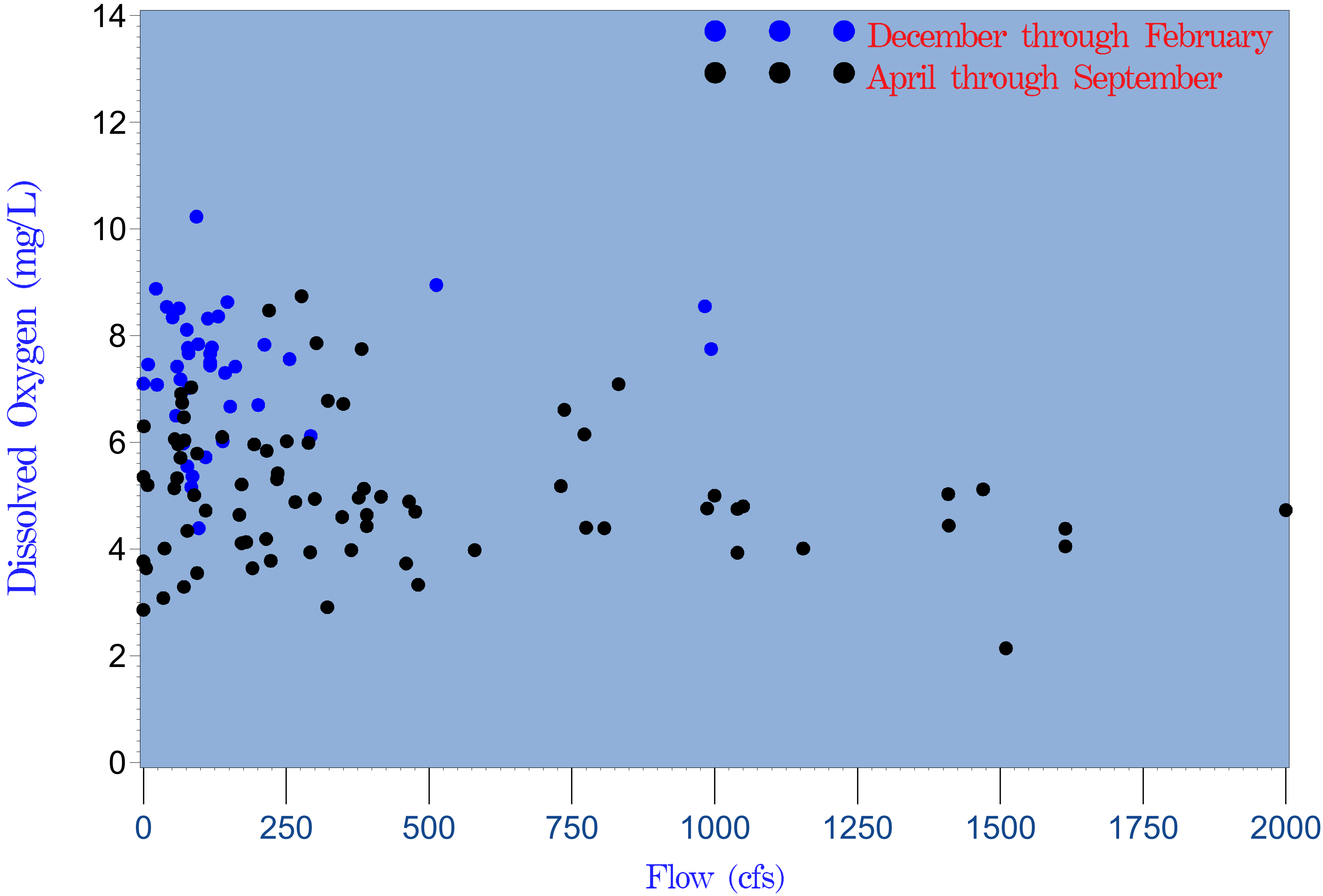


Figure 4.3.42 Bottom D.O. versus flow at Station #5 (River Kilometer 6.72), 1991-2004

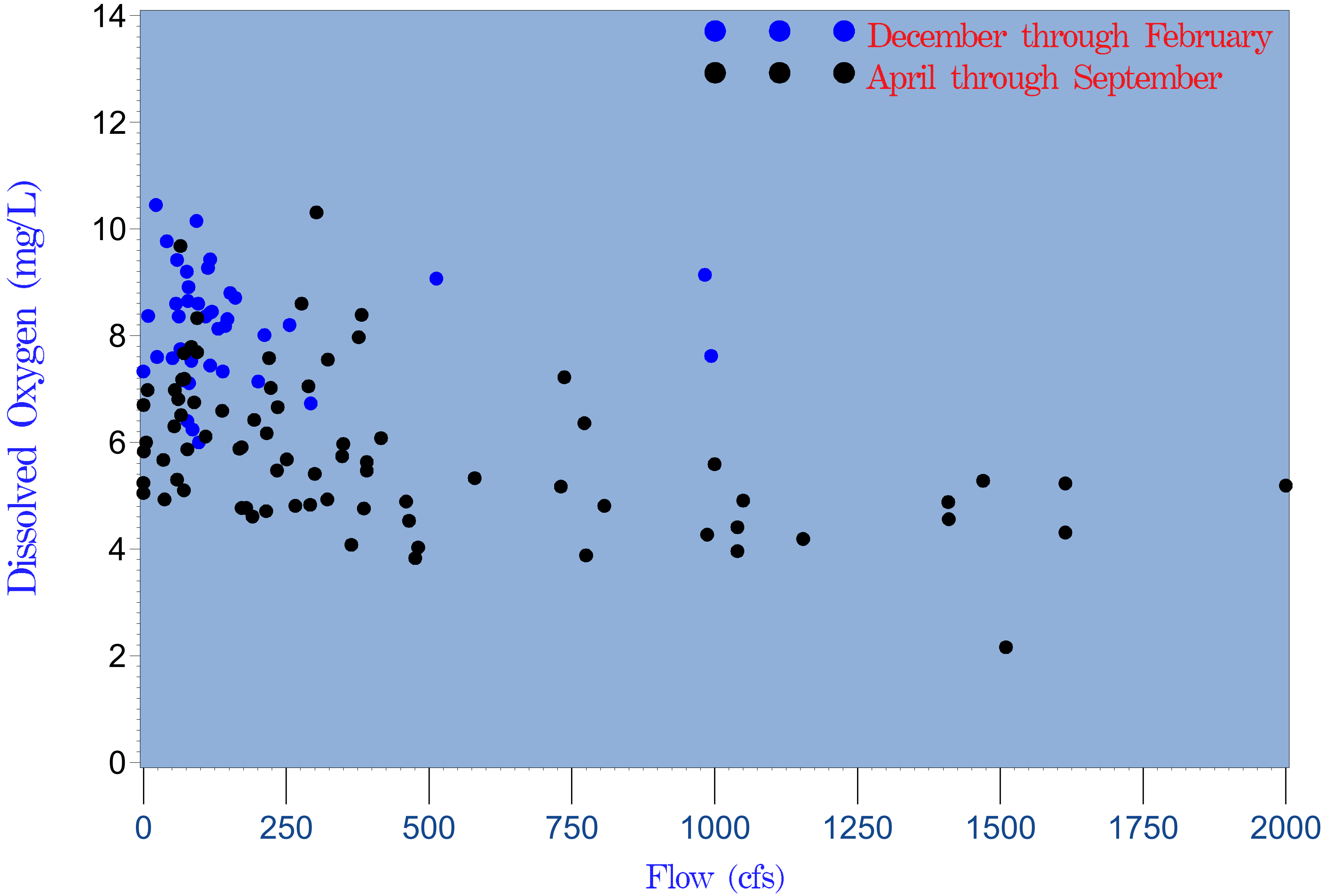


Figure 4.3.43 Surface D.O. versus flow at Station #6 (River Kilometer 4.61), 1991-2004

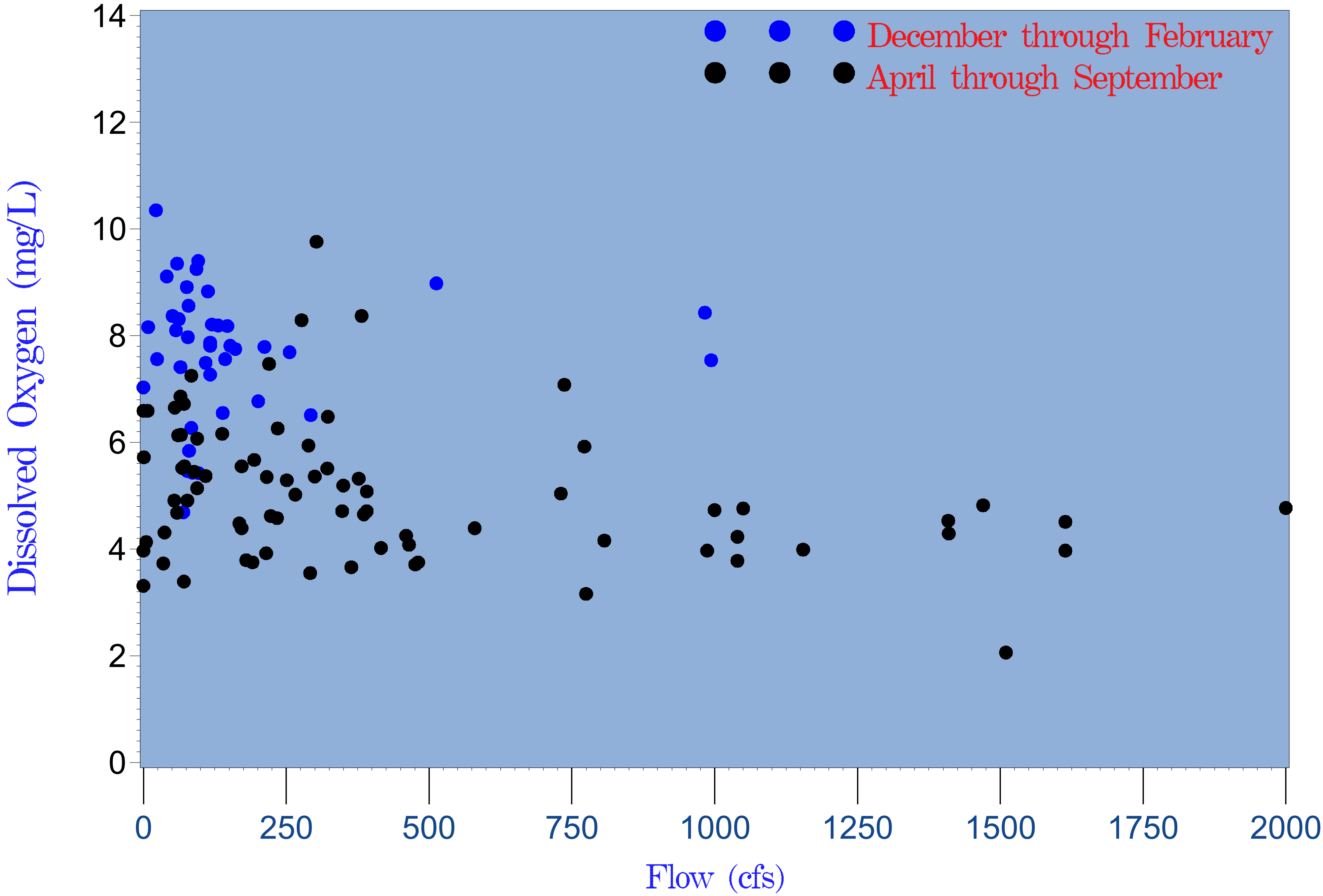


Figure 4.3.44 Bottom D.O. versus flow at Station #6 (River Kilometer 4.61), 1991-2004

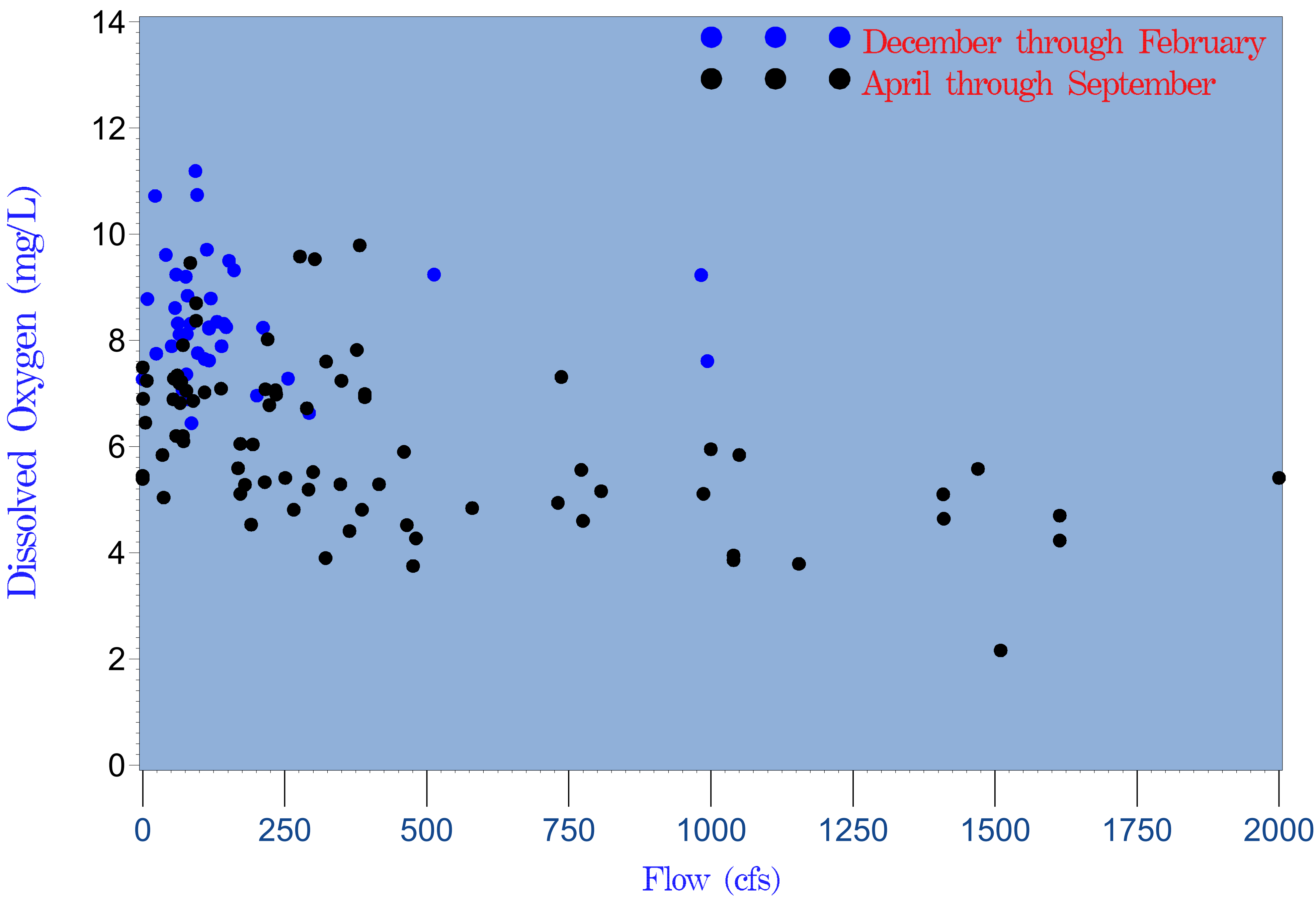


Figure 4.3.45 Surface D.O. versus flow at Station #7 (River Kilometer 2.35), 1991-2004

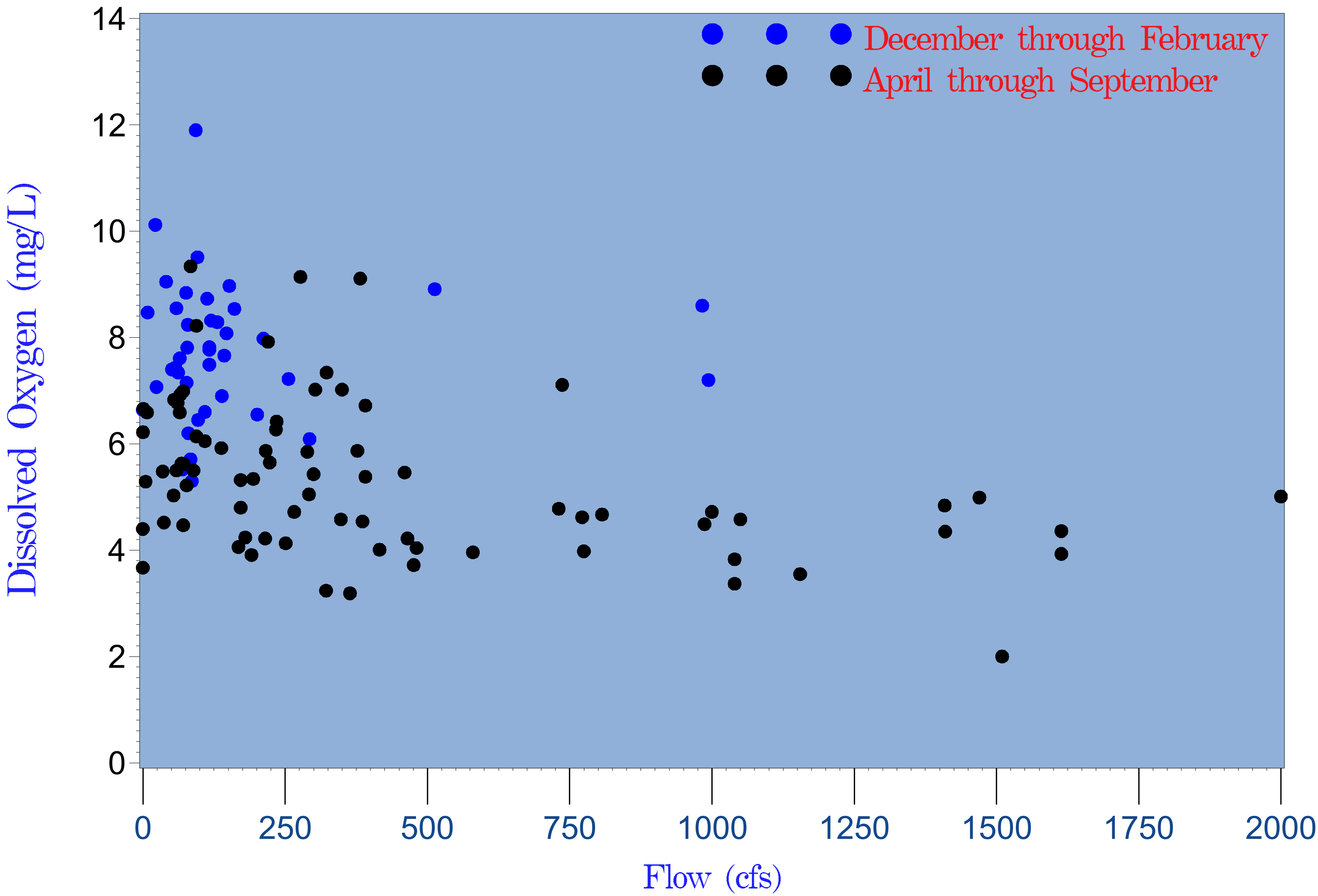


Figure 4.3.46 Bottom D.O. versus flow at Station #7 (River Kilometer 2.35), 1991-2004

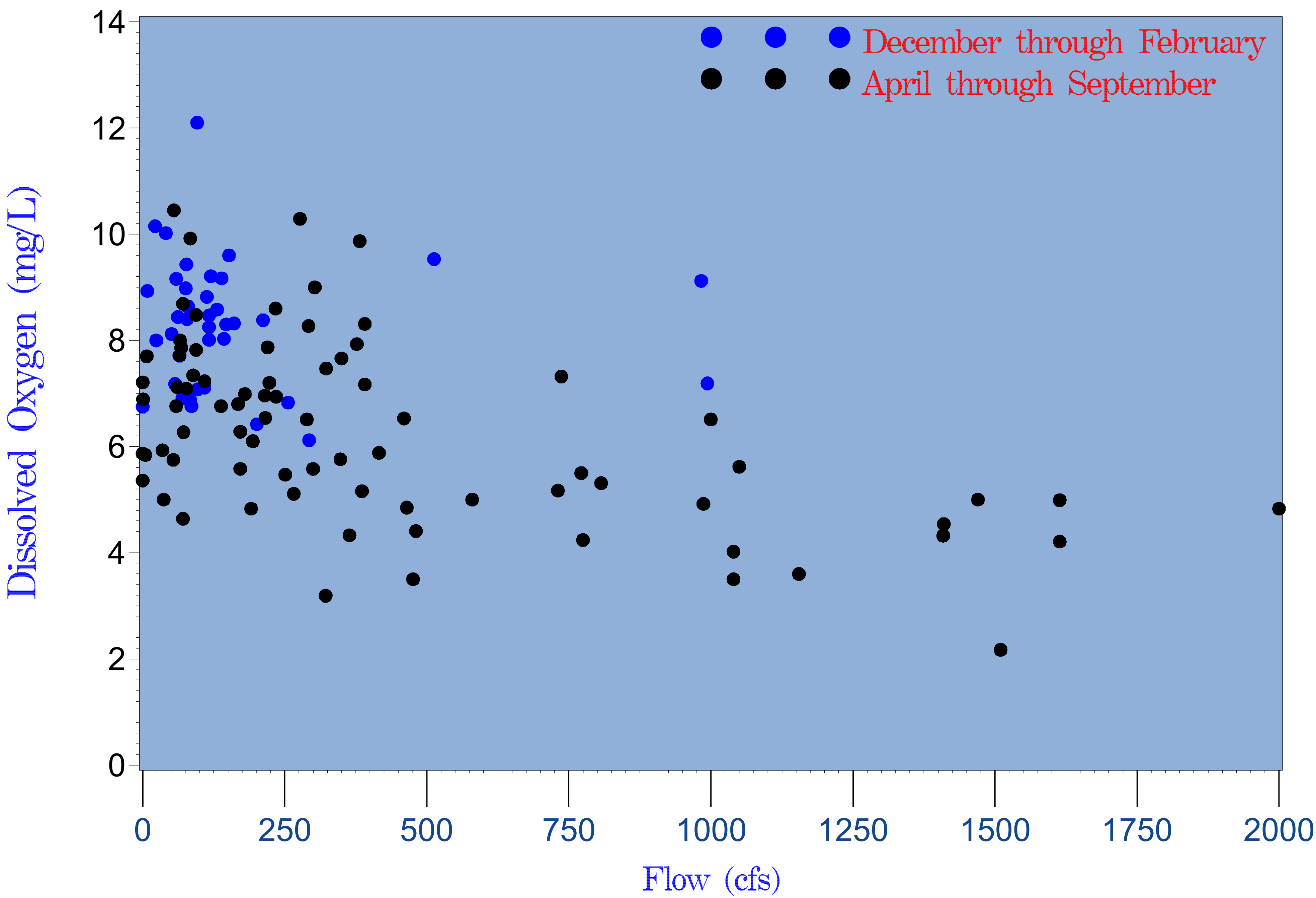


Figure 4.3.47 Surface D.O. versus flow at Station #16 (River Kilometer 1.26), 1991-2004

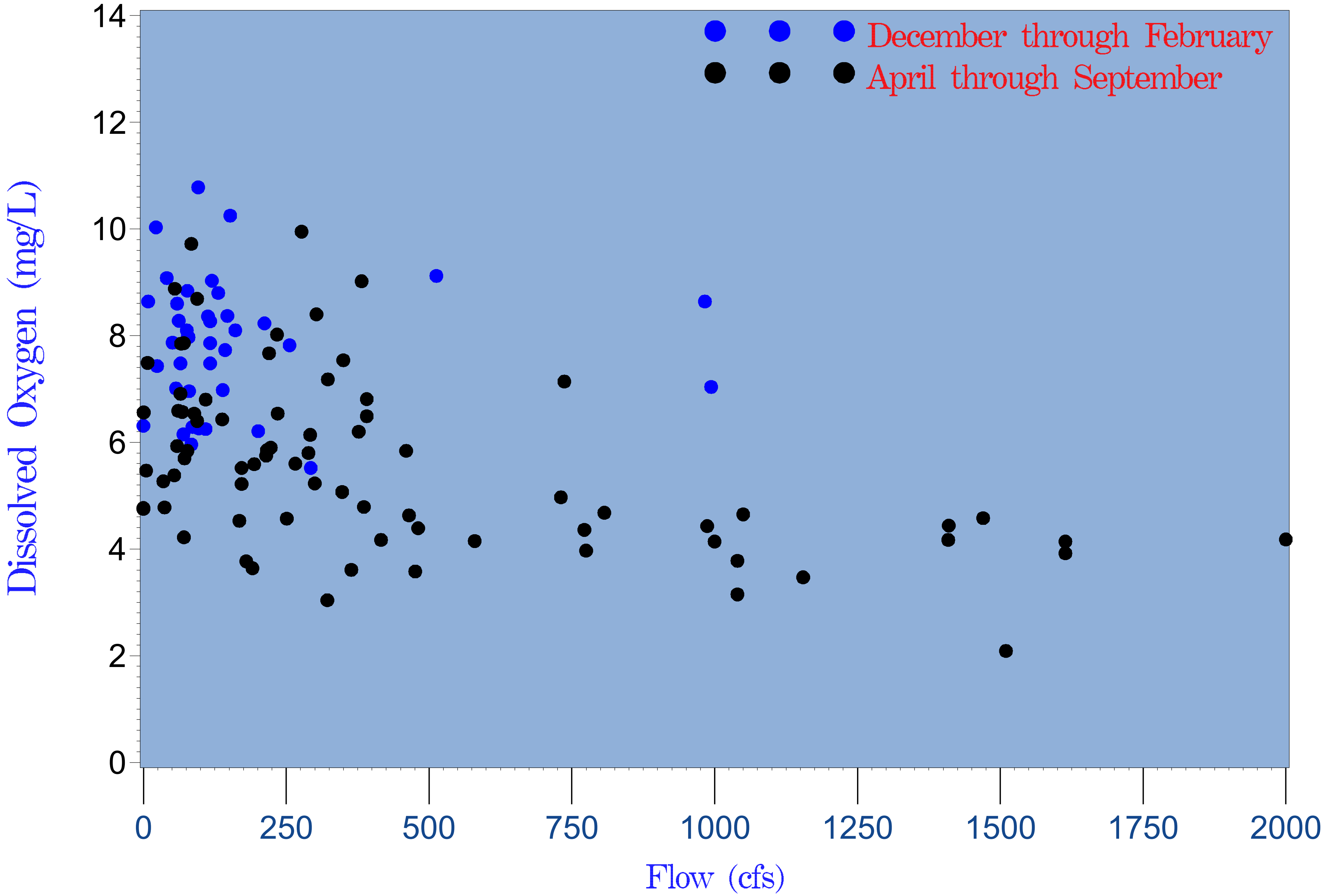


Figure 4.3.48 Bottom D.O. versus flow at Station #16 (River Kilometer 1.26), 1991-2004

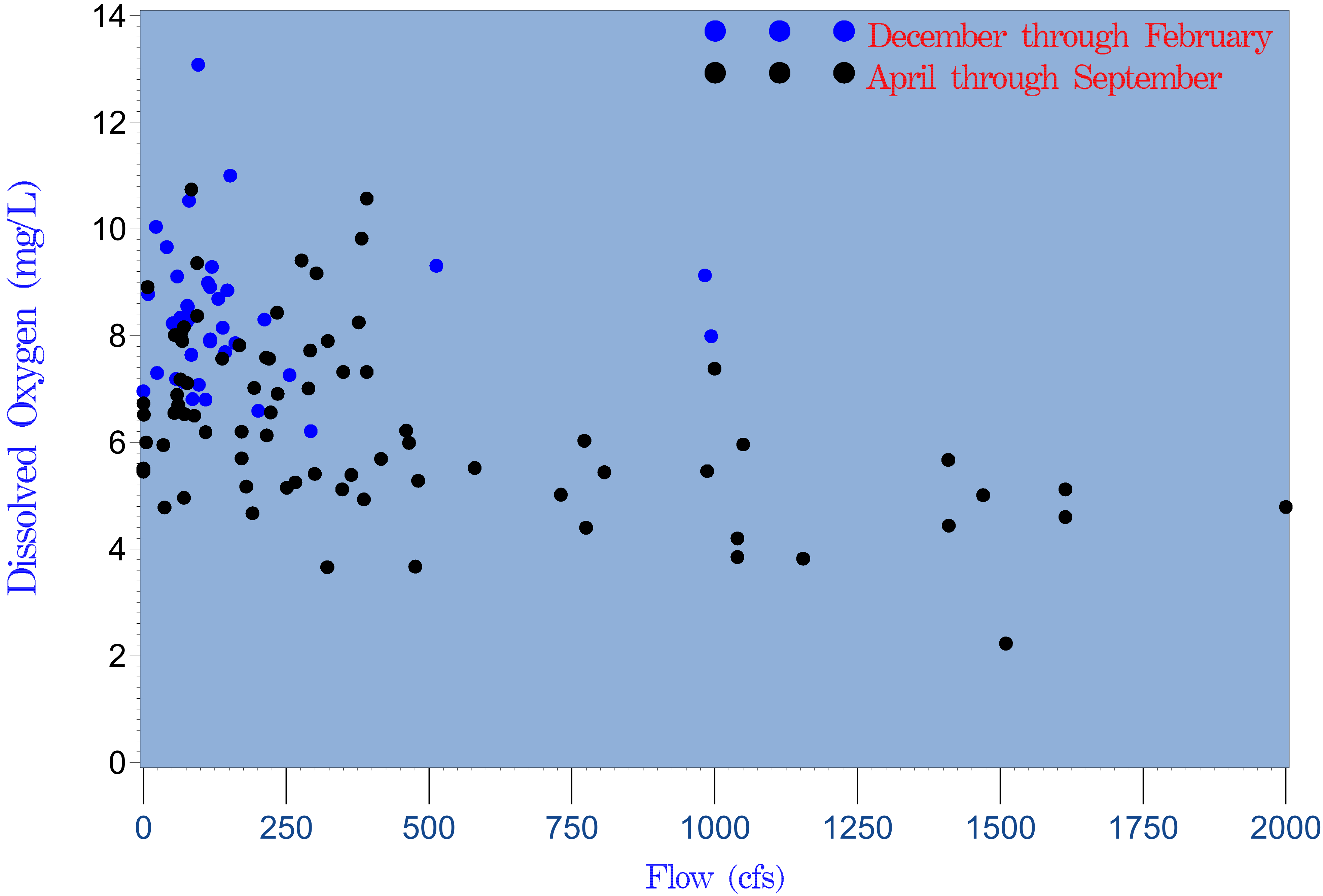


Figure 4.3.49 Surface D.O. versus flow at Station #17 (River Kilometer 0.43), 1991-2004

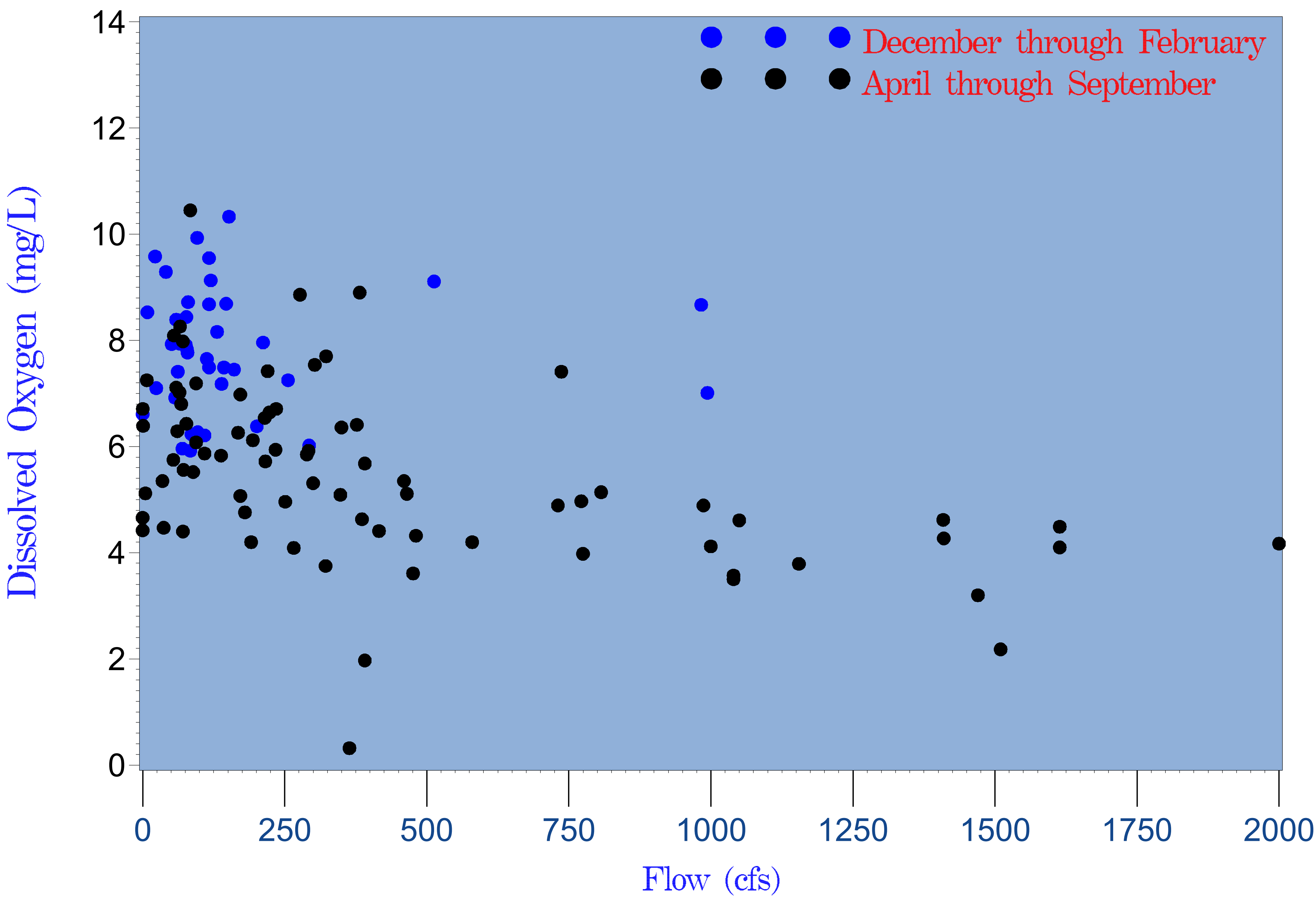


Figure 4.3.50 Bottom D.O. versus flow at Station #17 (River Kilometer 0.43), 1991-2004

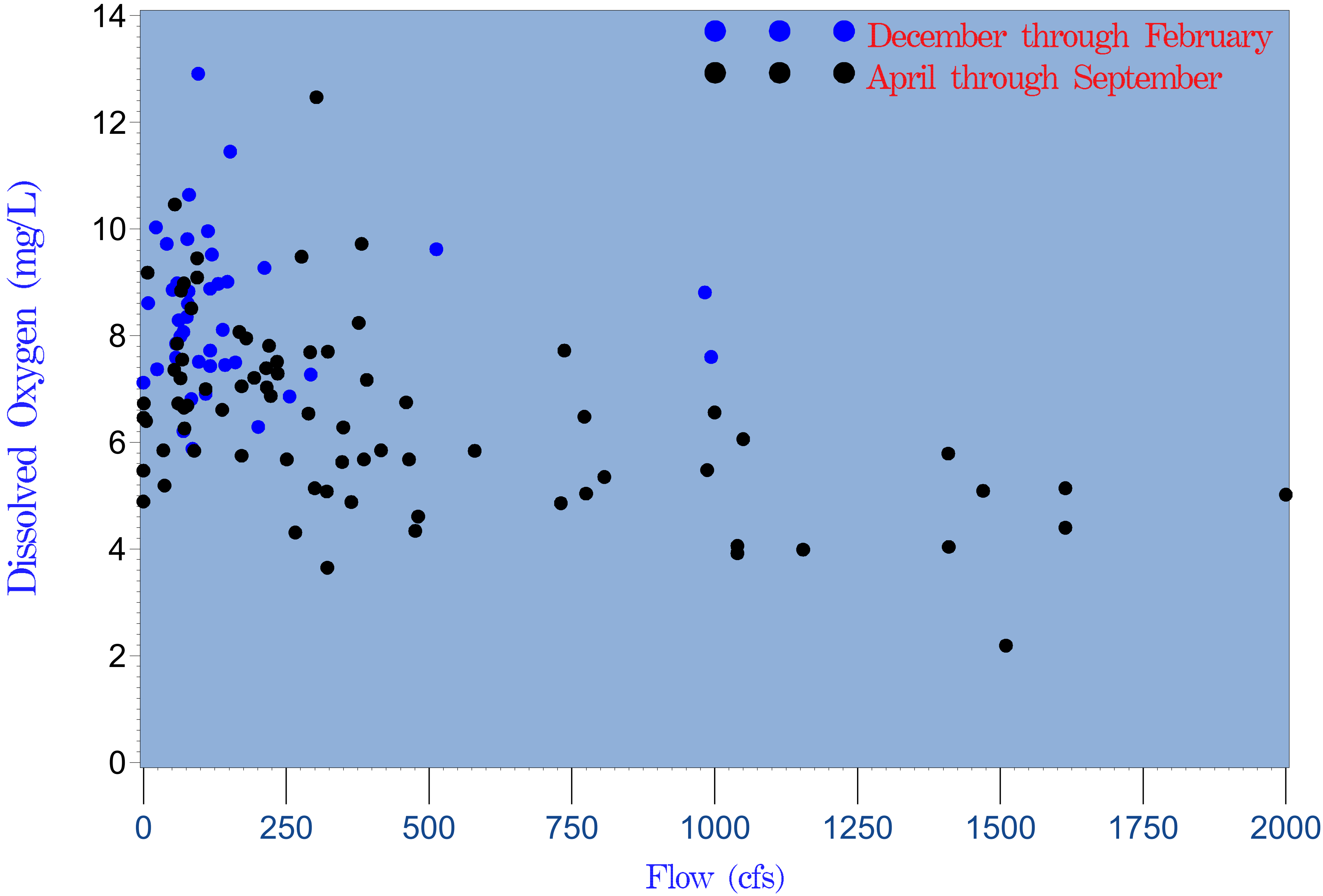


Figure 4.3.51 Surface D.O. versus flow at Station #9 (River Kilometer -0.37), 1991-2004

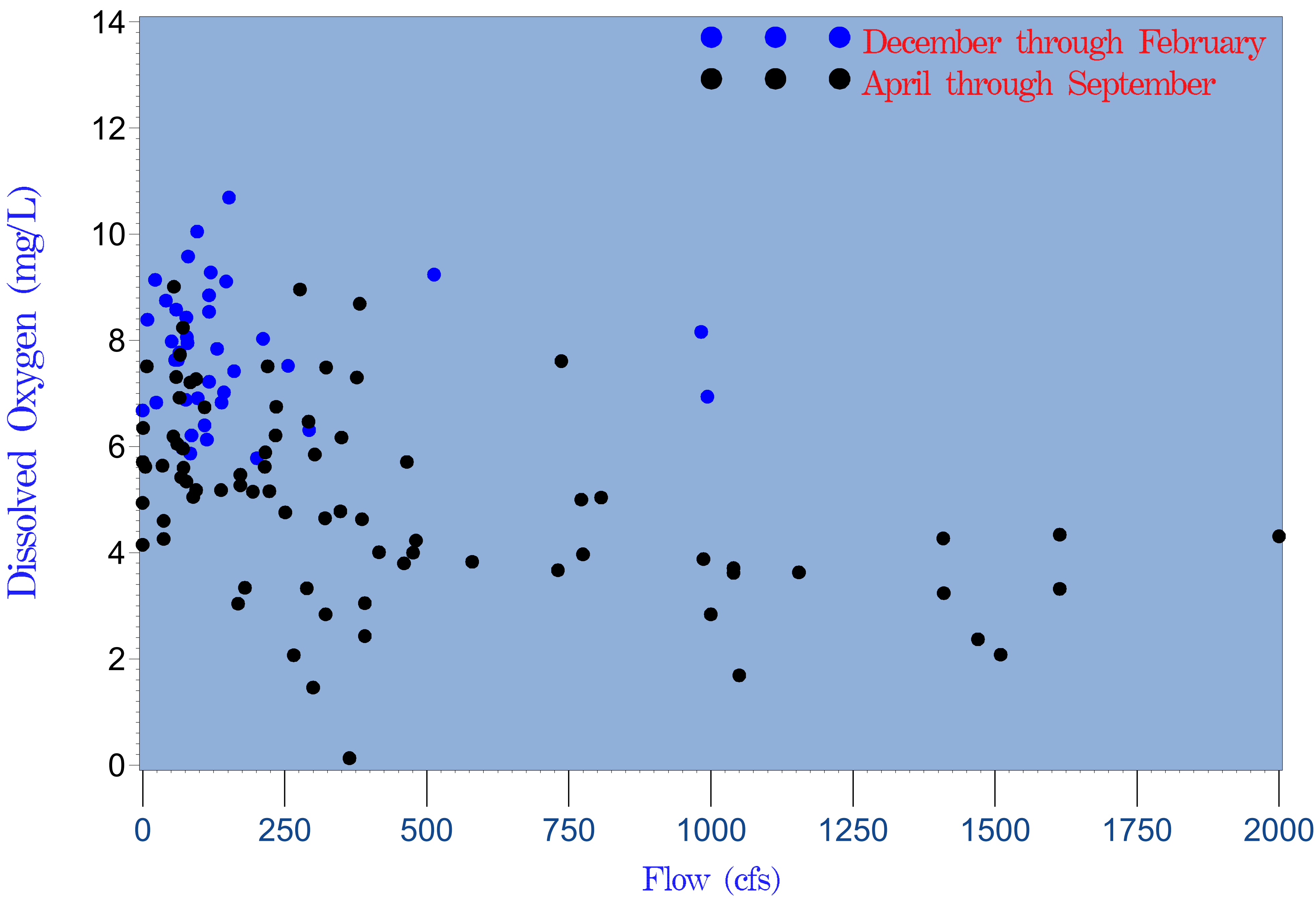


Figure 4.3.52 Bottom D.O. versus flow at Station #9 (River Kilometer -0.37), 1991-2004

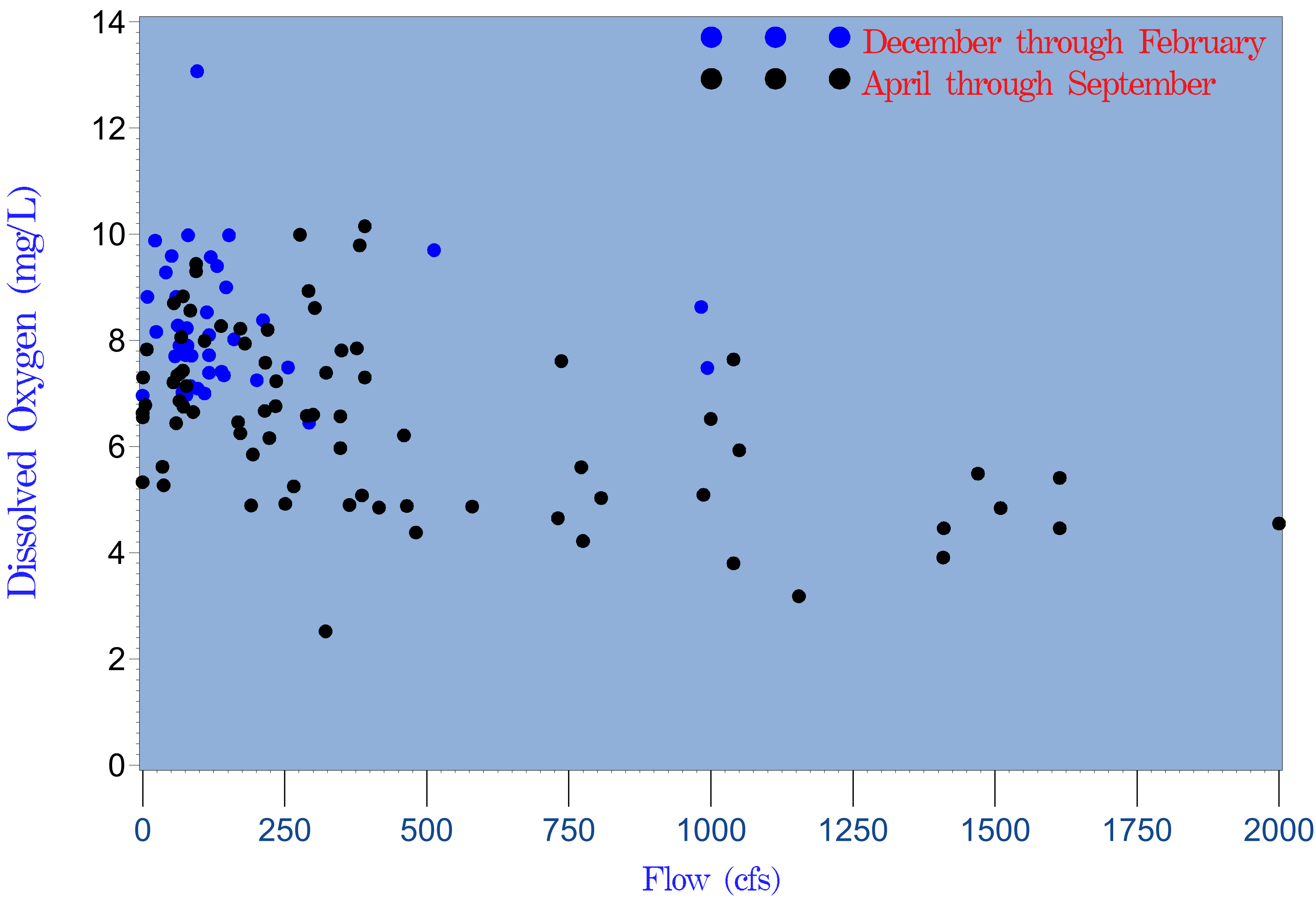


Figure 4.3.53 Surface D.O. versus flow at Station #8 (Lower Peace River), 1991-2004

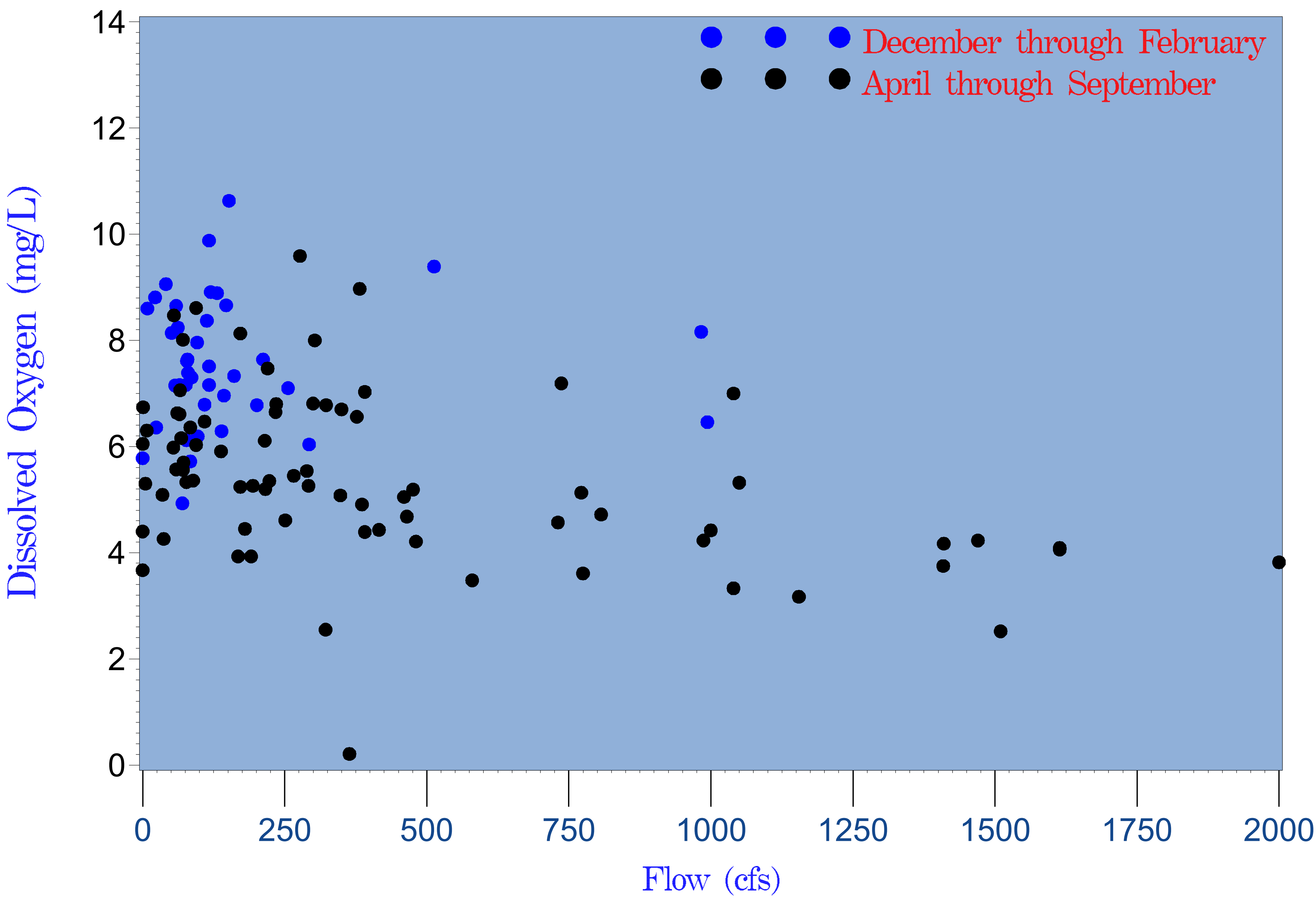


Figure 4.3.54 Bottom D.O. versus flow at Station #8 (Lower Peace River), 1991-2004

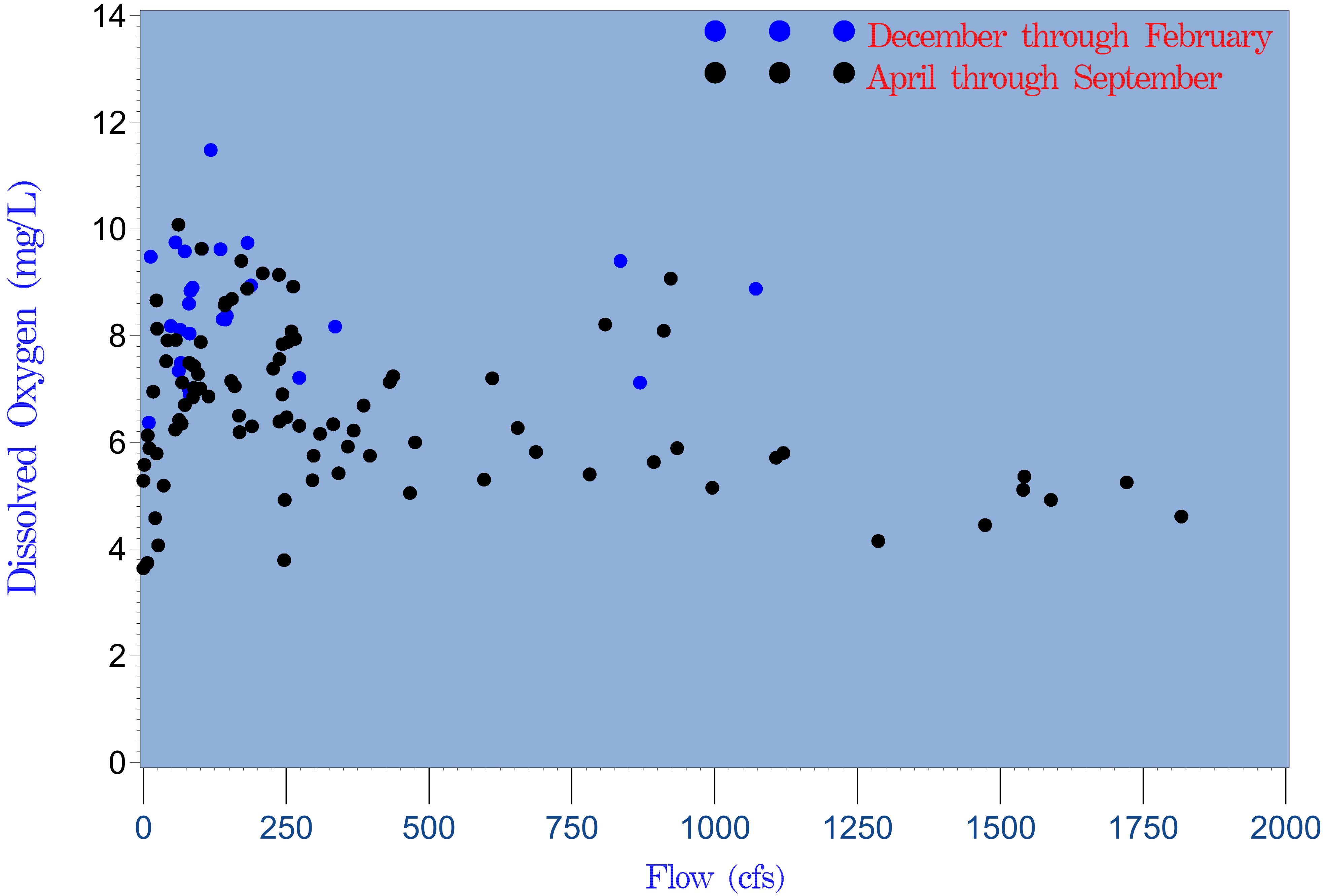


Figure 4.3.55 Surface D.O. versus 7-day average flow at Station #11 (River Kilometer 9.90), 1991-2004

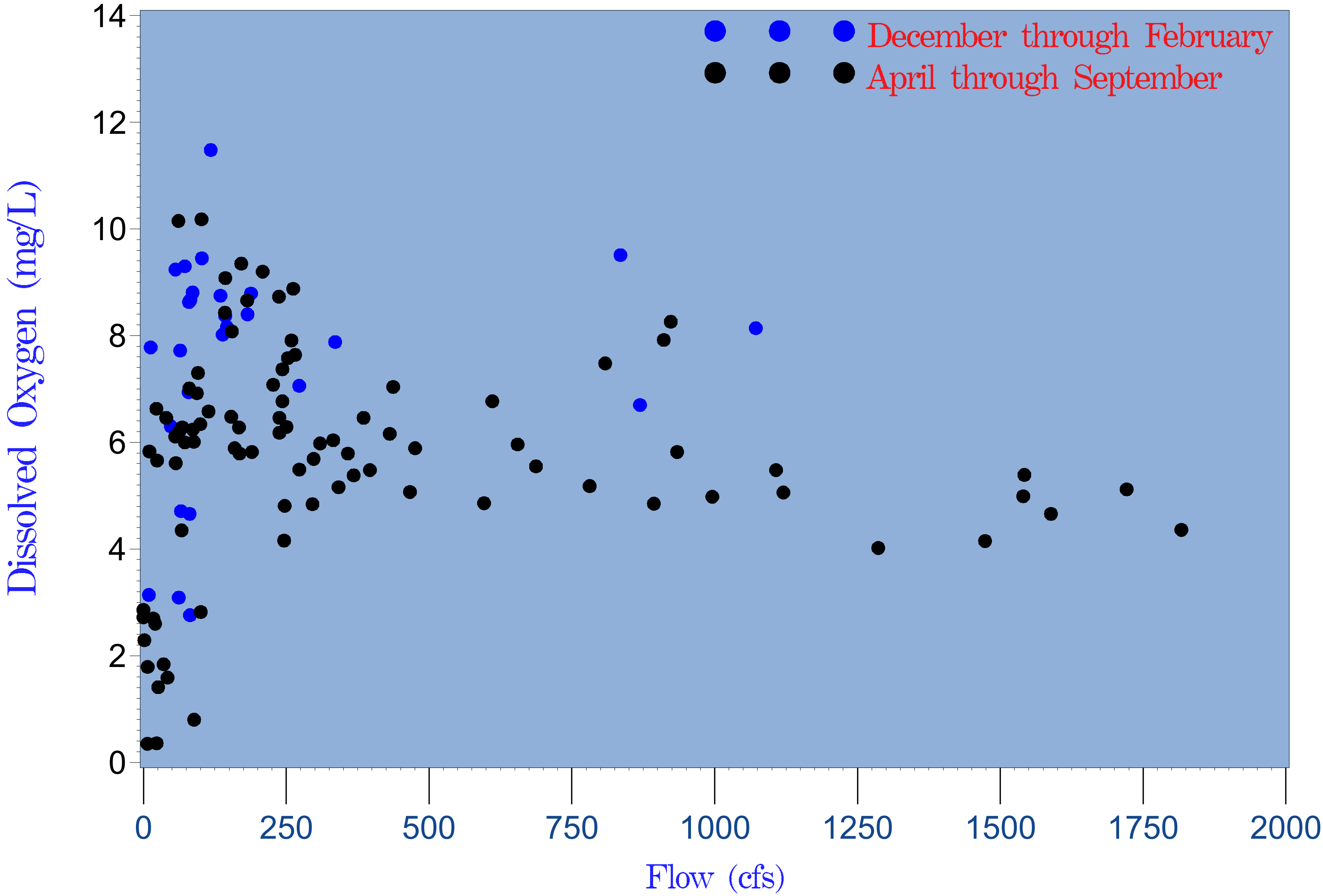


Figure 4.3.56 Bottom D.O. versus 7-day average flow at Station #11 (River Kilometer 9.90), 1991-2004

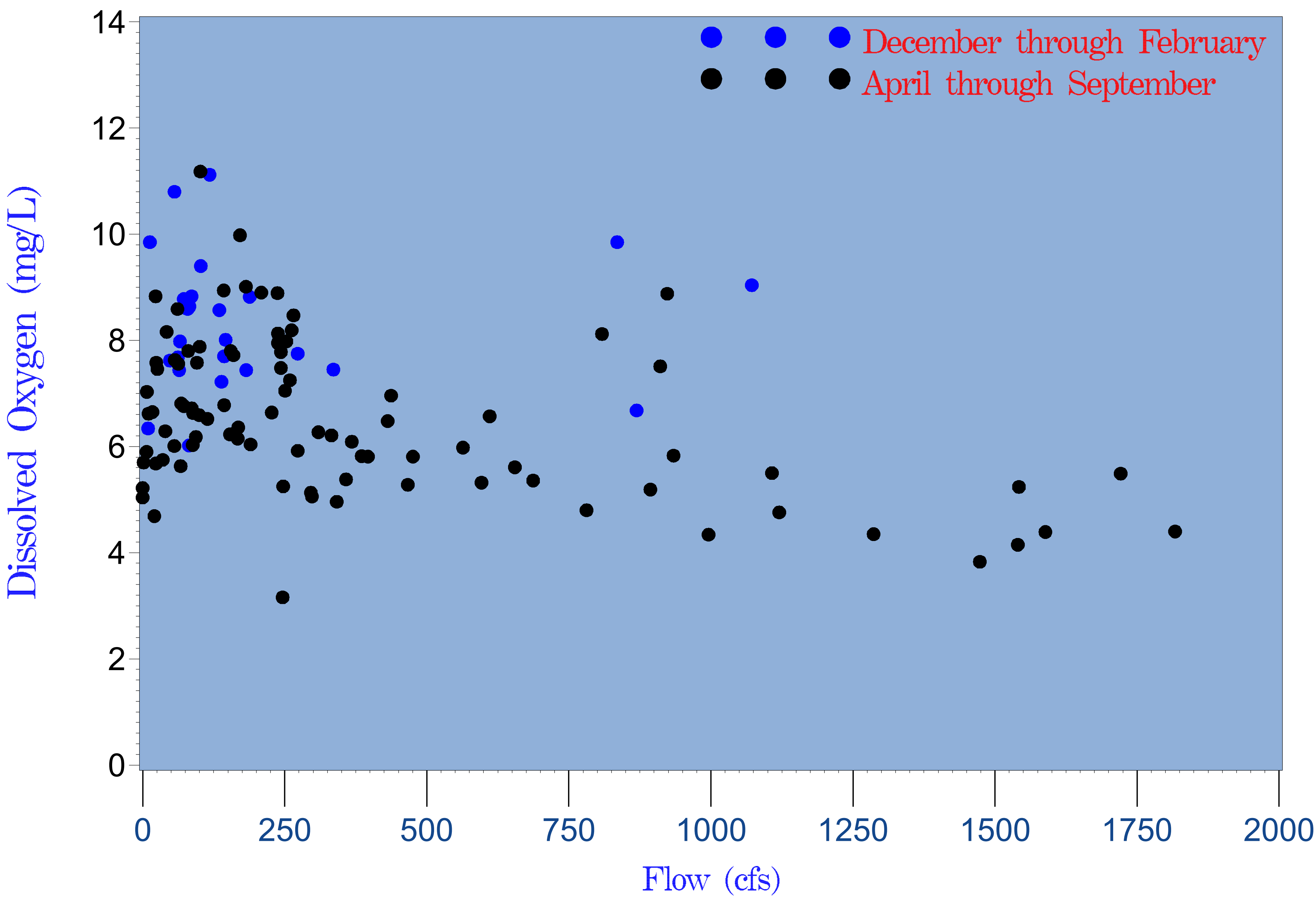


Figure 4.3.57 Surface D.O. versus 7-day average flow at Station #4 (River Kilometer 8.74), 1991-2004

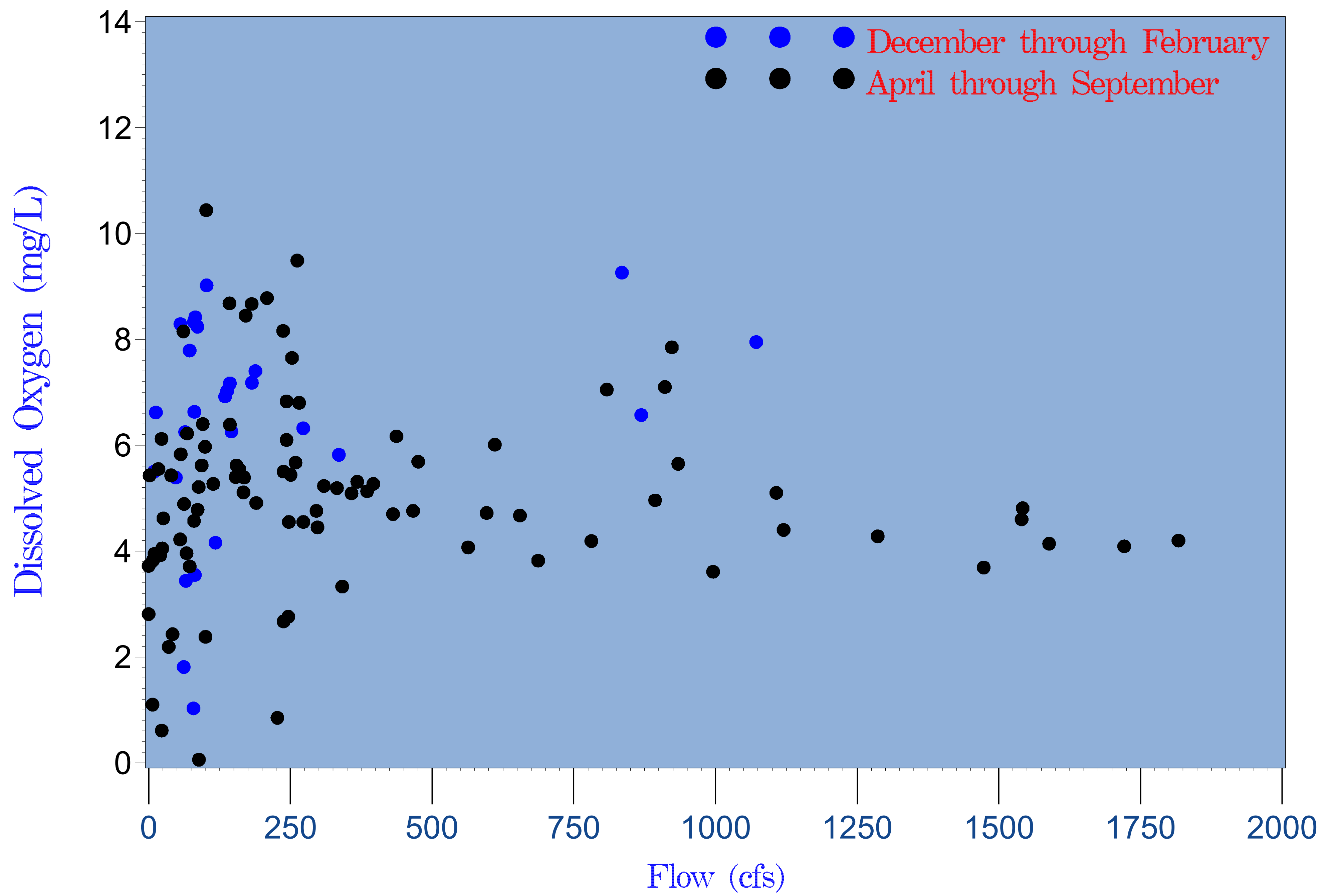


Figure 4.3.58 Bottom D.O. versus 7-day average flow at Station #4 (River Kilometer 8.74), 1991-2004

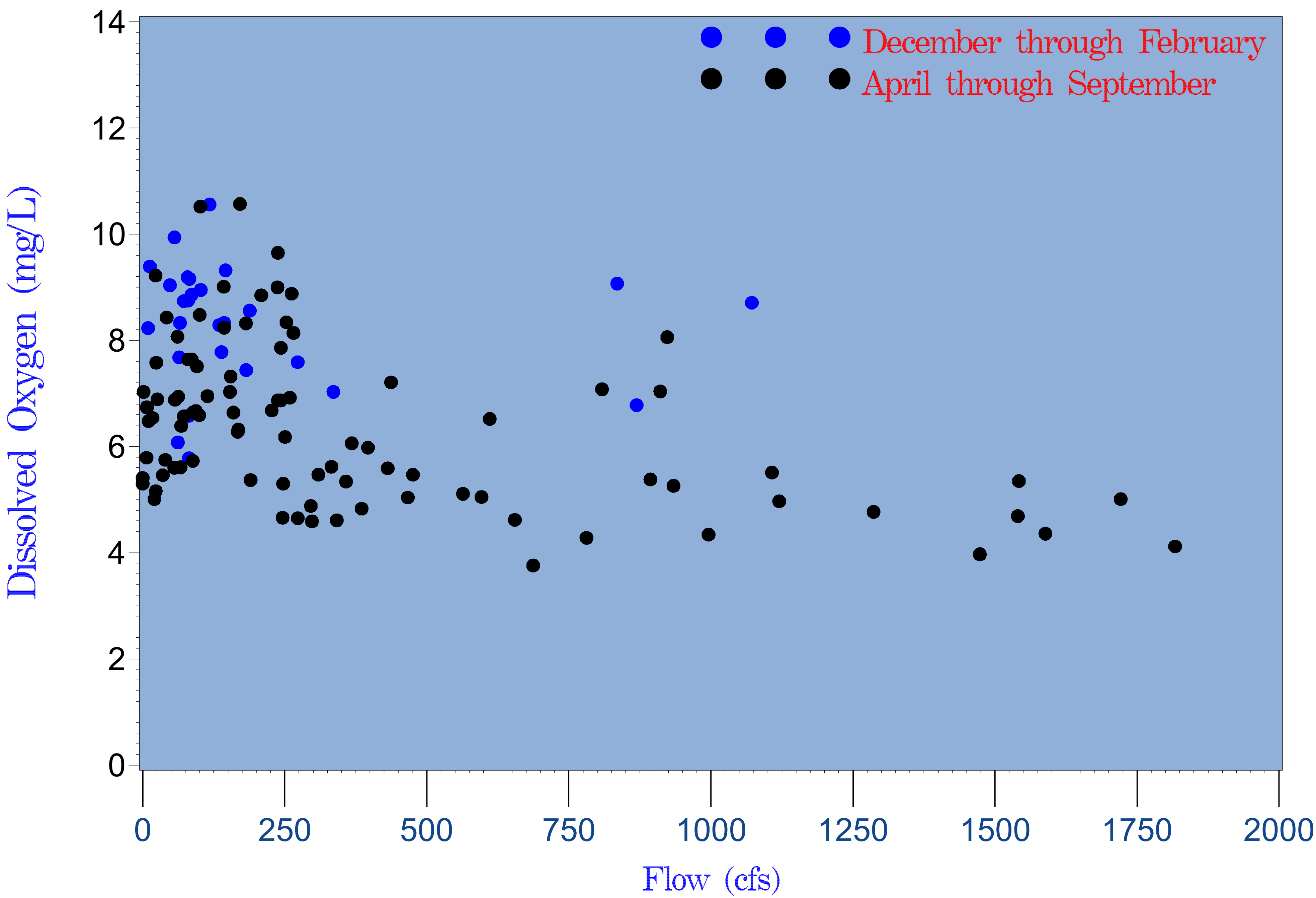


Figure 4.3.59 Surface D.O. versus 7-day average flow at Station #5 (River Kilometer 6.72), 1991-2004

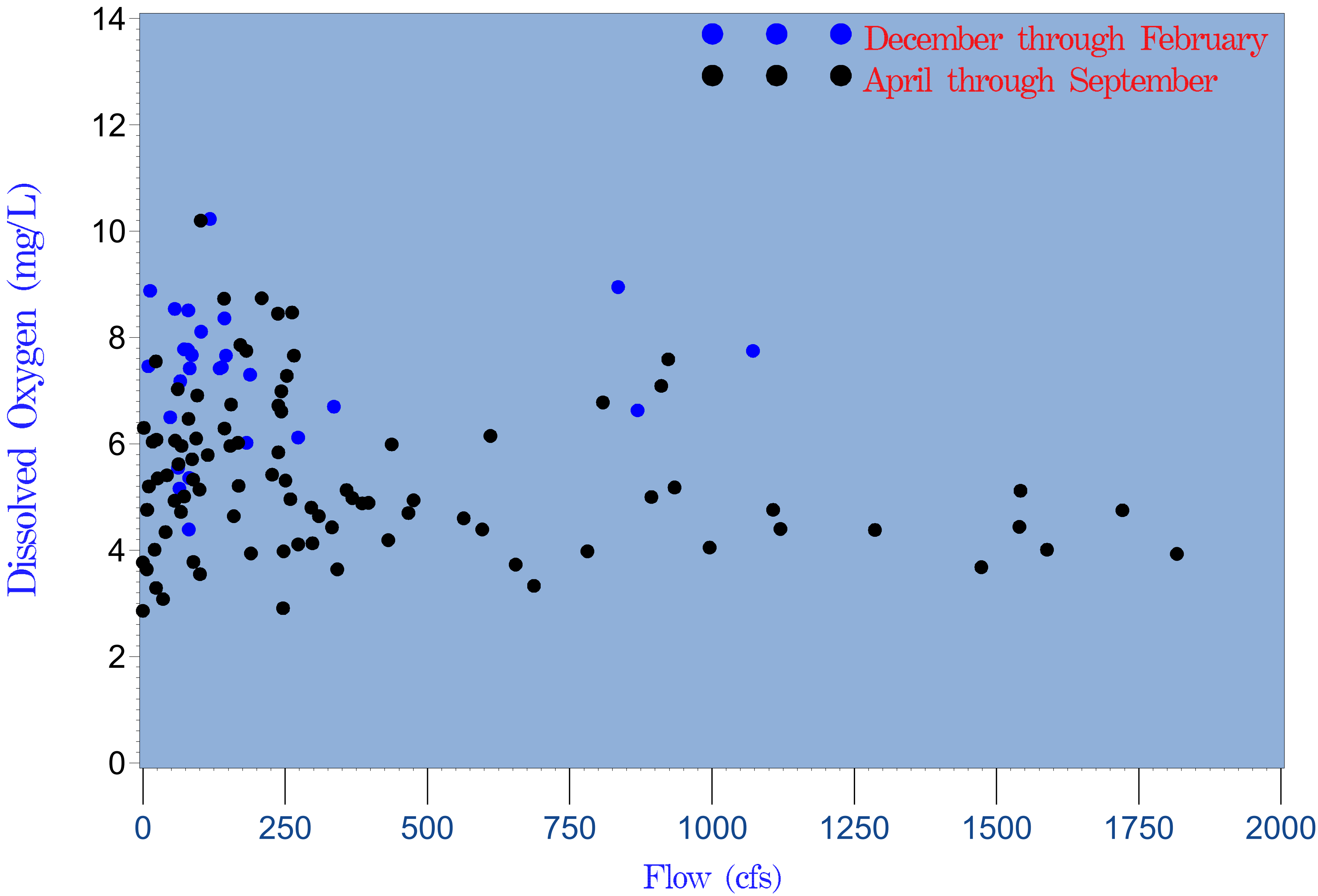


Figure 4.3.60 Bottom D.O. versus 7-day average flow at Station #5 (River Kilometer 6.72), 1991-2004

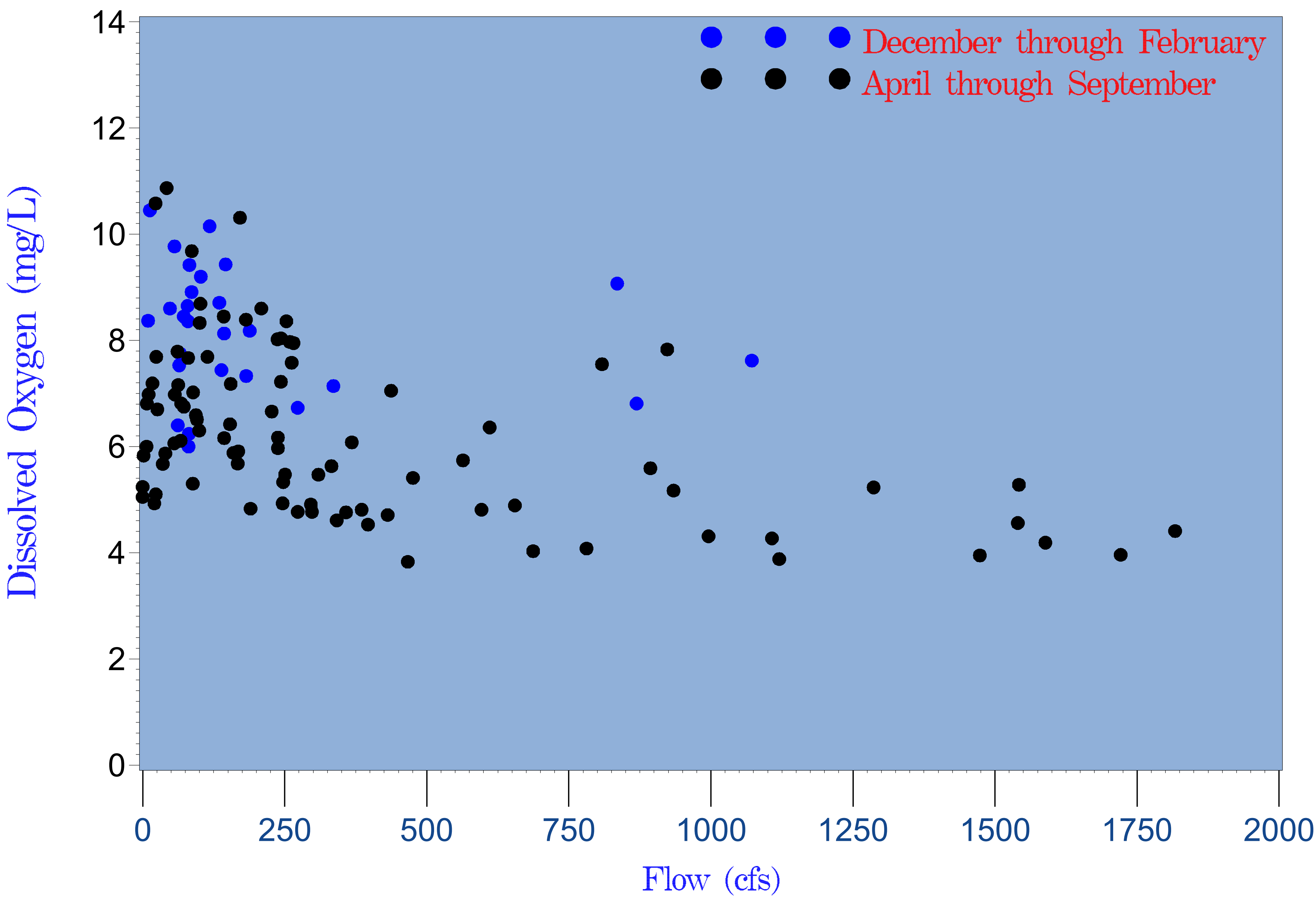


Figure 4.3.61 Surface D.O. versus 7-day average flow at Station #6 (River Kilometer 4.61), 1991-2004

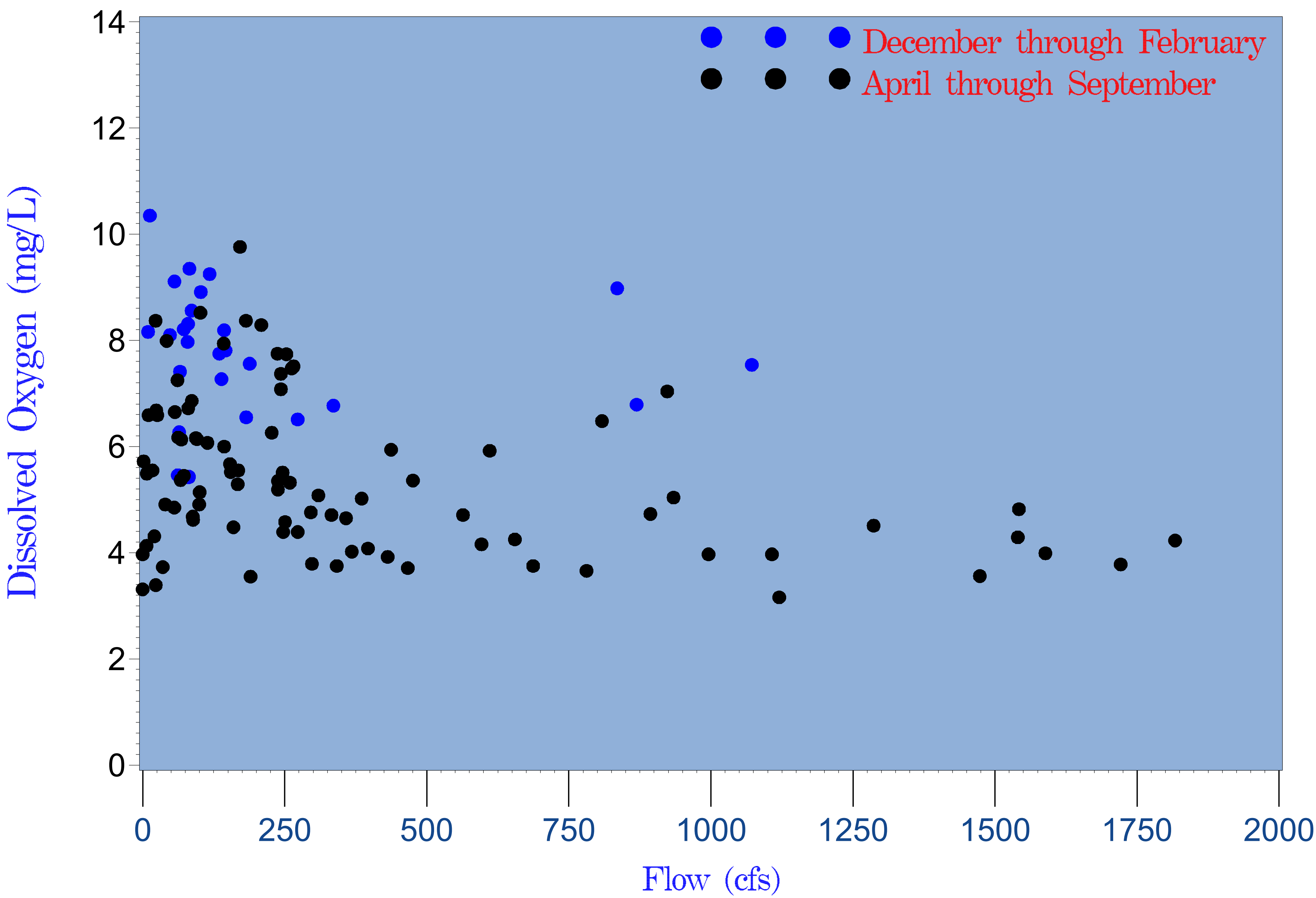


Figure 4.3.62 Bottom D.O. versus 7-day average flow at Station #6 (River Kilometer 4.61), 1991-2004

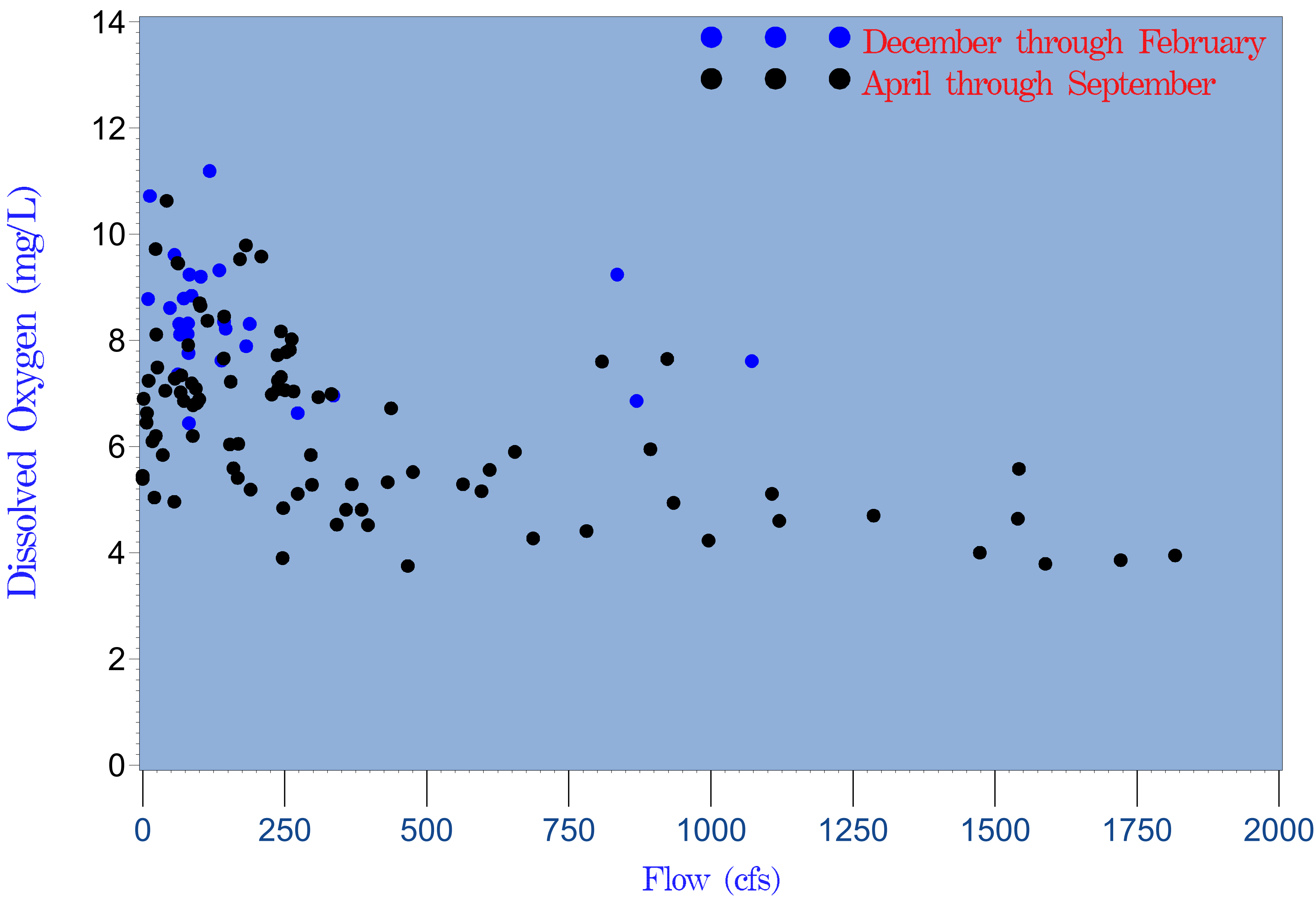


Figure 4.3.63 Surface D.O. versus 7-day average flow at Station #7 (River Kilometer 2.35), 1991-2004

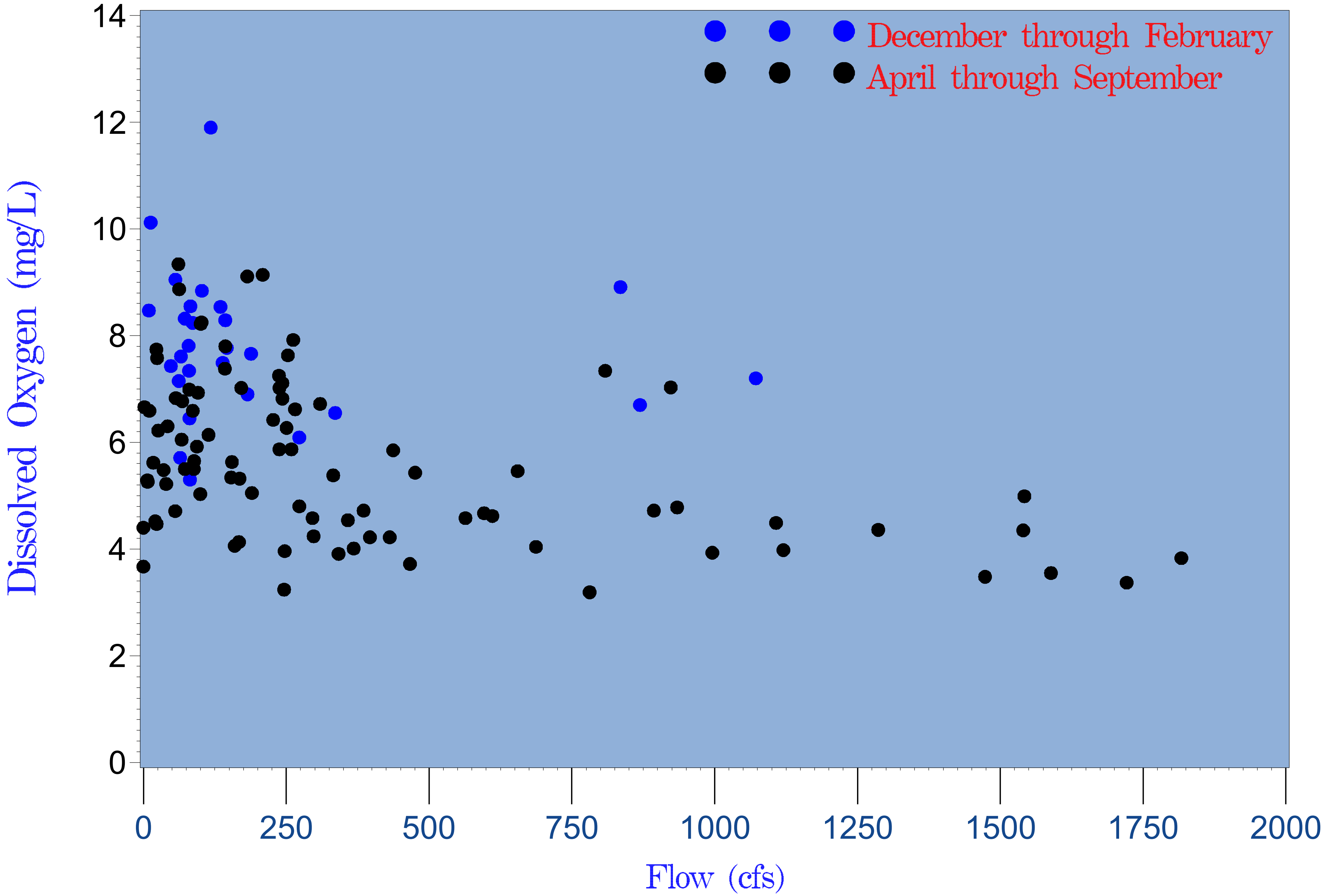


Figure 4.3.64 Bottom D.O. versus 7-day average flow at Station #7 (River Kilometer 2.35), 1991-2004

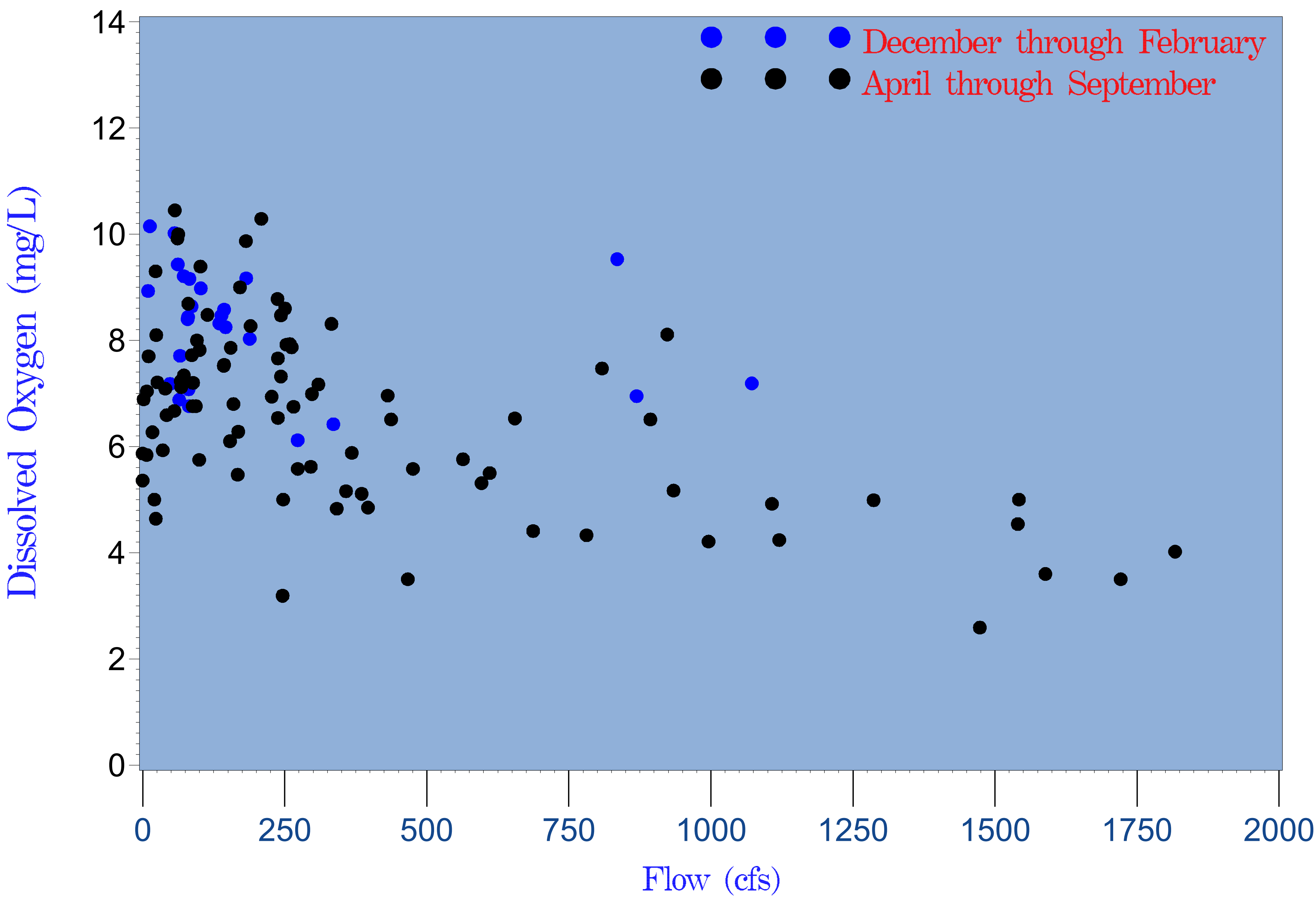


Figure 4.3.65 Surface D.O. versus 7-day average flow at Station #16 (River Kilometer 1.26), 1991-2004

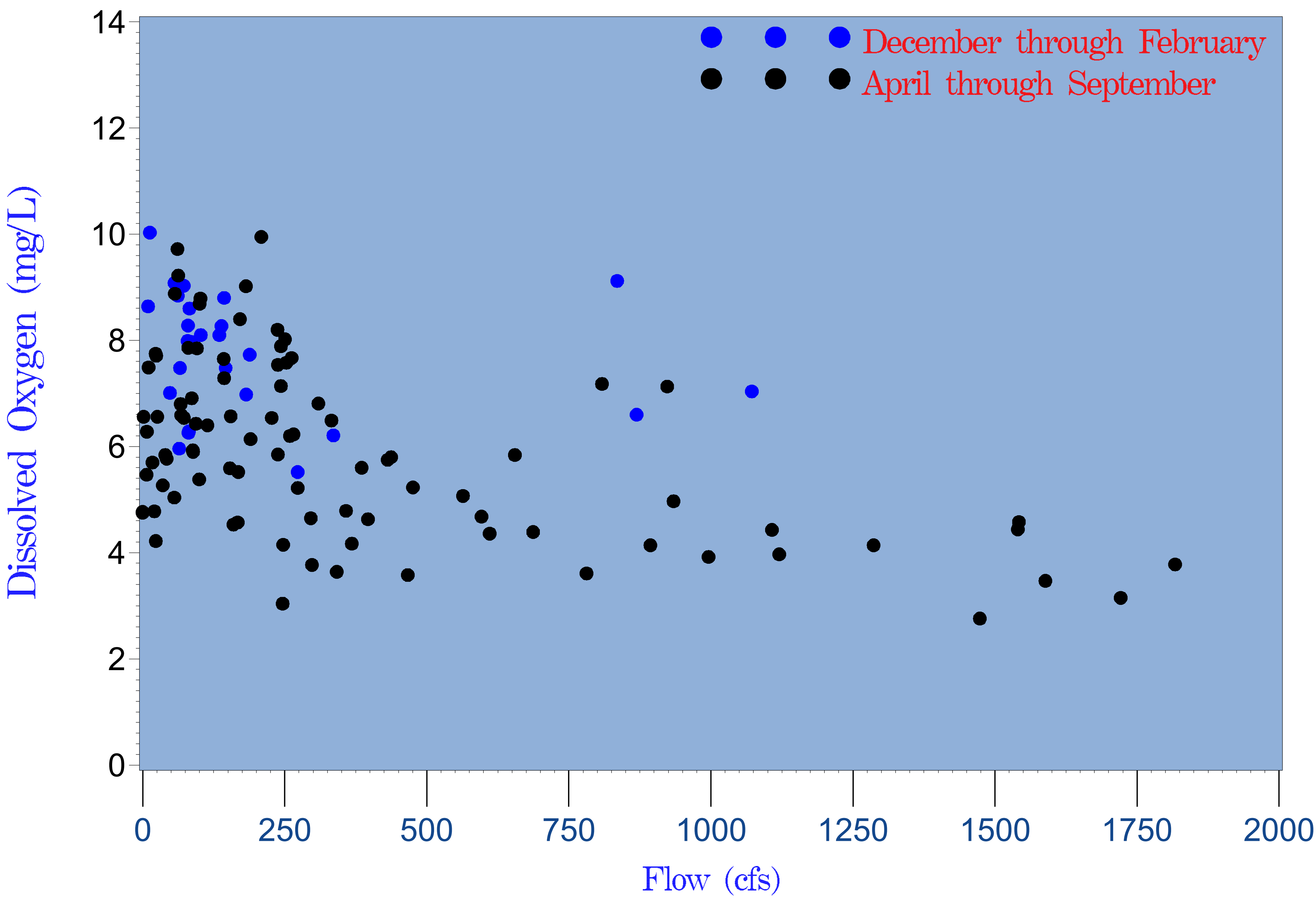


Figure 4.3.66 Bottom D.O. versus 7-day average flow at Station #16 (River Kilometer 1.26), 1991-2004

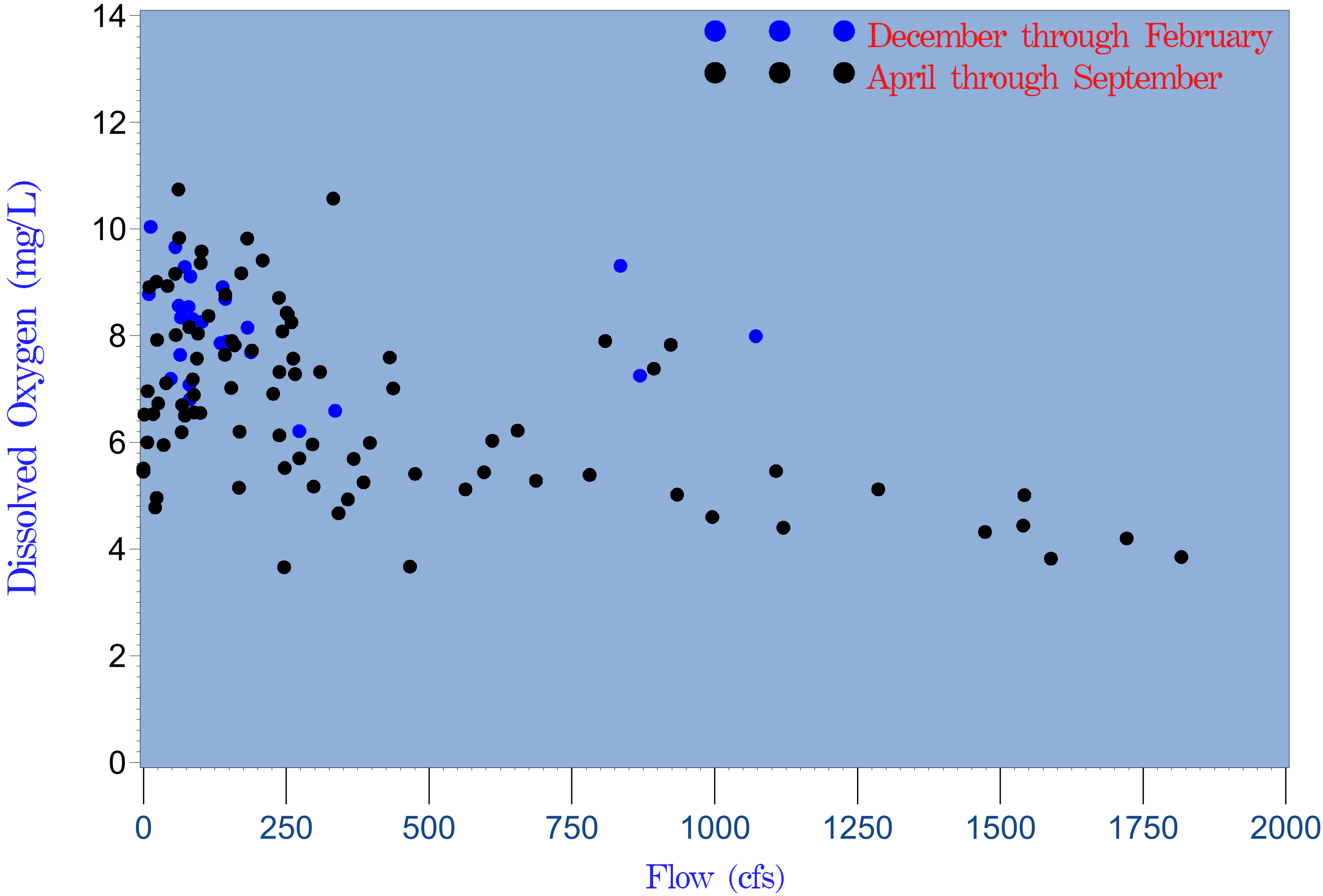


Figure 4.3.67 Surface D.O. versus 7-day average flow at Station #17 (River Kilometer 0.43), 1991-2004

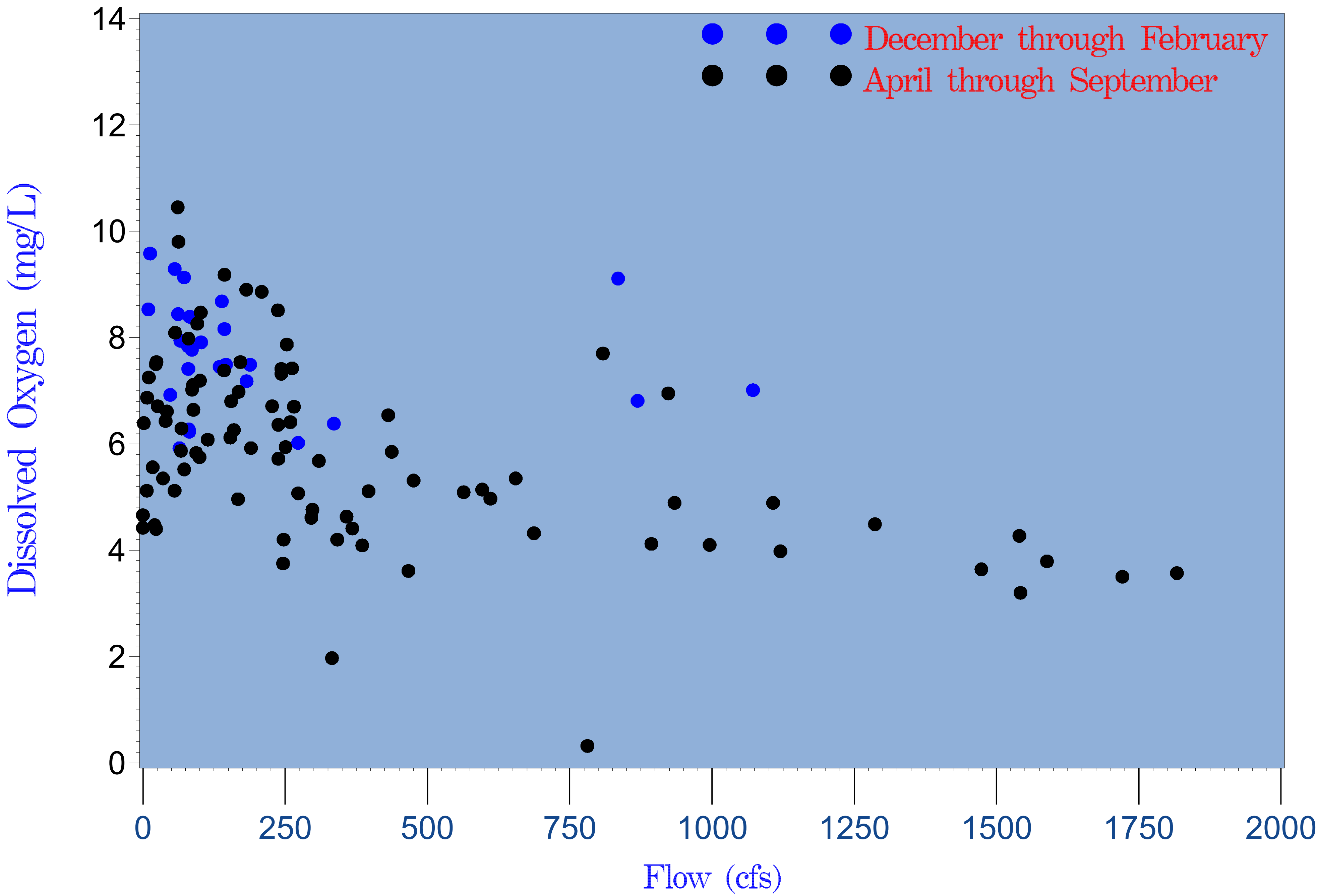


Figure 4.3.68 Bottom D.O. versus 7-day average flow at Station #17 (River Kilometer 0.43), 1991-2004

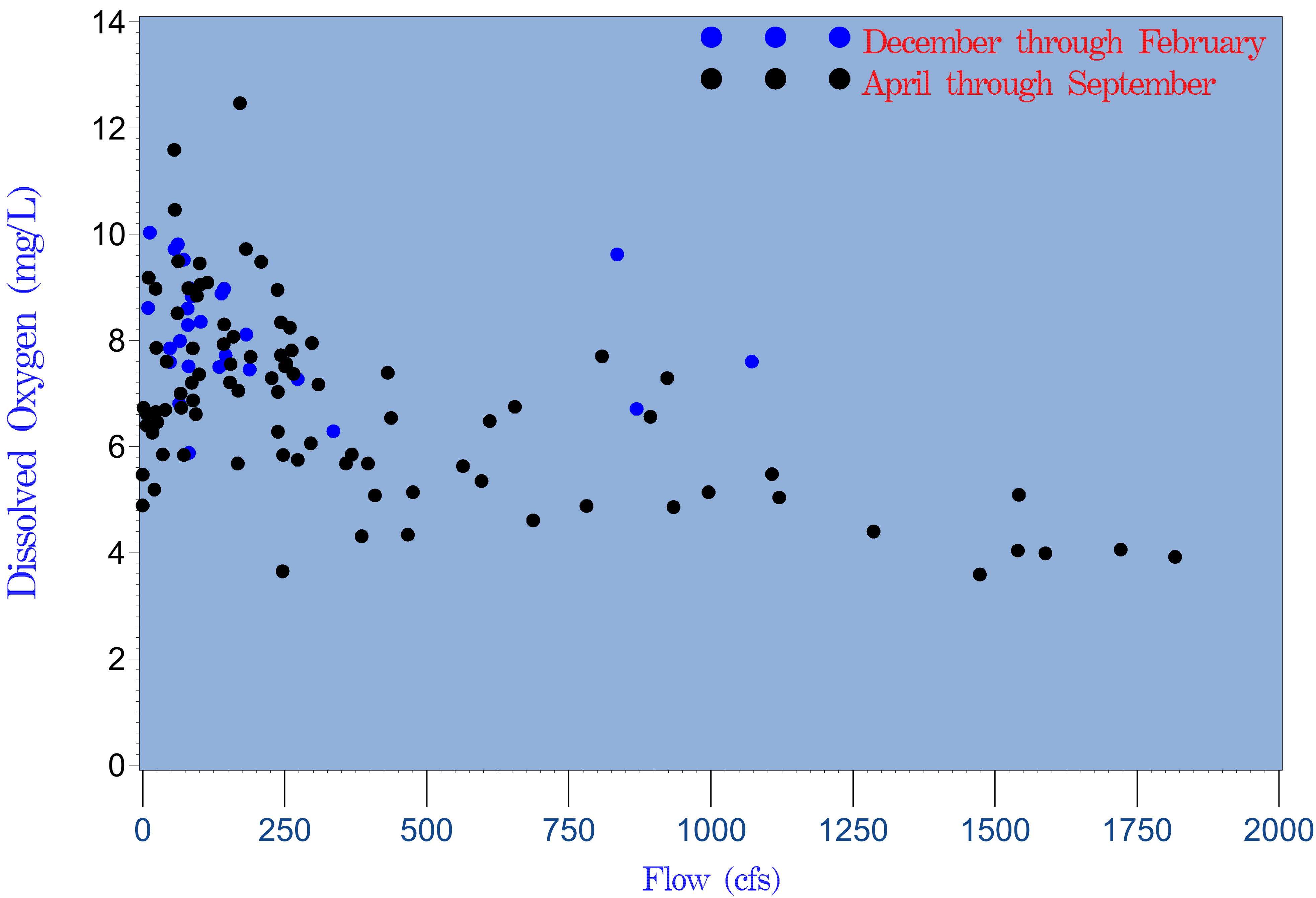


Figure 4.3.69 Surface D.O. versus 7-day average flow at Station #9 (River Kilometer -0.37), 1991-2004

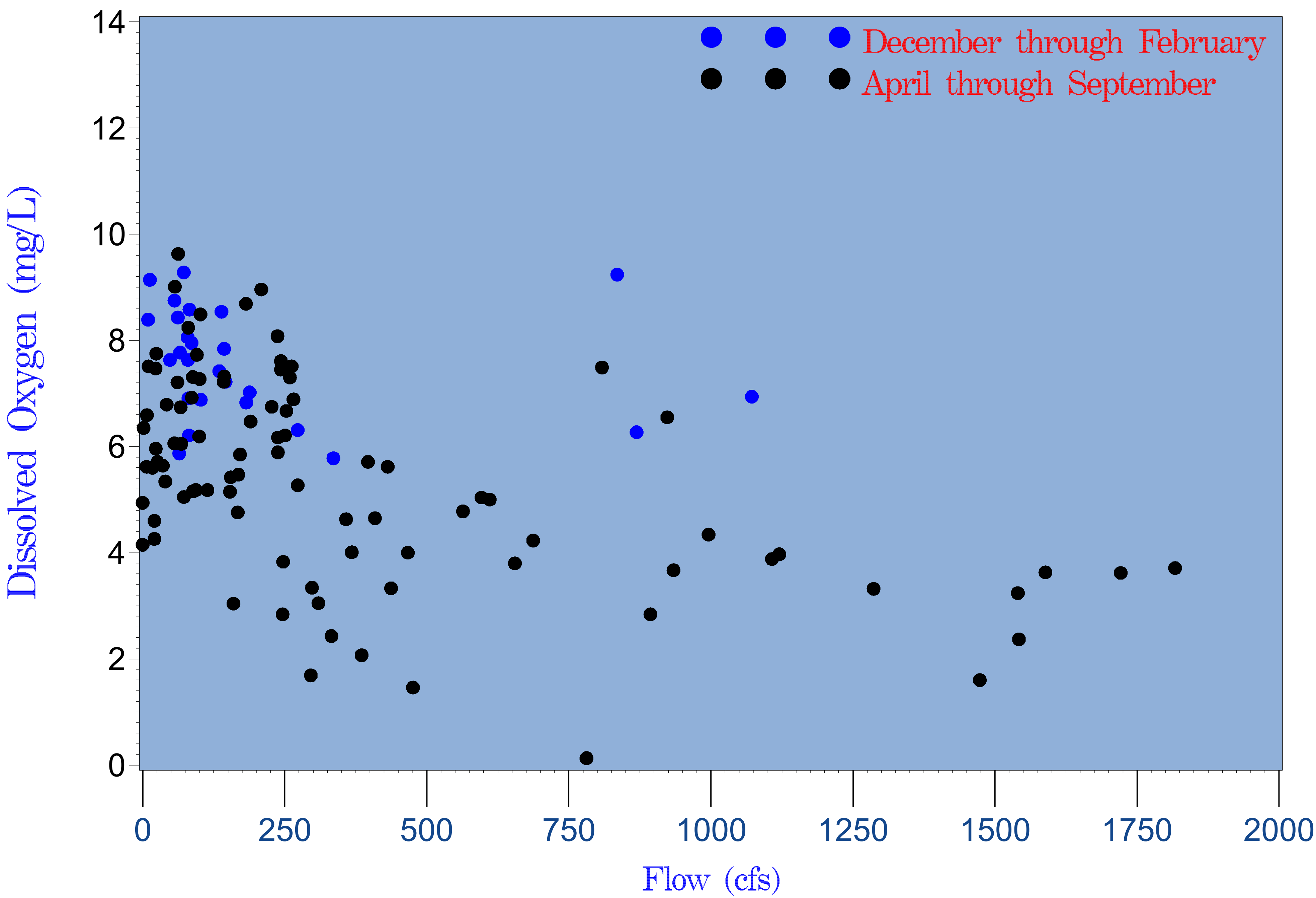


Figure 4.3.70 Bottom D.O. versus 7-day average flow at Station #9 (River Kilometer -0.37), 1991-2004

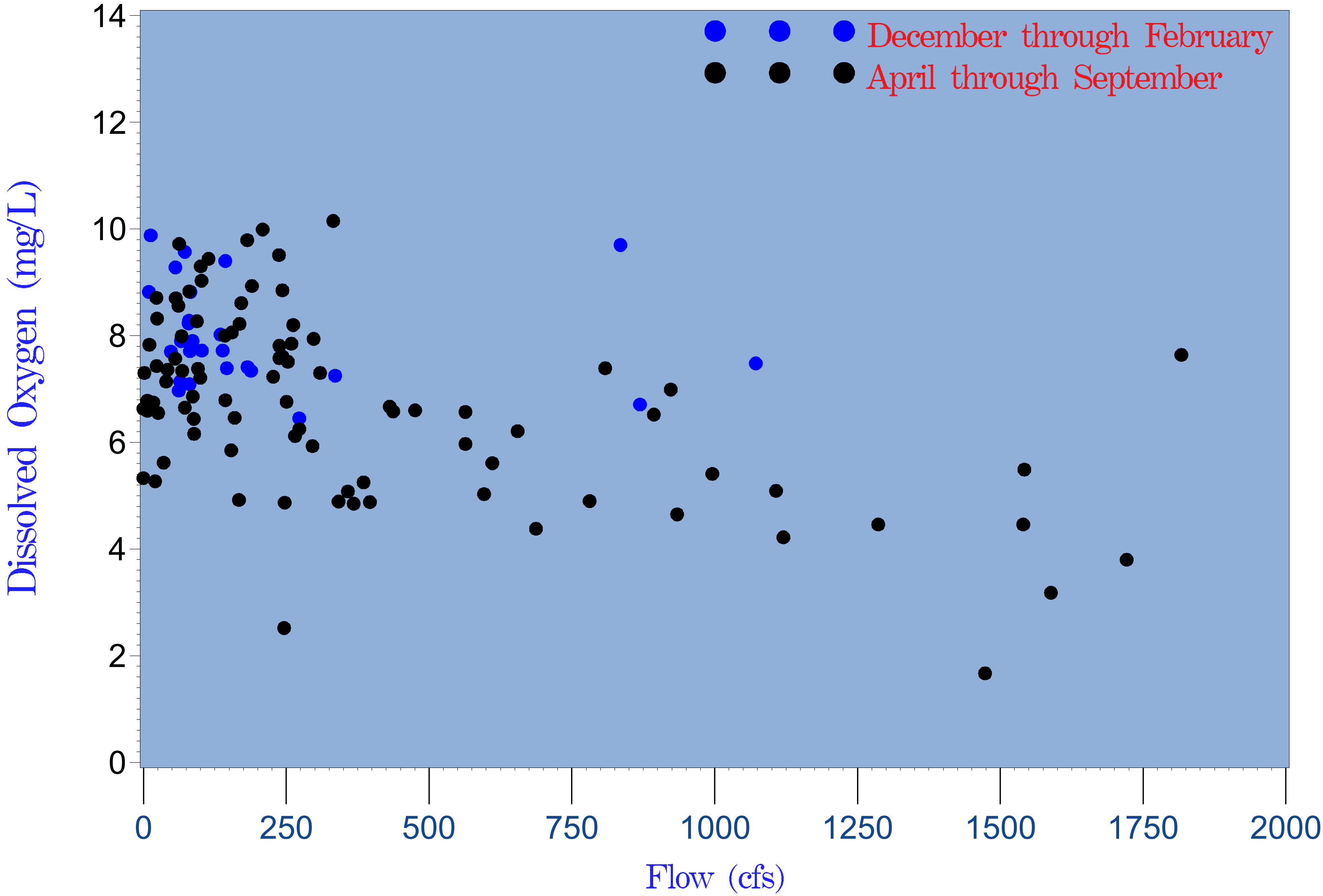


Figure 4.3.71 Surface D.O. versus 7-day average flow at Station #8 (Lower Peace River), 1991-2004

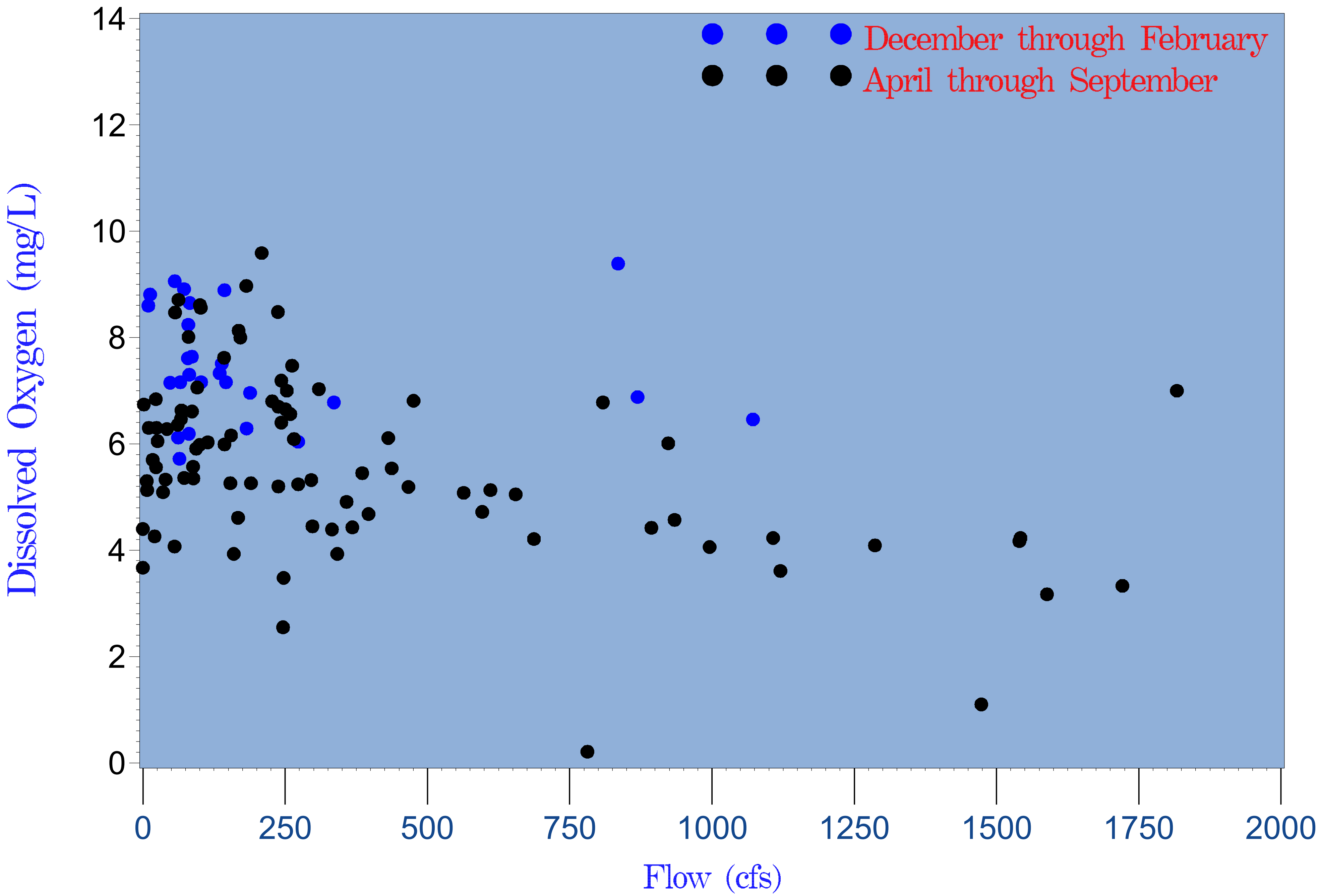


Figure 4.3.72 Bottom D.O. versus 7-day average flow at Station #8 (Lower Peace River), 1991-2004

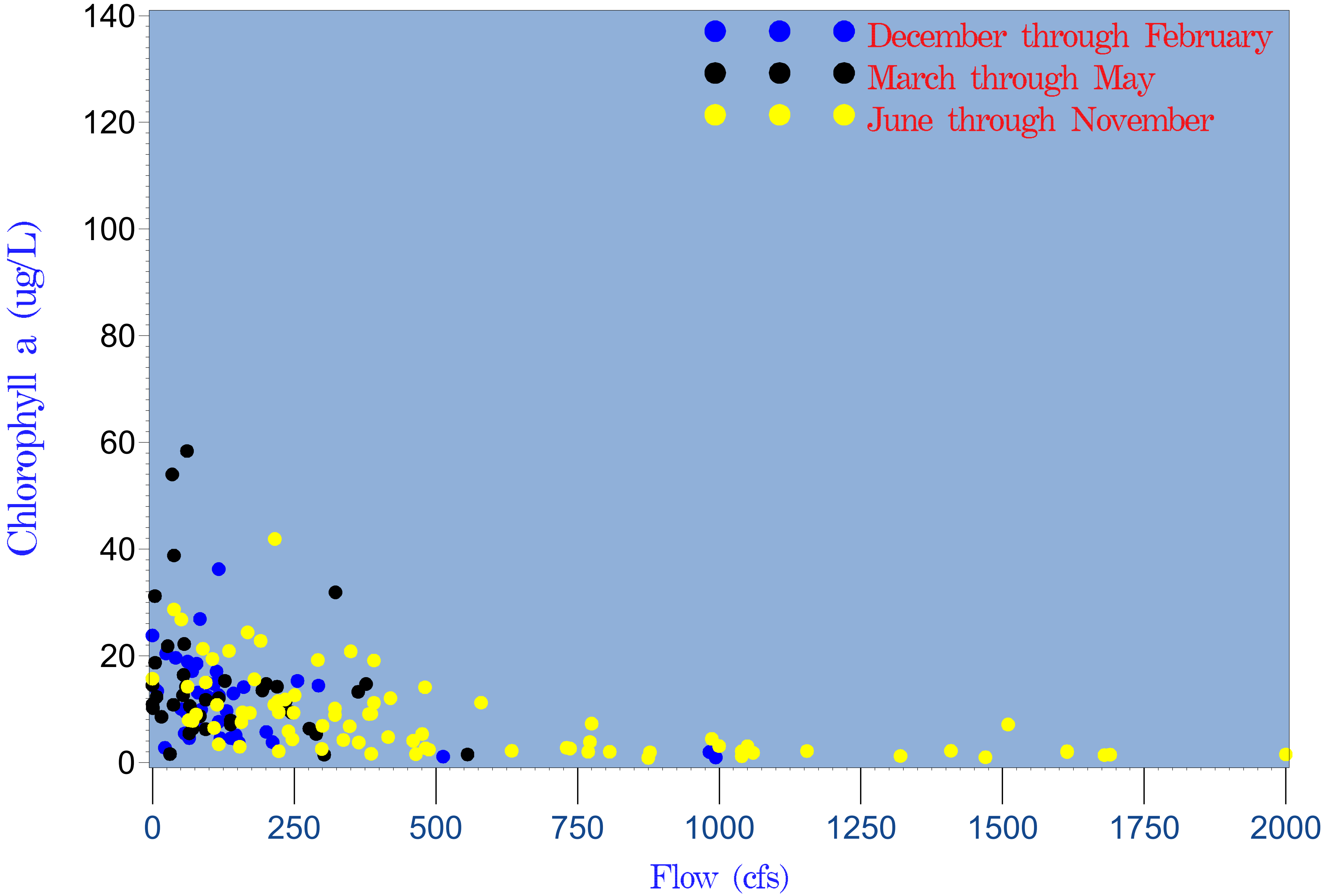


Figure 4.3.73 Surface chlorophyll a versus flow at Station #4 (River Kilometer 8.74), 1991-2004

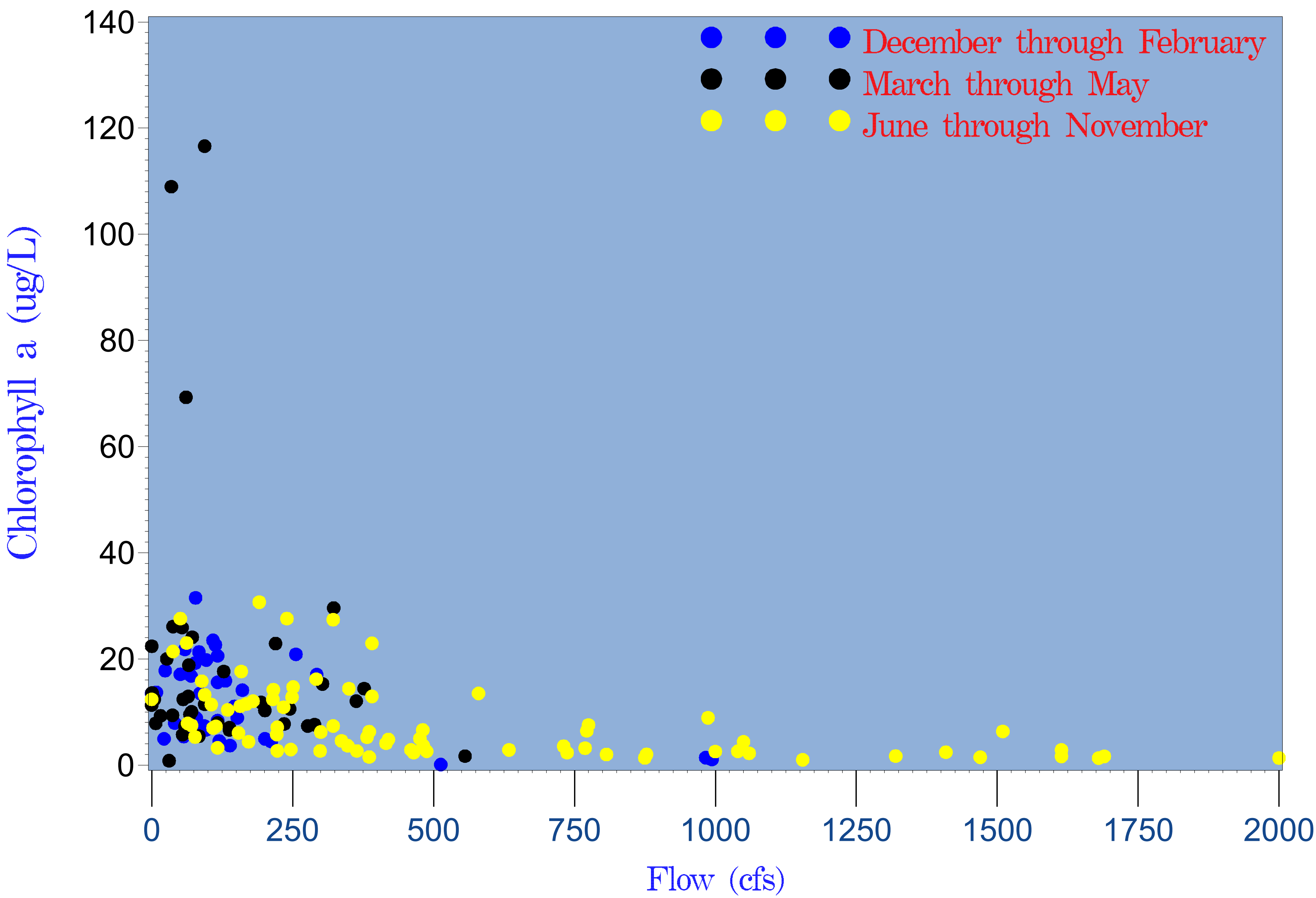


Figure 4.3.74 Surface chlorophyll a versus flow at Station #5 (River Kilometer 6.72), 1991-2004

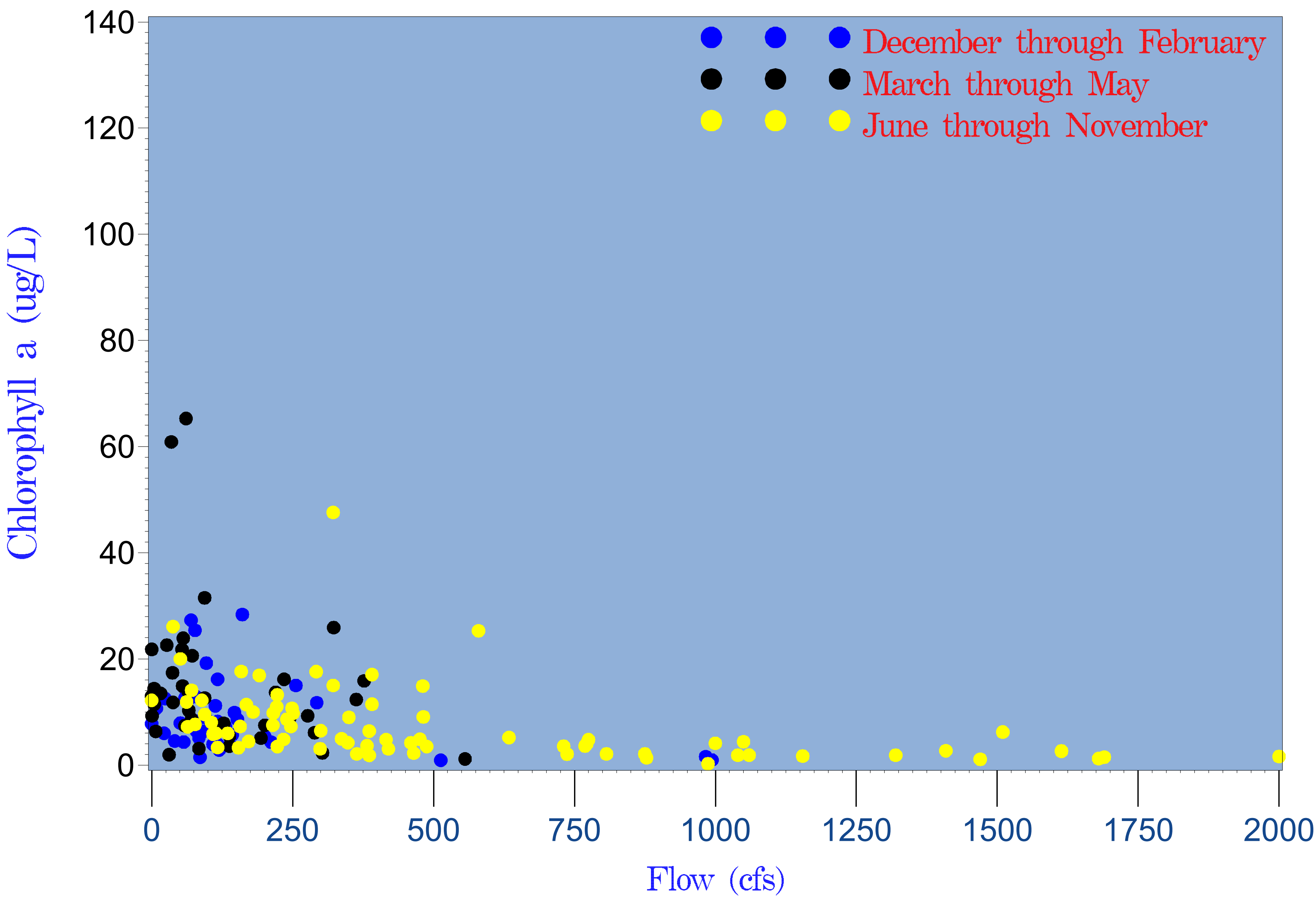


Figure 4.3.75 Surface chlorophyll a versus flow at Station #6 (River Kilometer 4.61), 1991-2004

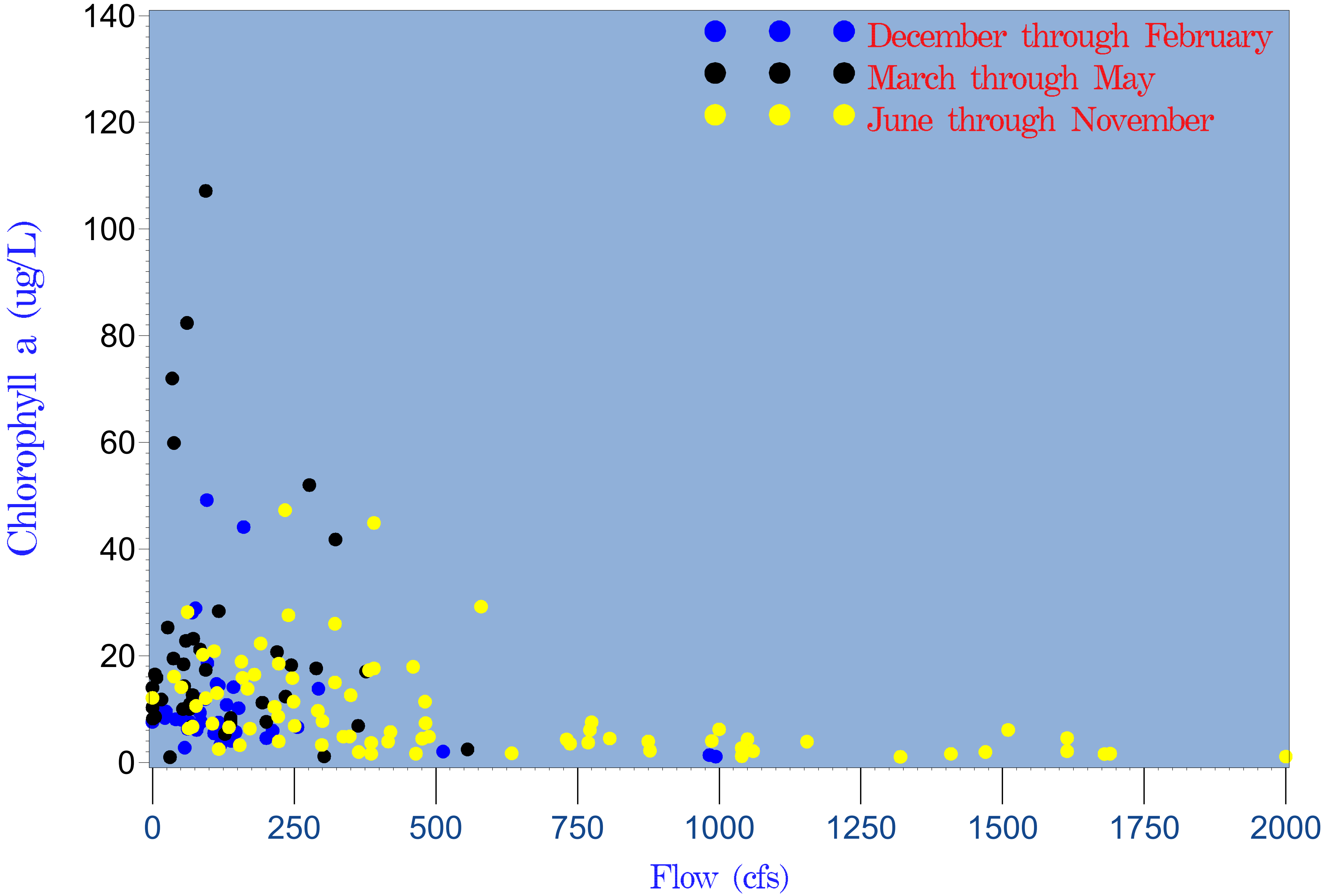


Figure 4.3.76 Surface chlorophyll a versus flow at Station #7 (River Kilometer 2.35), 1991-2004

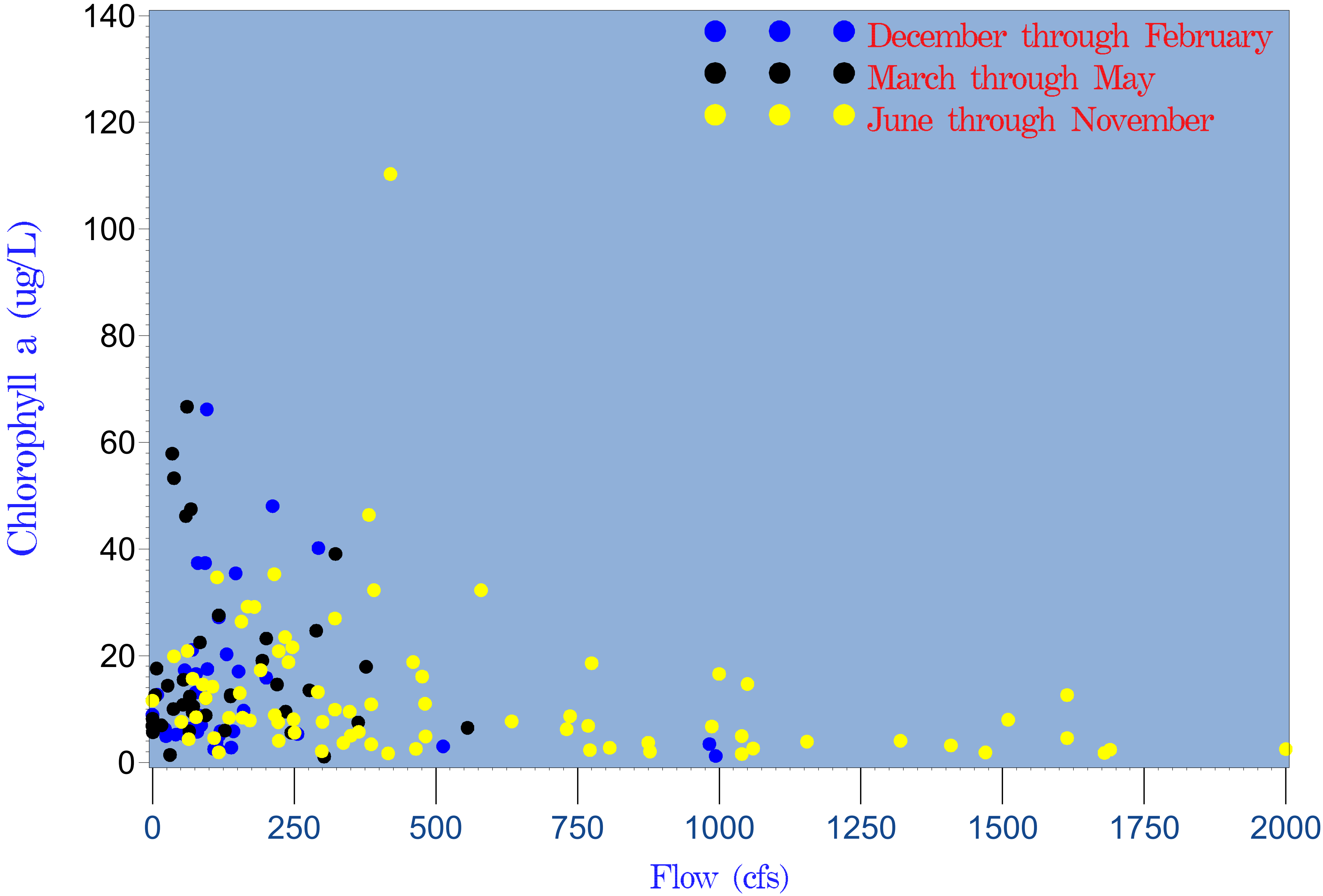


Figure 4.3.77 Surface chlorophyll a versus flow at Station #9 (River Kilometer -0.37), 1991-2004

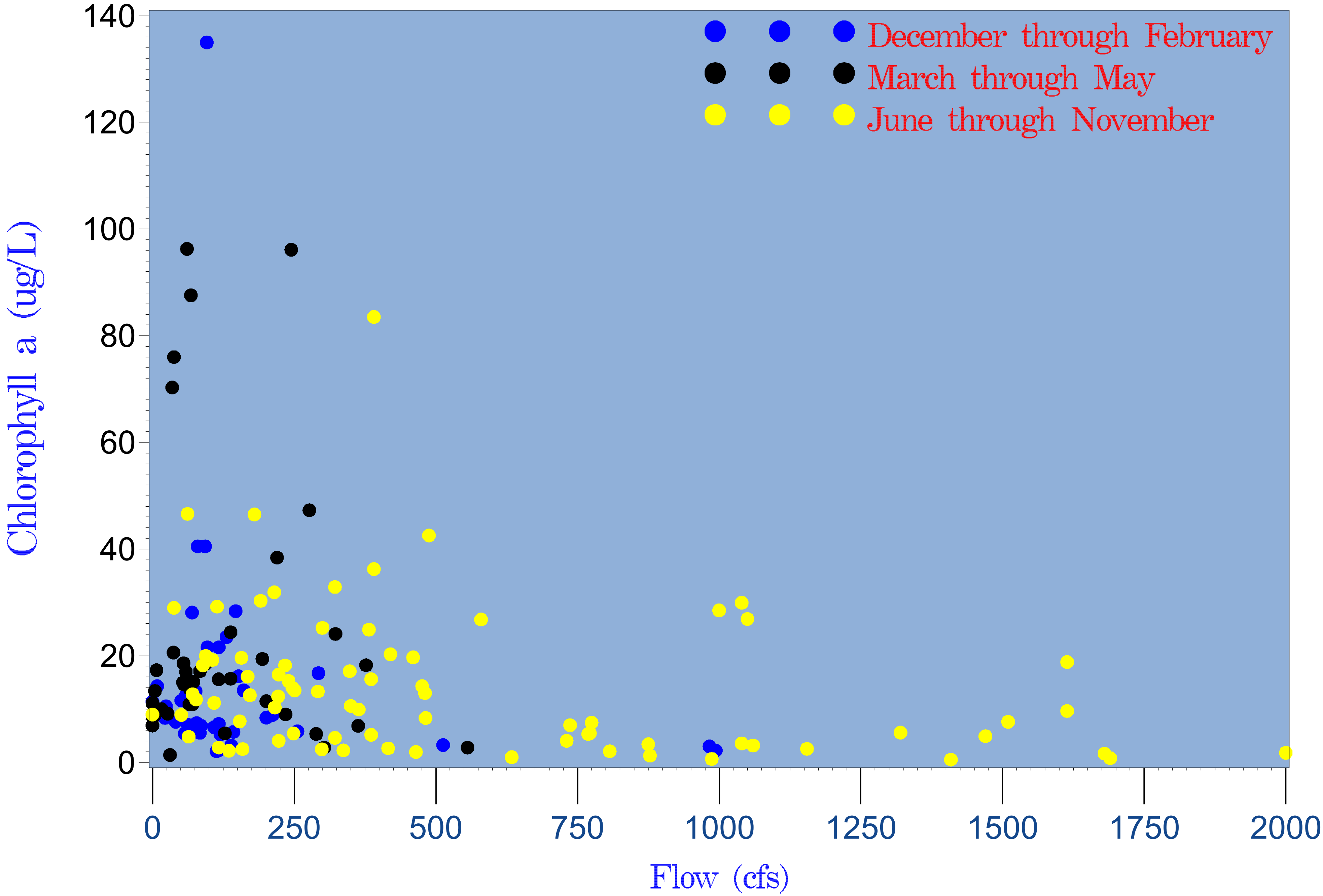


Figure 4.3.78 Surface chlorophyll a versus flow at Station #8 (Lower Peace River), 1991-2004

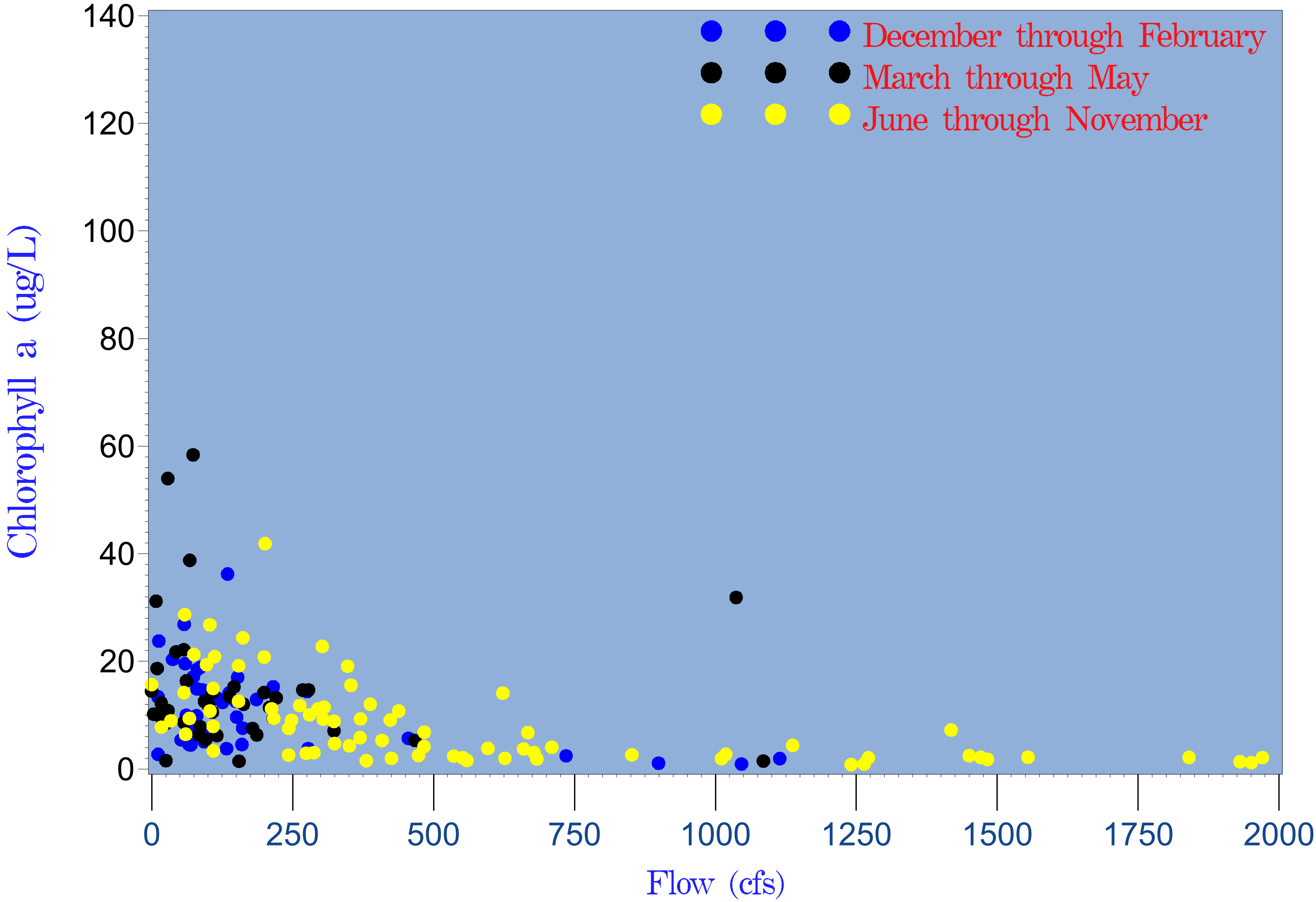


Figure 4.3.79 Surface chlorophyll a versus 10-day average flow at Station #4 (River Kilometer 8.74), 1991-2004

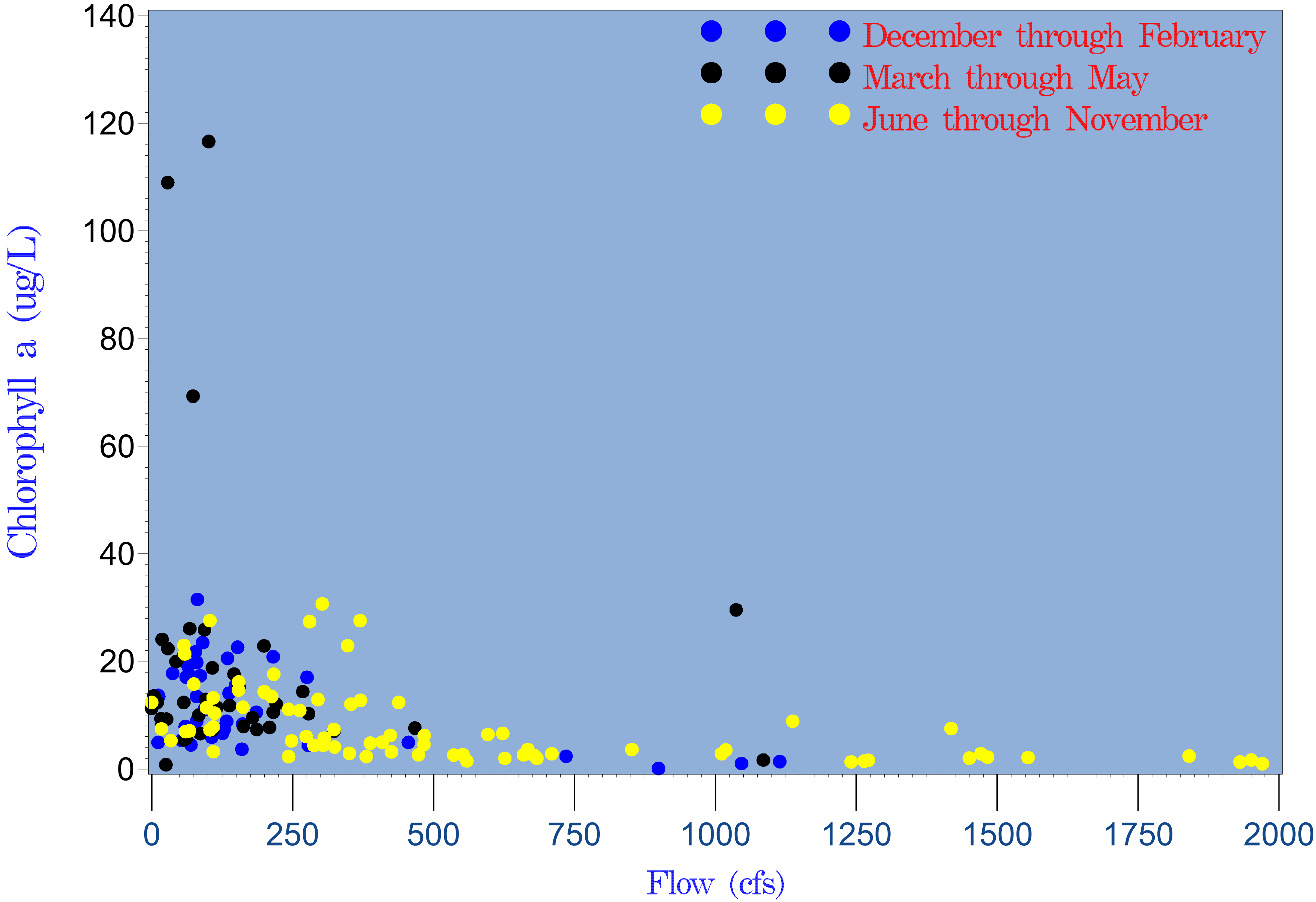


Figure 4.3.80 Surface chlorophyll a versus 10-day average flow at Station #5 (River Kilometer 6.72), 1991-2004

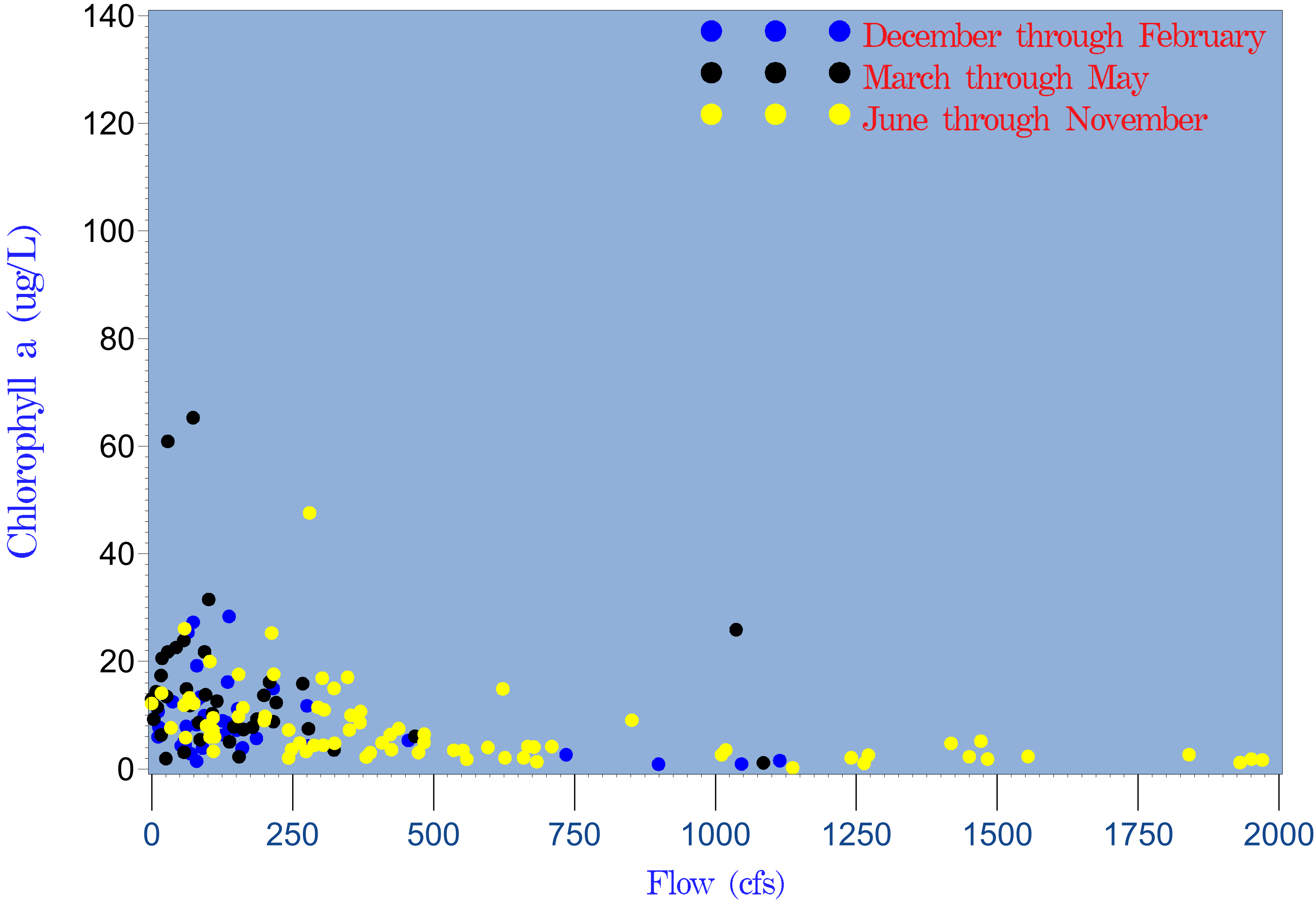


Figure 4.3.81 Surface chlorophyll a versus 10-day average flow at Station #6 (River Kilometer 4.61), 1991-2004

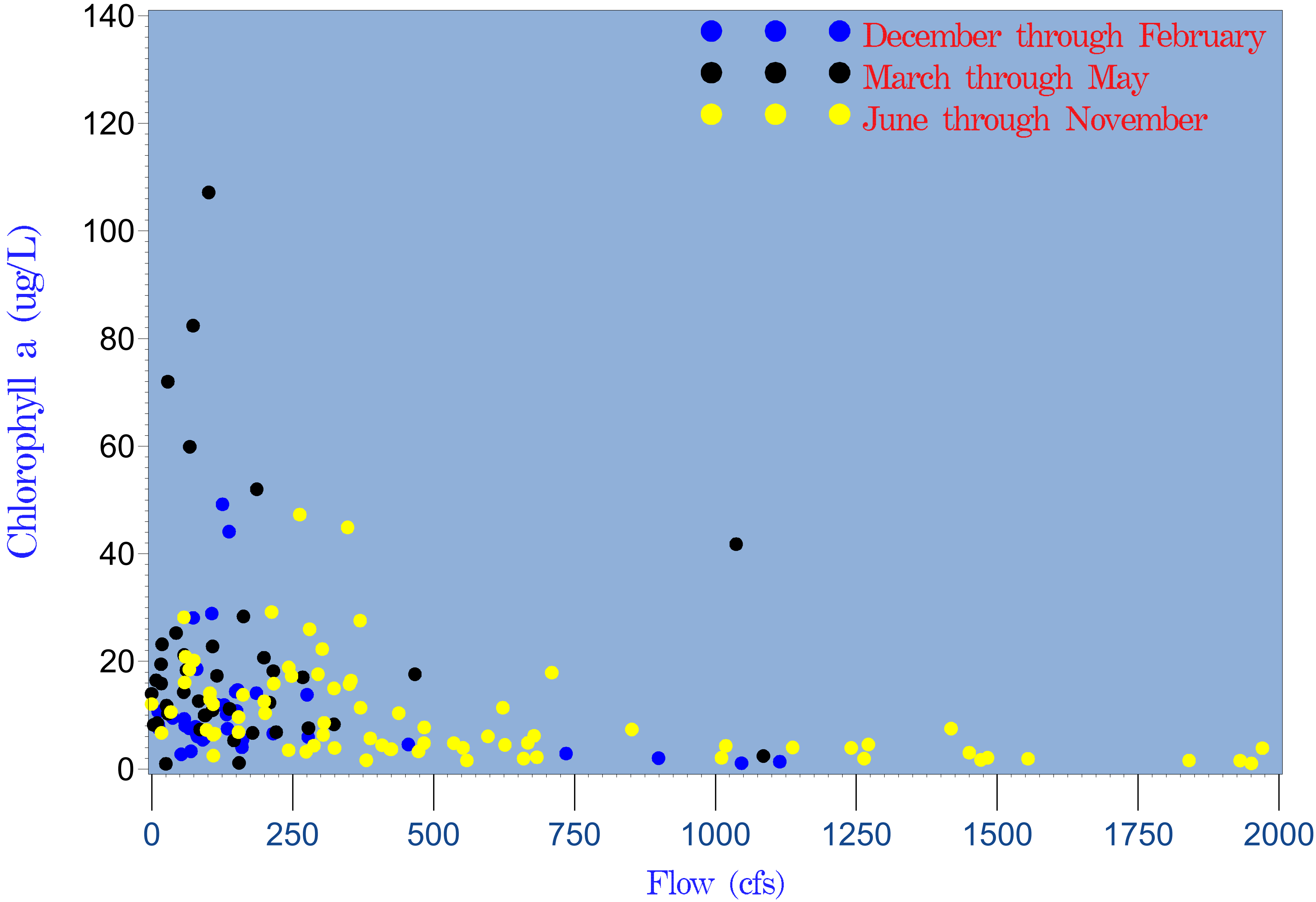


Figure 4.3.82 Surface chlorophyll a versus 10-day average flow at Station #7 (River Kilometer 2.35), 1991-2004

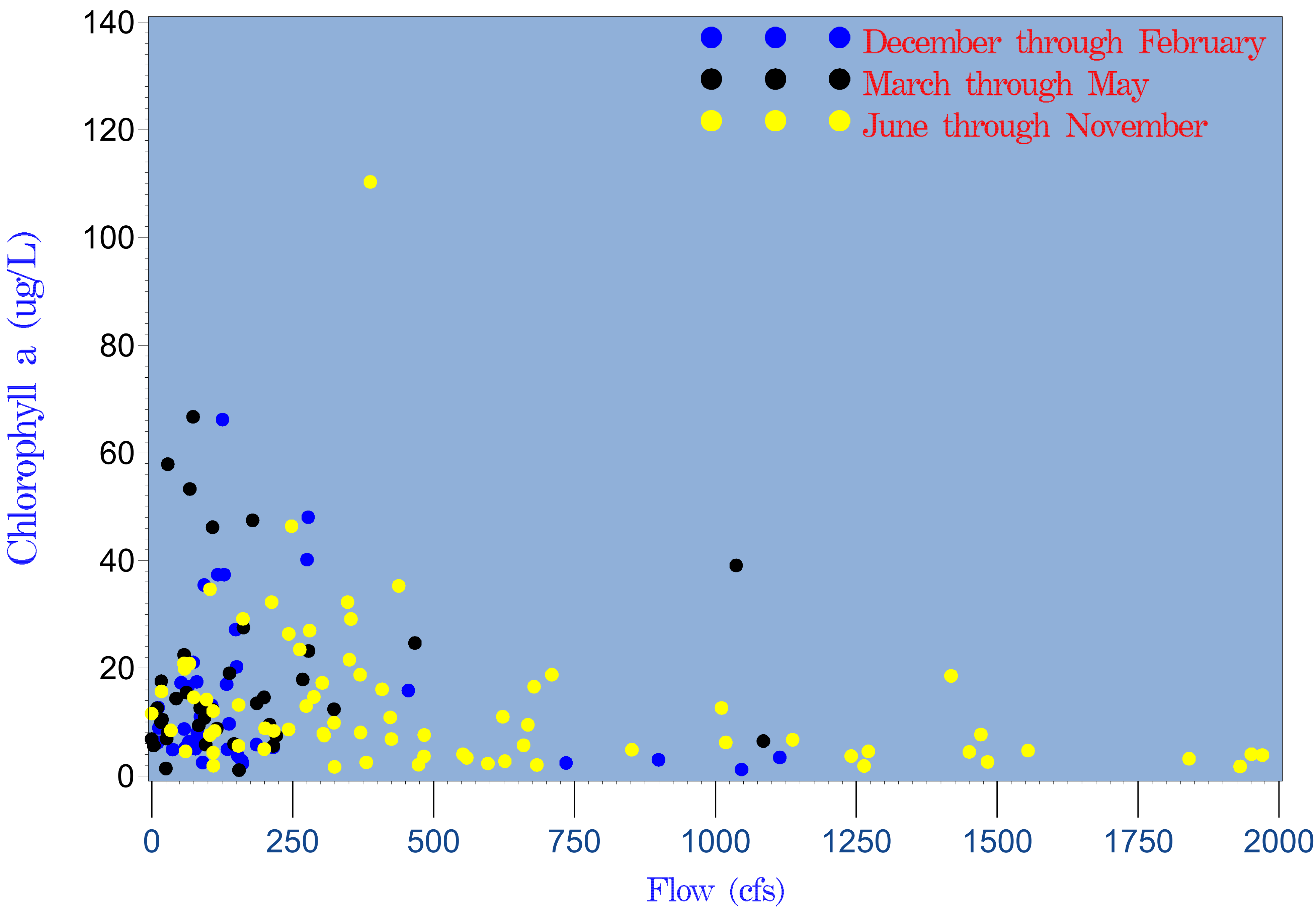


Figure 4.3.83 Surface chlorophyll a versus 10-day average flow at Station #9 (River Kilometer -0.37), 1991-2004

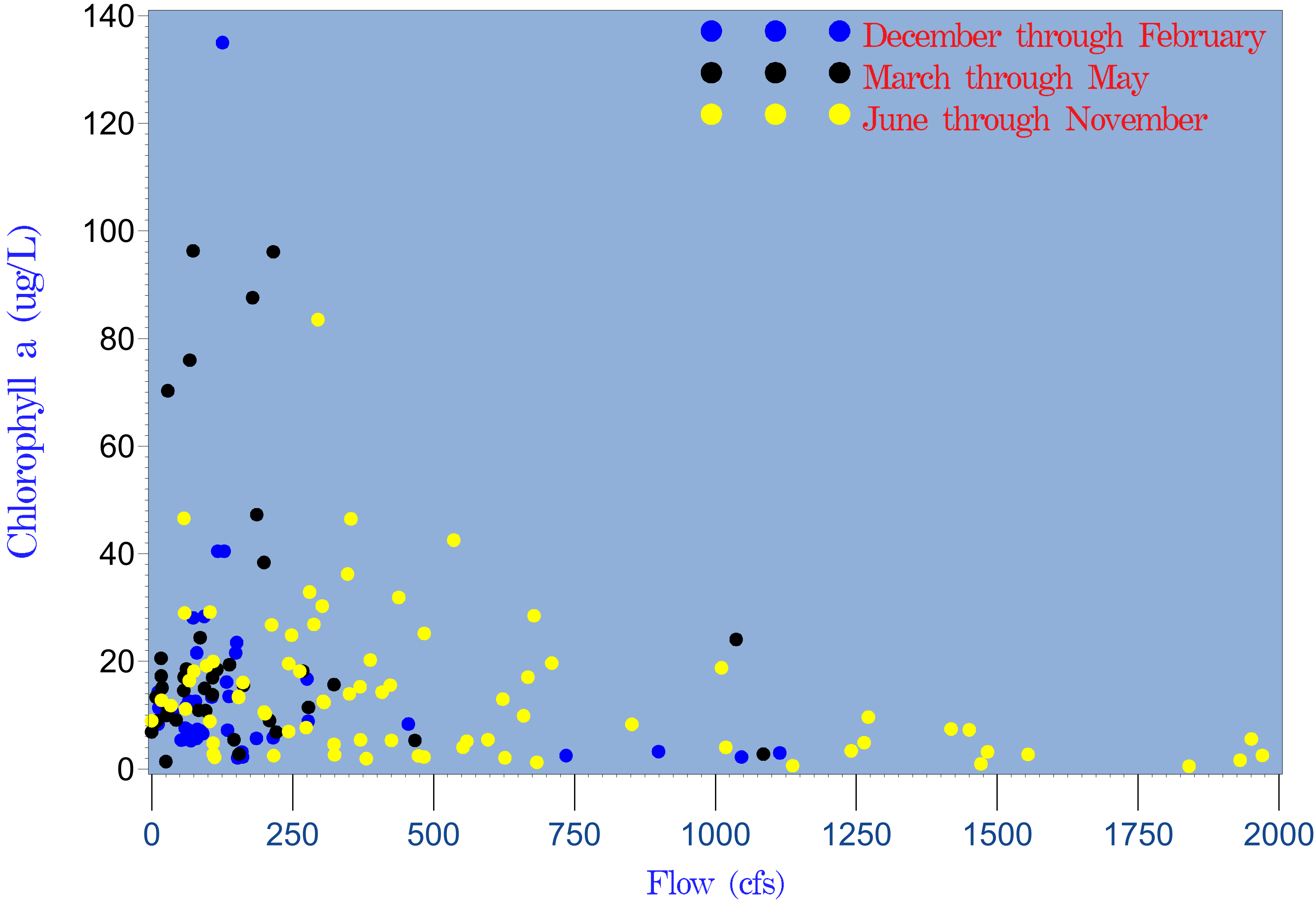


Figure 4.3.84 Surface chlorophyll a versus 10-day average flow at Station #8 (Lower Peace River), 1991-2004

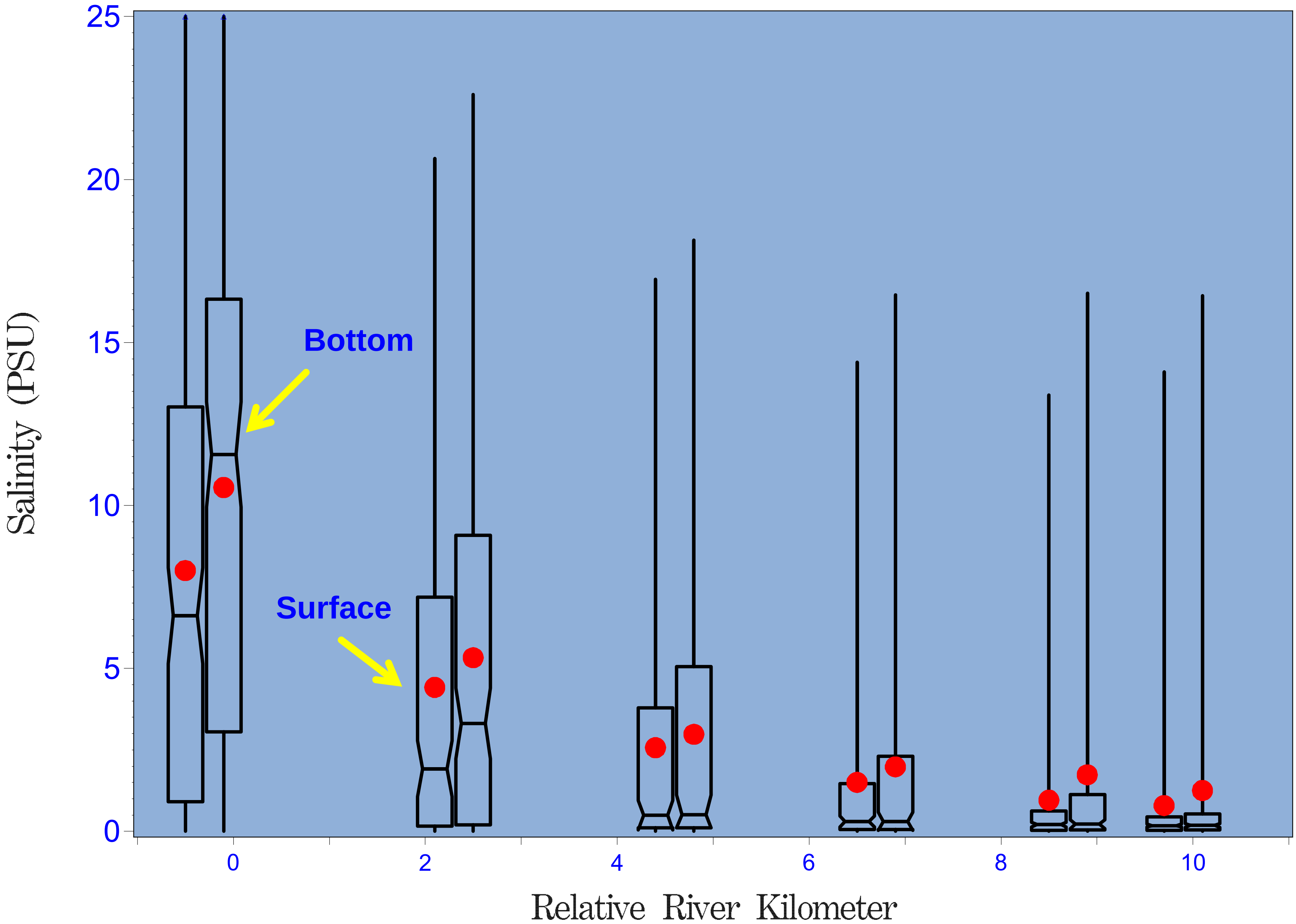


Figure 4.3.85 Surface and bottom salinities along Shell Creek transect by river kilometer

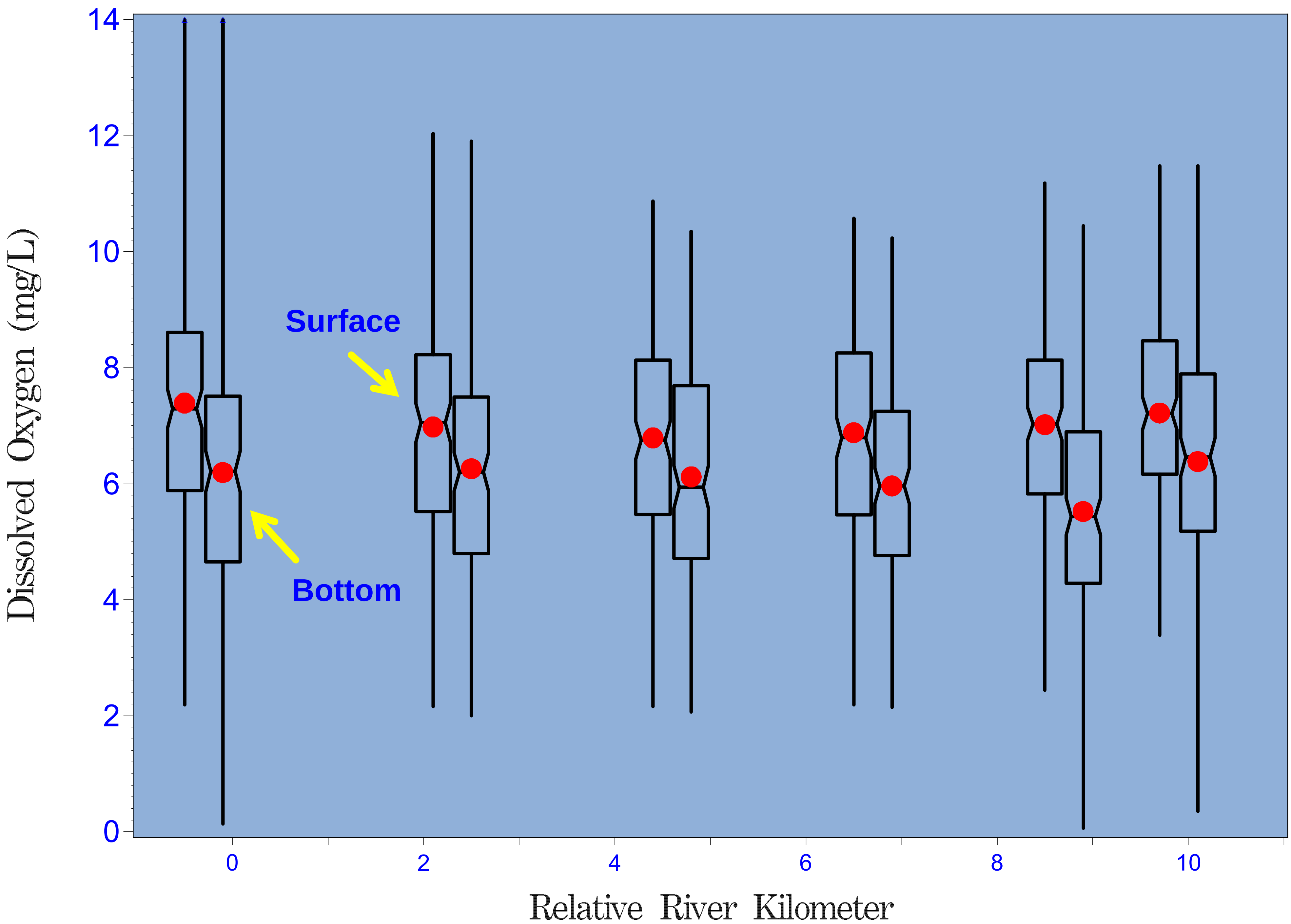


Figure 4.3.86 Surface and bottom dissolved oxygen along Shell Creek transect by river kilometer

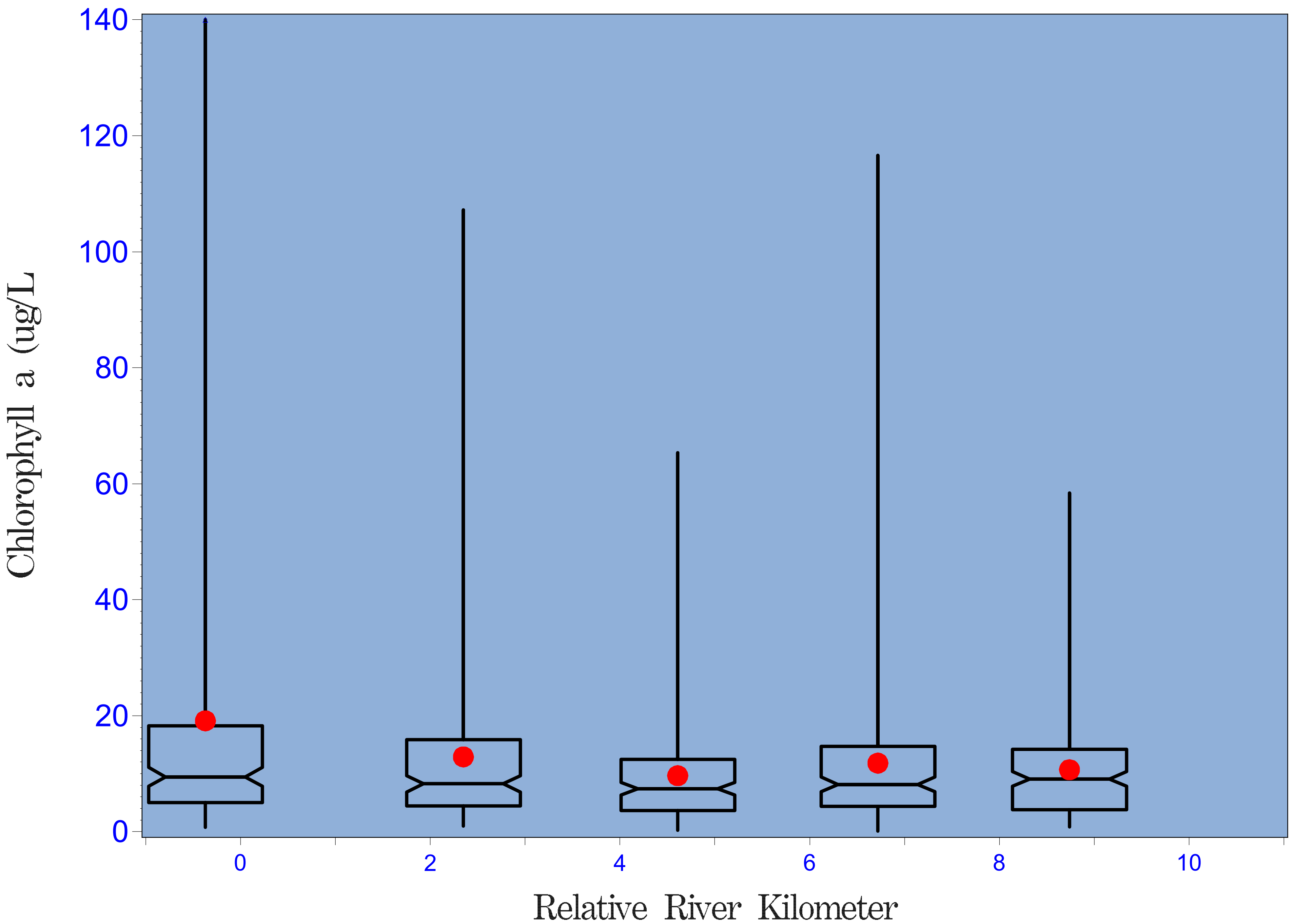


Figure 4.3.87 Surface chlorophyll along Shell Creek transect by river kilometer

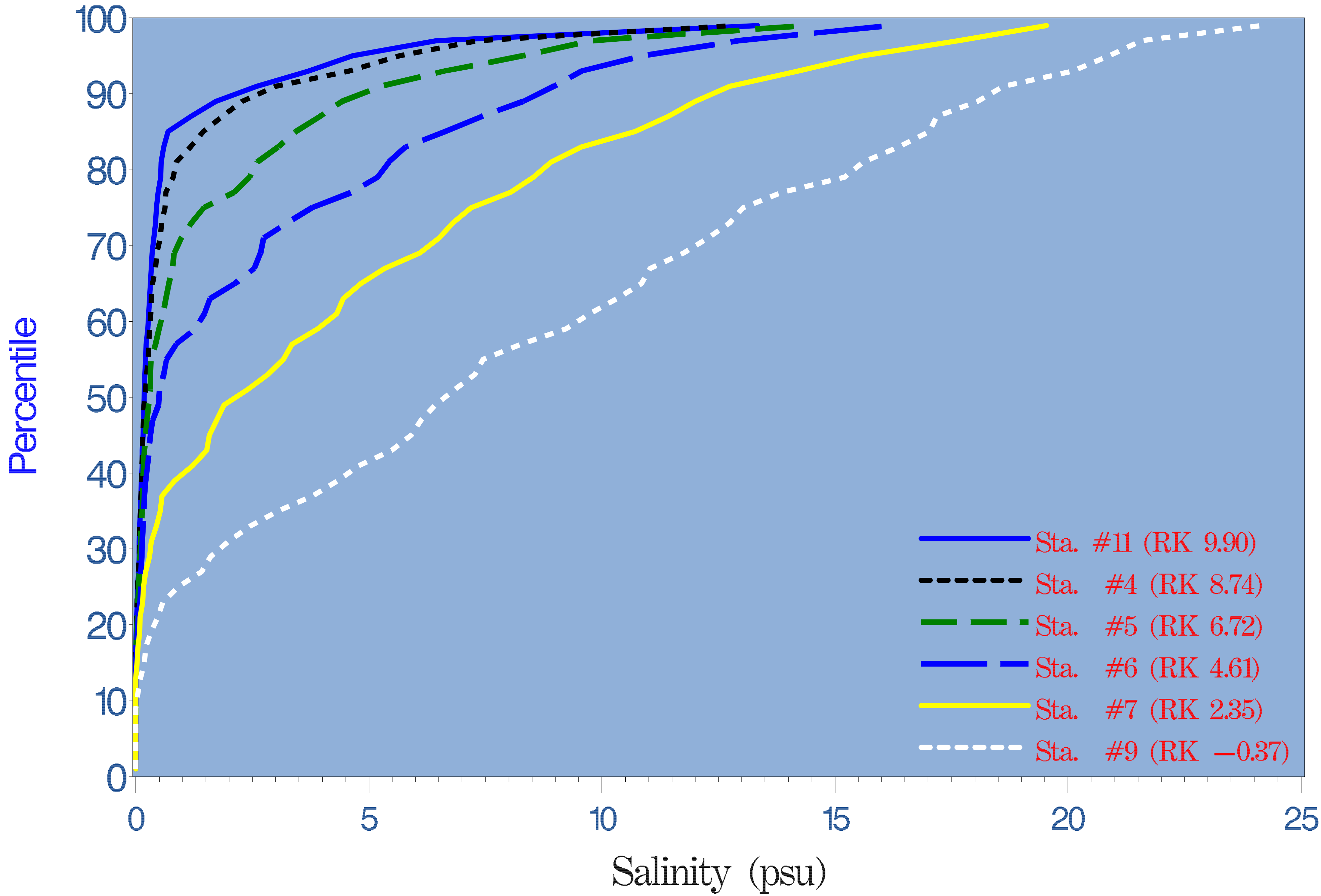


Figure 4.3.88 CDF plots of surface salinity among selected Shell Creek transect locations

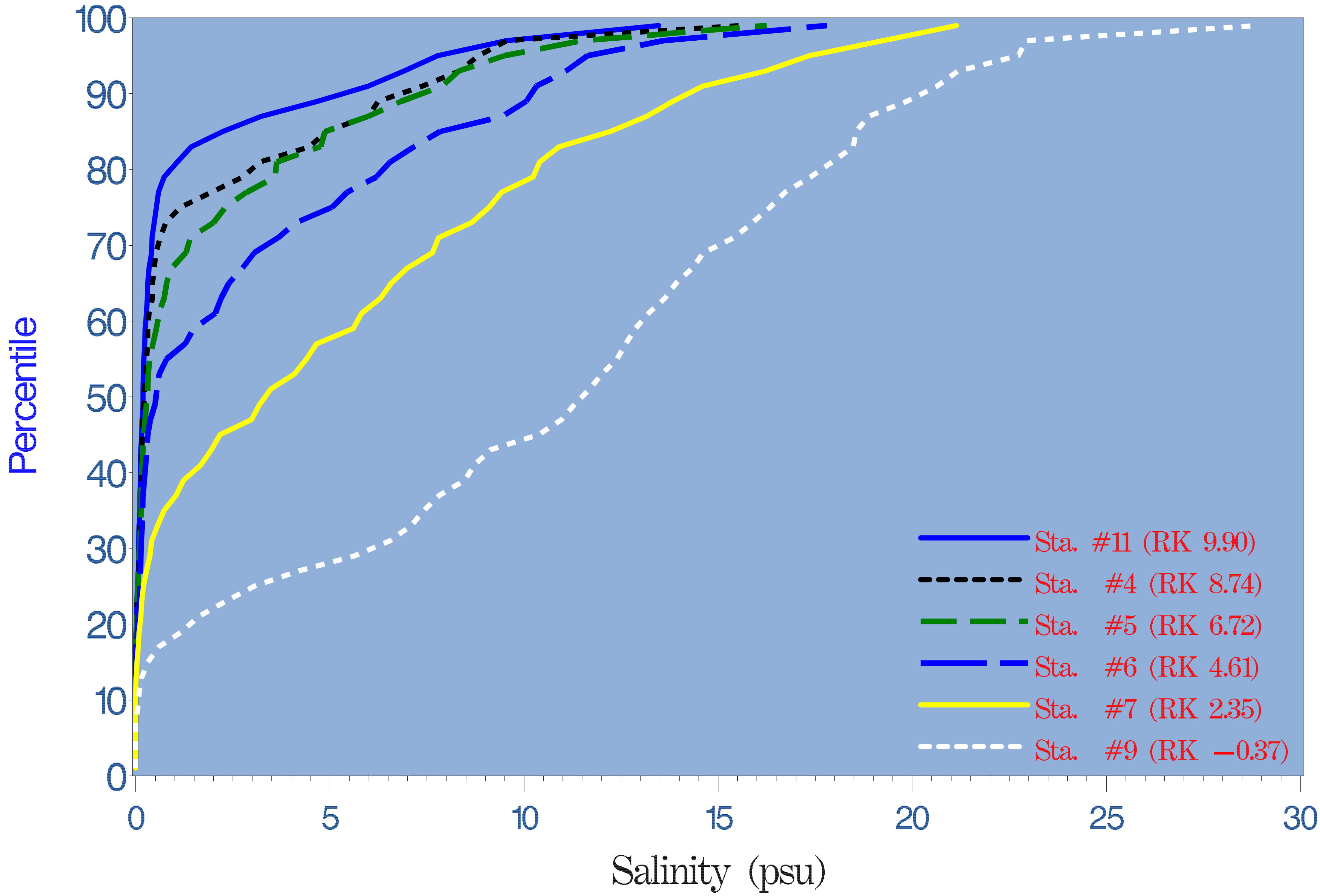


Figure 4.3.89 CDF plots of bottom salinity among selected Shell Creek transect locations

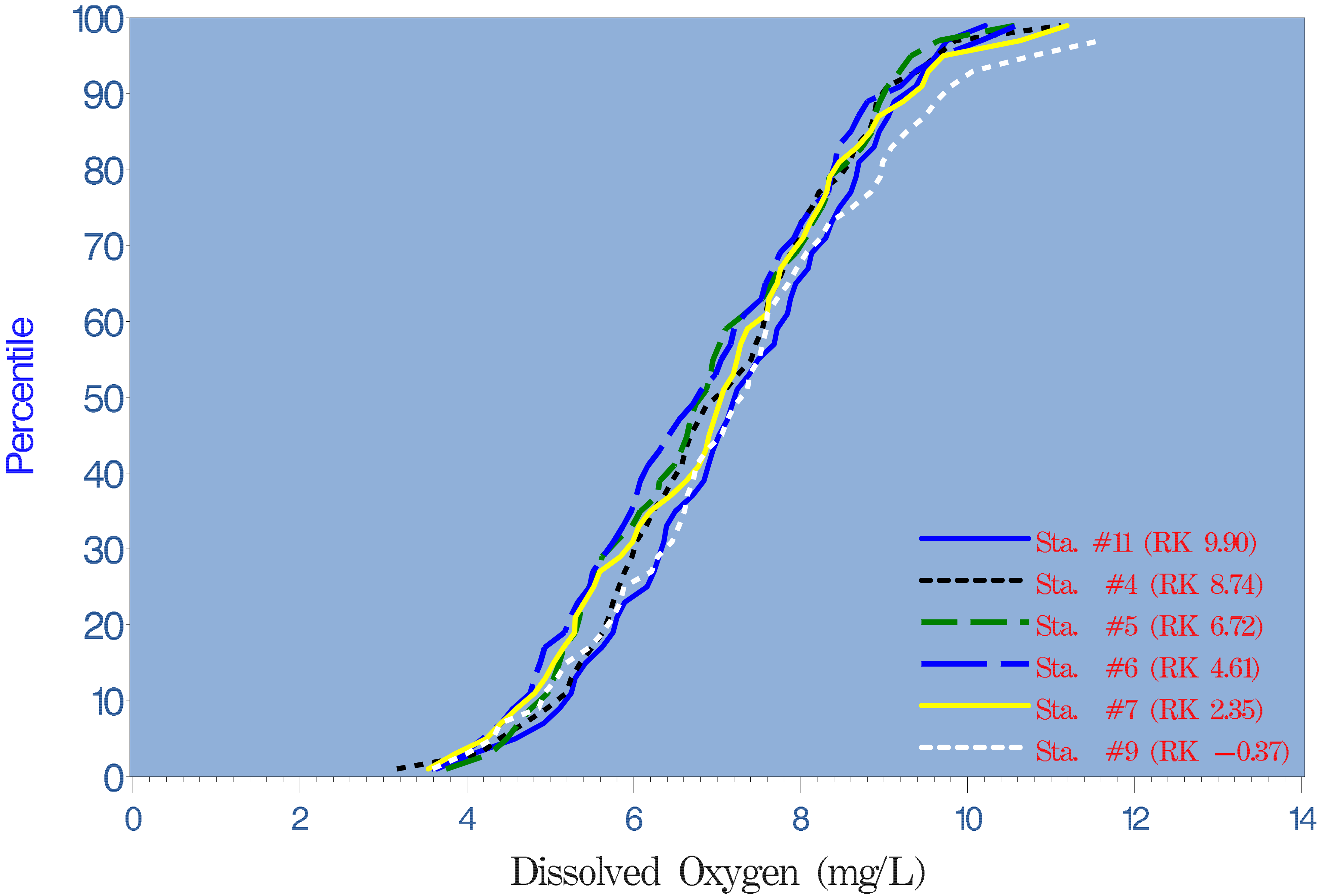


Figure 4.3.90 CDF plots of surface dissolved oxygen among selected Shell Creek transect locations

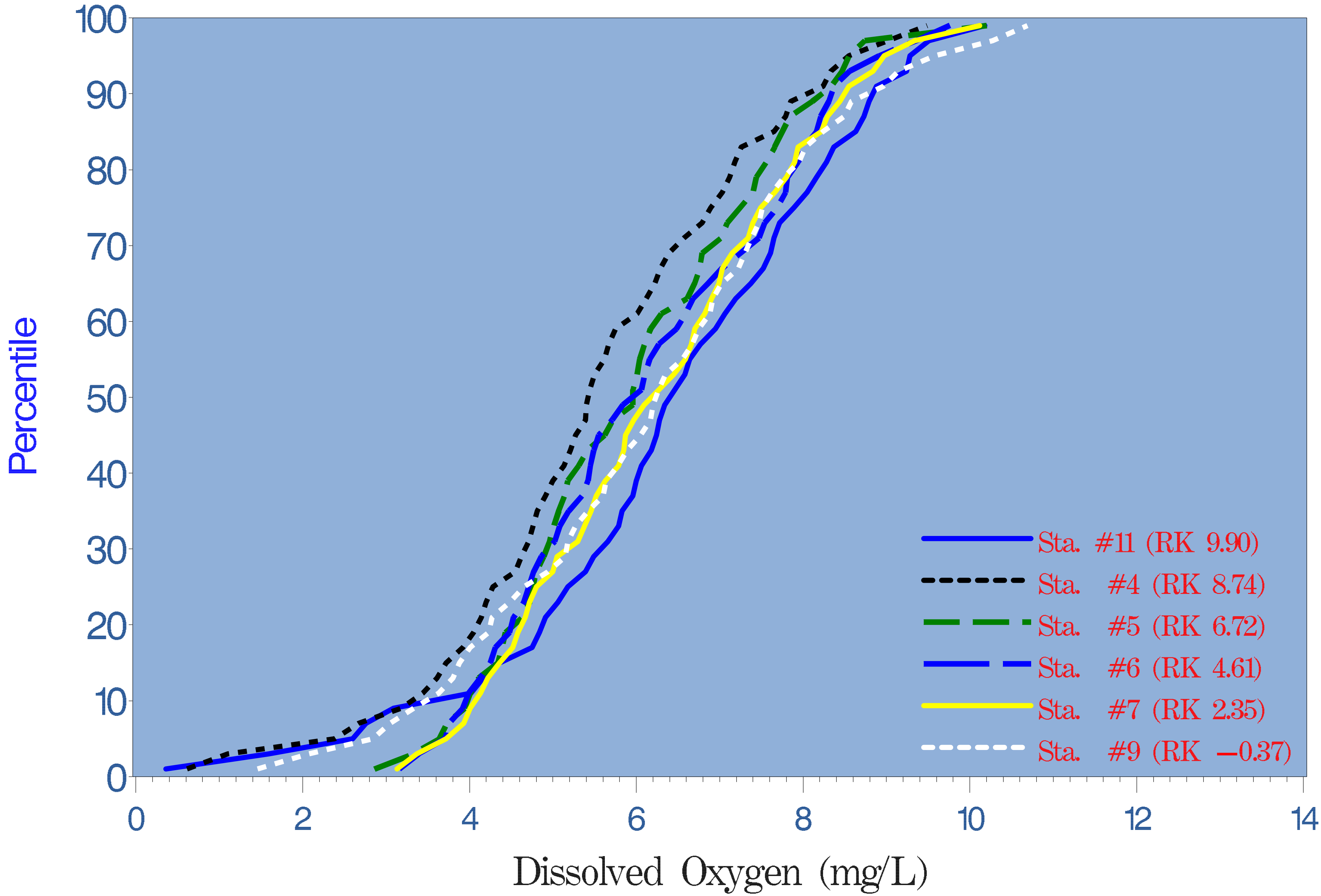


Figure 4.3.91 CDF plots of bottom dissolved oxygen among selected Shell Creek transect locations

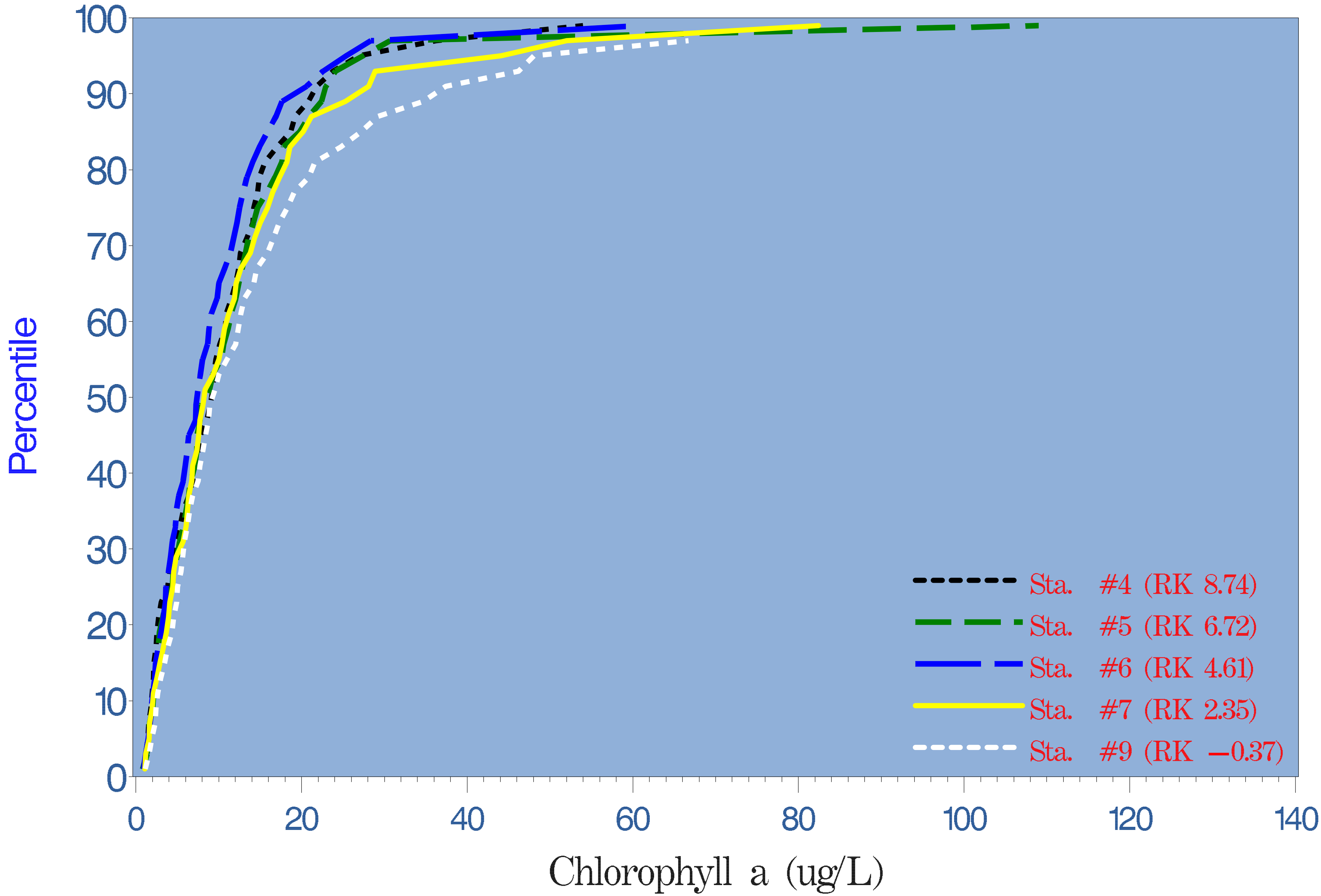


Figure 4.3.92 CDF plots of surface chlorophyll a among selected Shell Creek transect locations

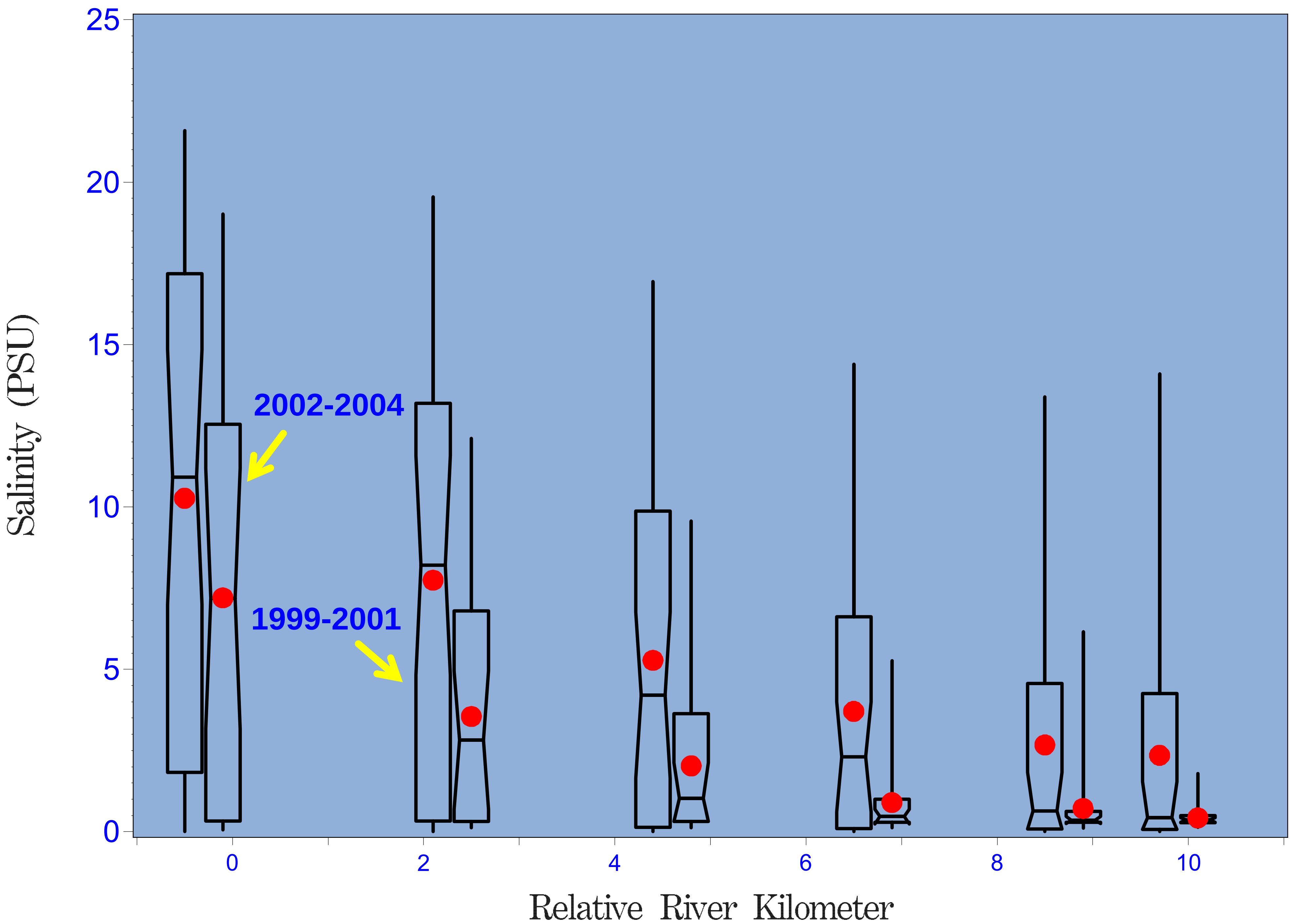


Figure 4.3.93 Surface salinities comparing 1999-2001 and 2002-2004 periods along Shell Creek transect by river kilometer

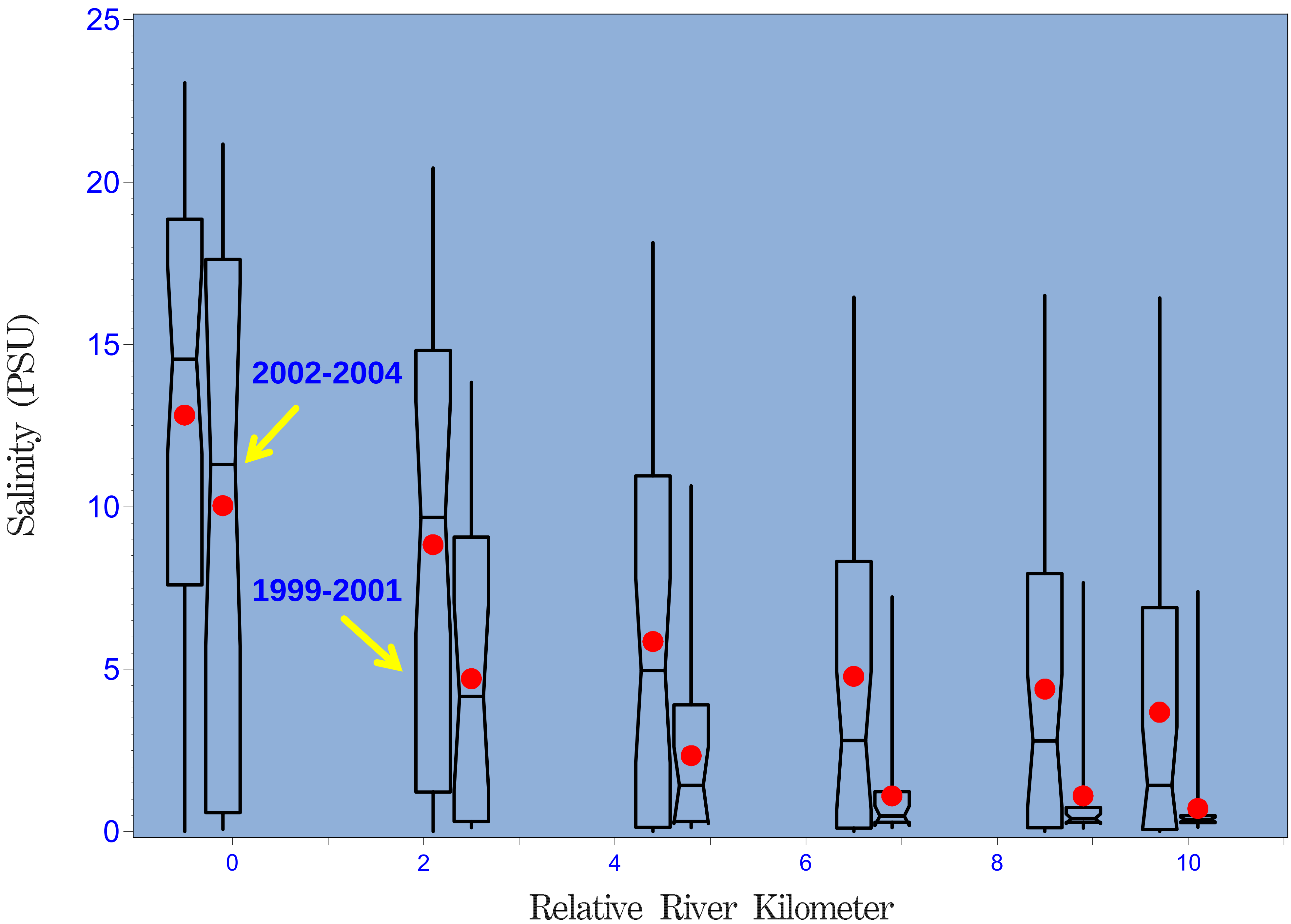


Figure 4.3.94 Bottom salinities comparing 1999-2001 and 2002-2004 periods along Shell Creek transect by river kilometer

Appendix D

Potential Salinity Impacts

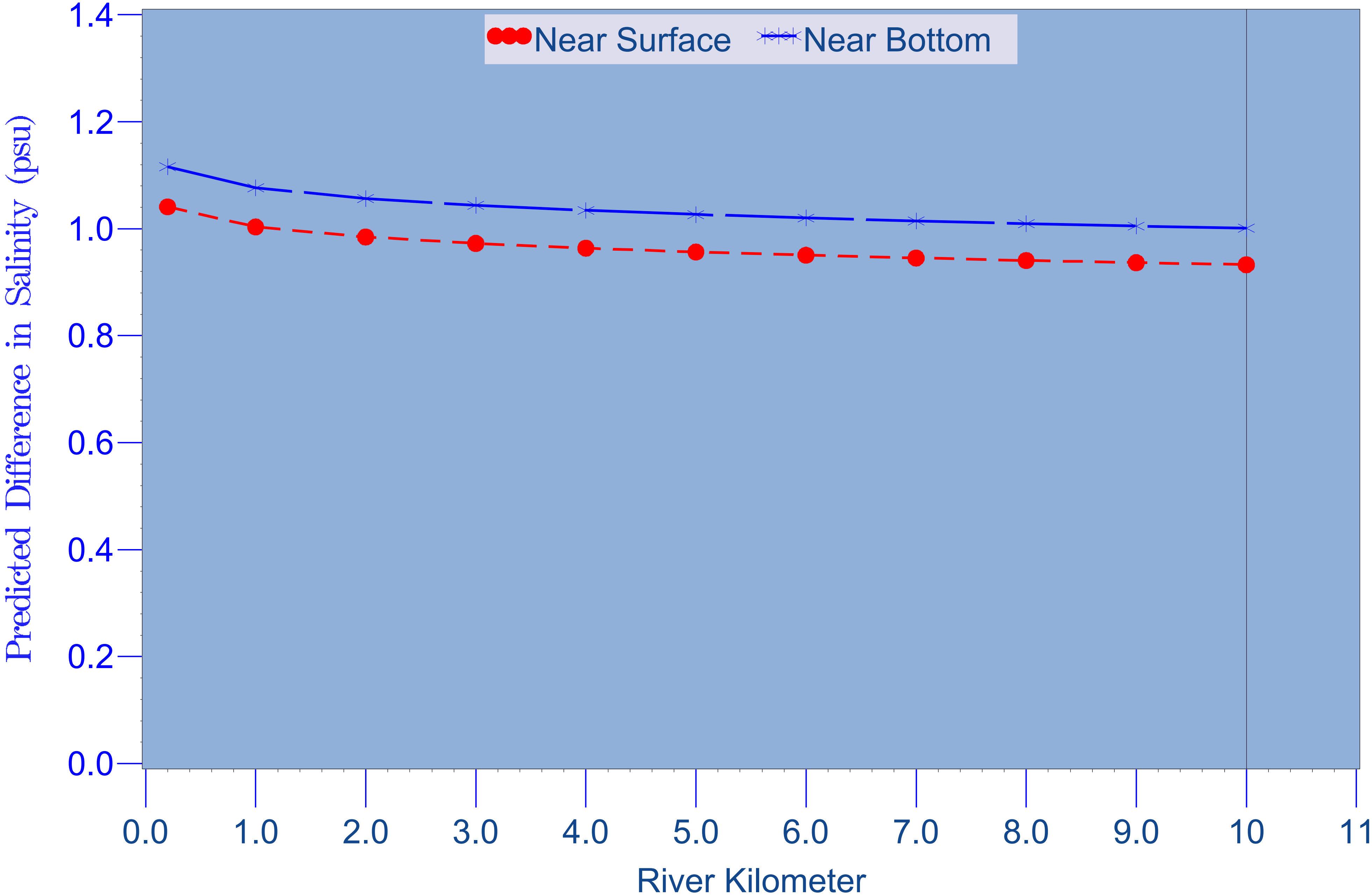


Figure 4.4.1 Predicted Difference in Salinity Versus River Kilometer
Shell Creek Flow = 25 cfs & Withdrawal = 6.9 mgd

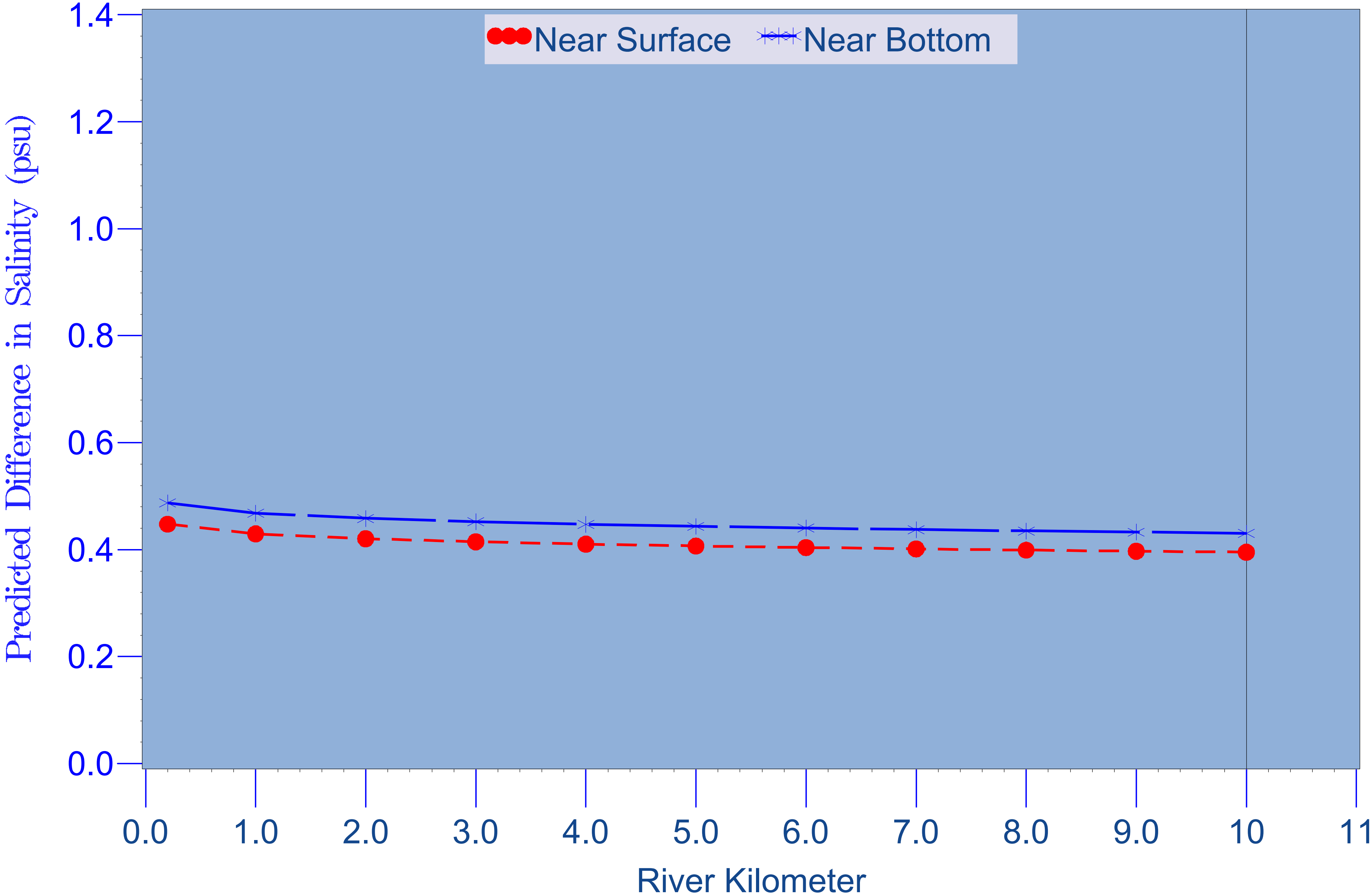


Figure 4.4.2 Predicted Difference in Salinity Versus River Kilometer
Shell Creek Flow = 50 cfs & Withdrawal = 6.9 mgd

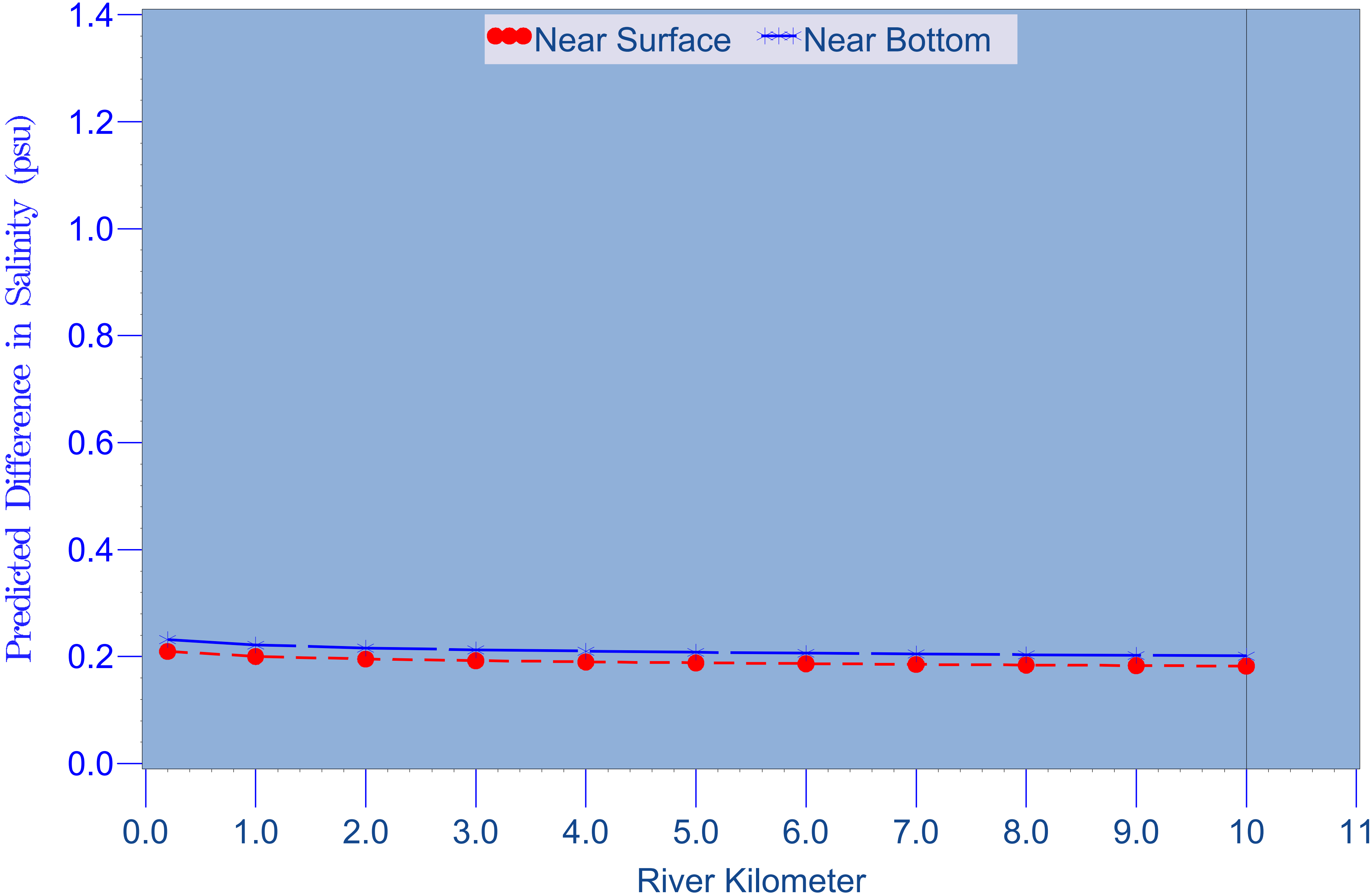


Figure 4.4.3 Predicted Difference in Salinity Versus River Kilometer
Shell Creek Flow = 100 cfs & Withdrawal = 6.9 mgd

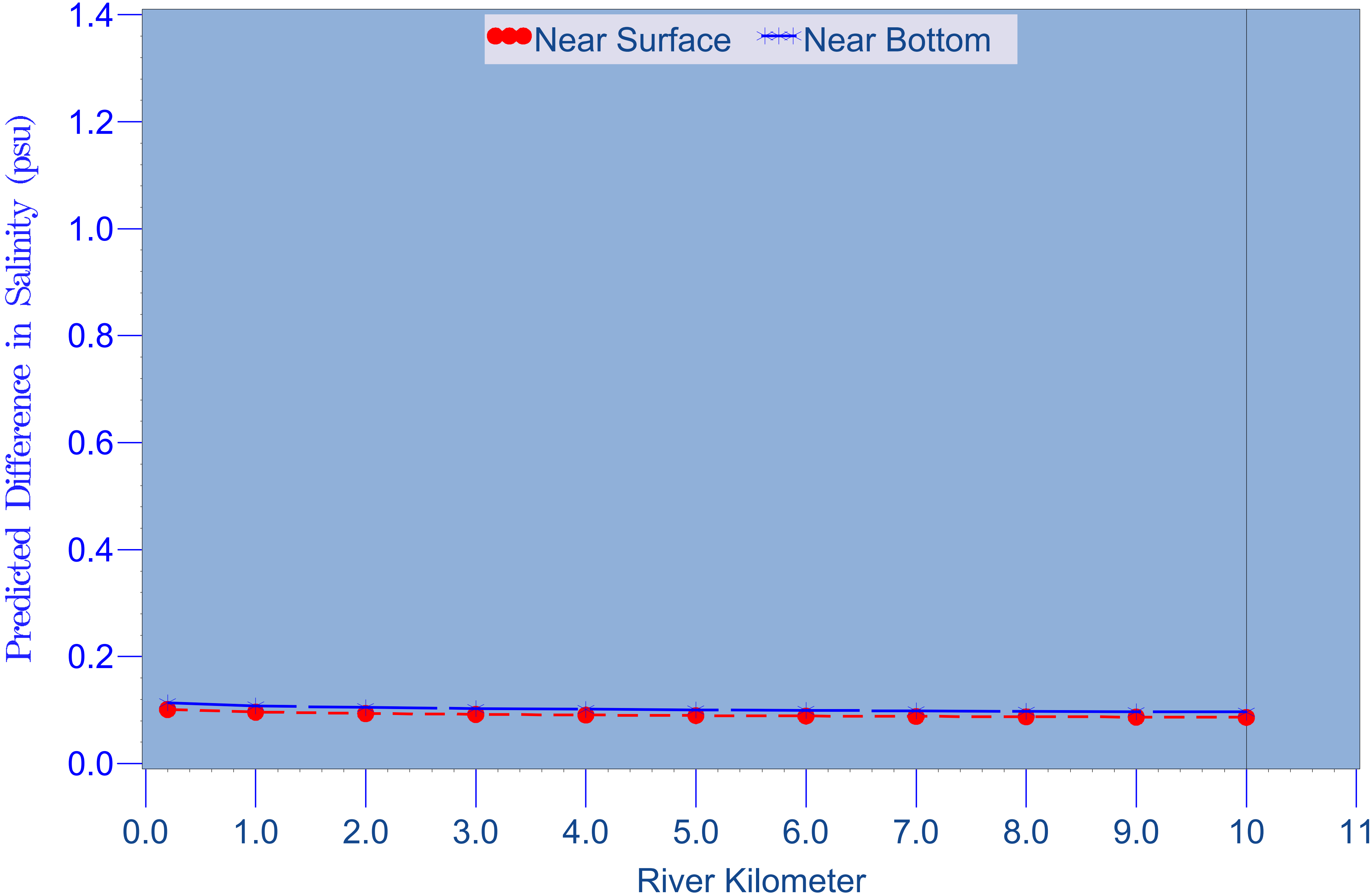


Figure 4.4.4 Predicted Difference in Salinity Versus River Kilometer
Shell Creek Flow = 200 cfs & Withdrawal = 6.9 mgd

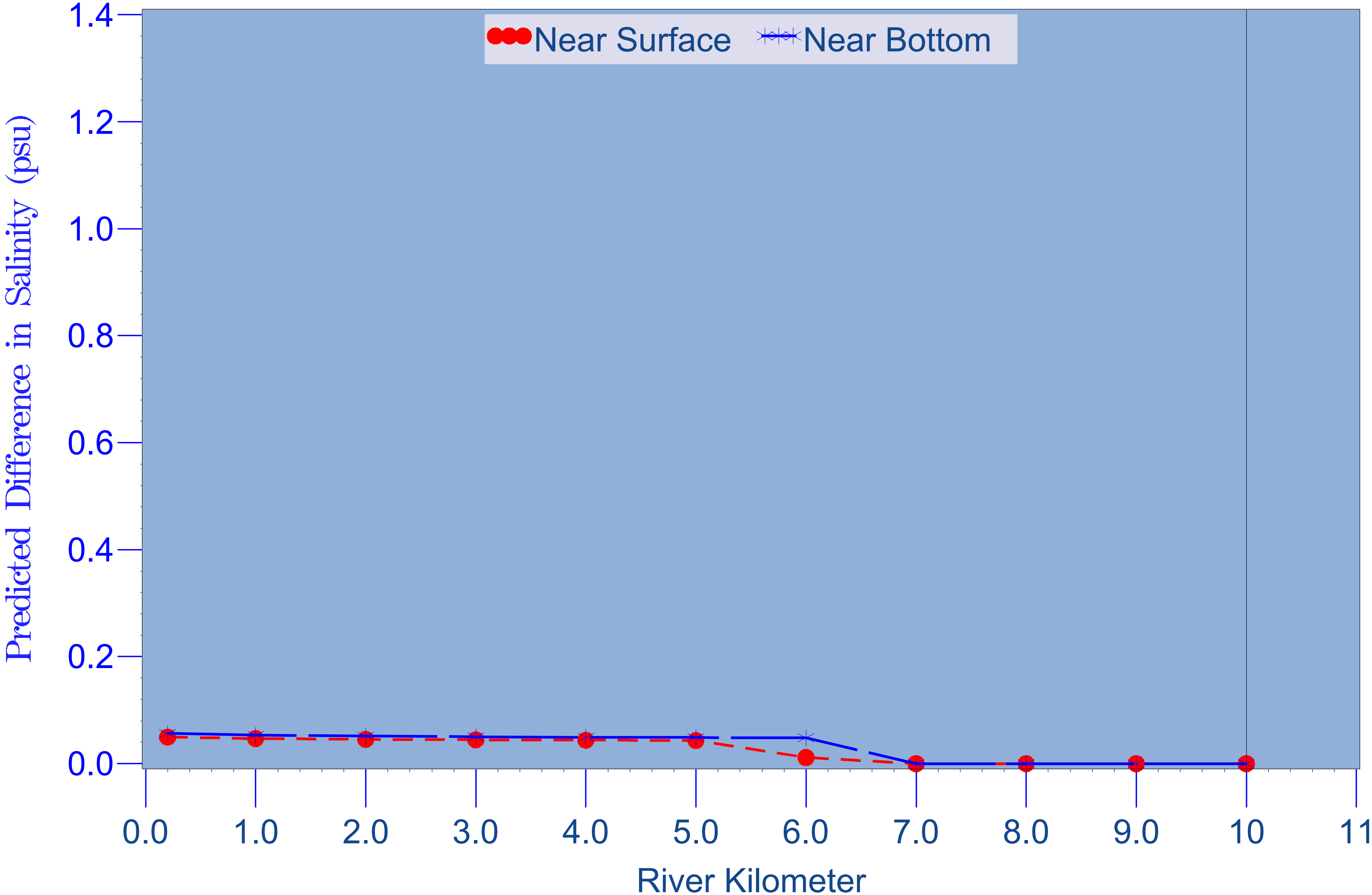


Figure 4.4.5 Predicted Difference in Salinity Versus River Kilometer
Shell Creek Flow = 400 cfs & Withdrawal = 6.9 mgd

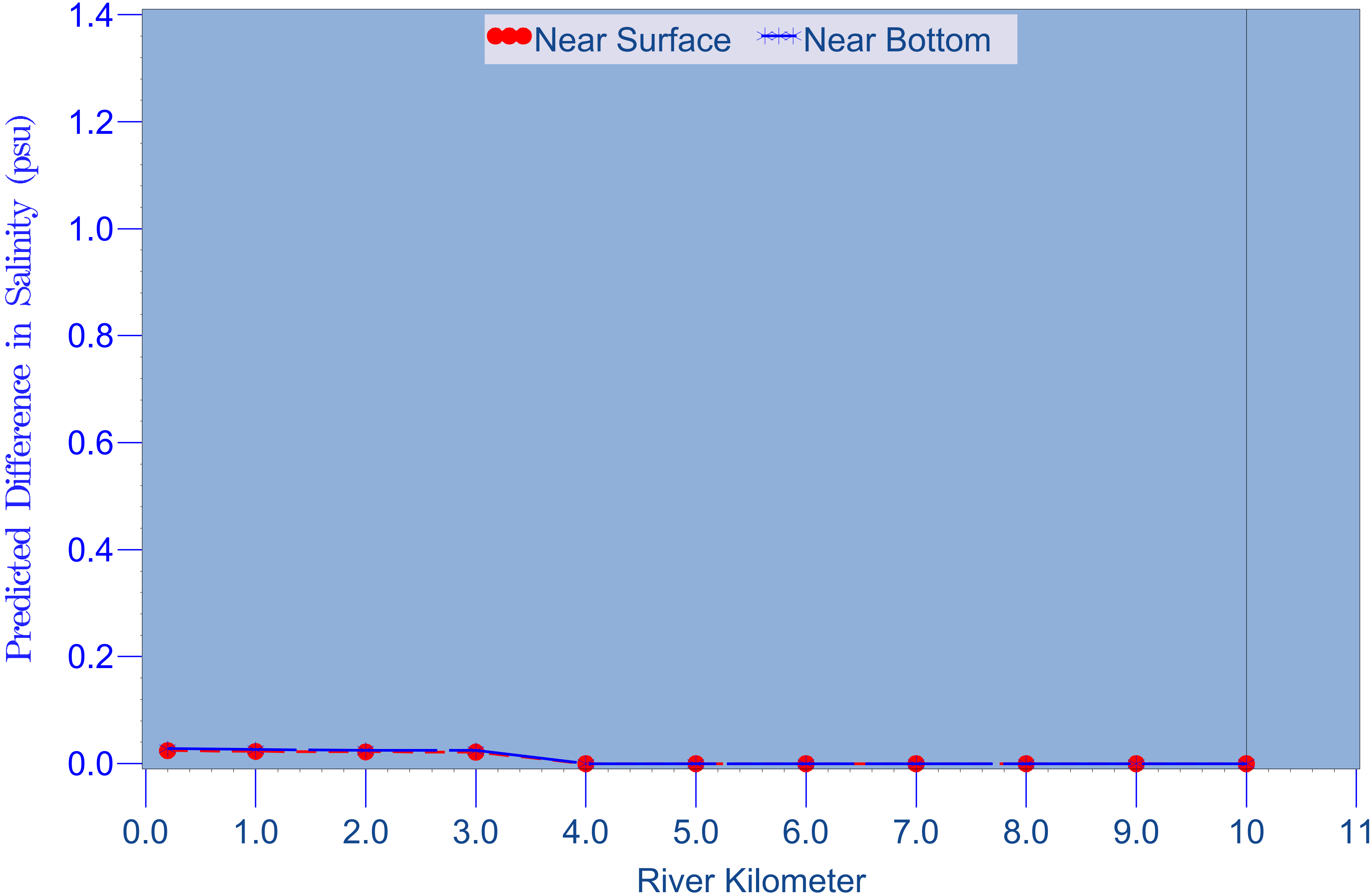


Figure 4.4.6 Predicted Difference in Salinity Versus River Kilometer
Shell Creek Flow = 800 cfs & Withdrawal = 6.9 mgd

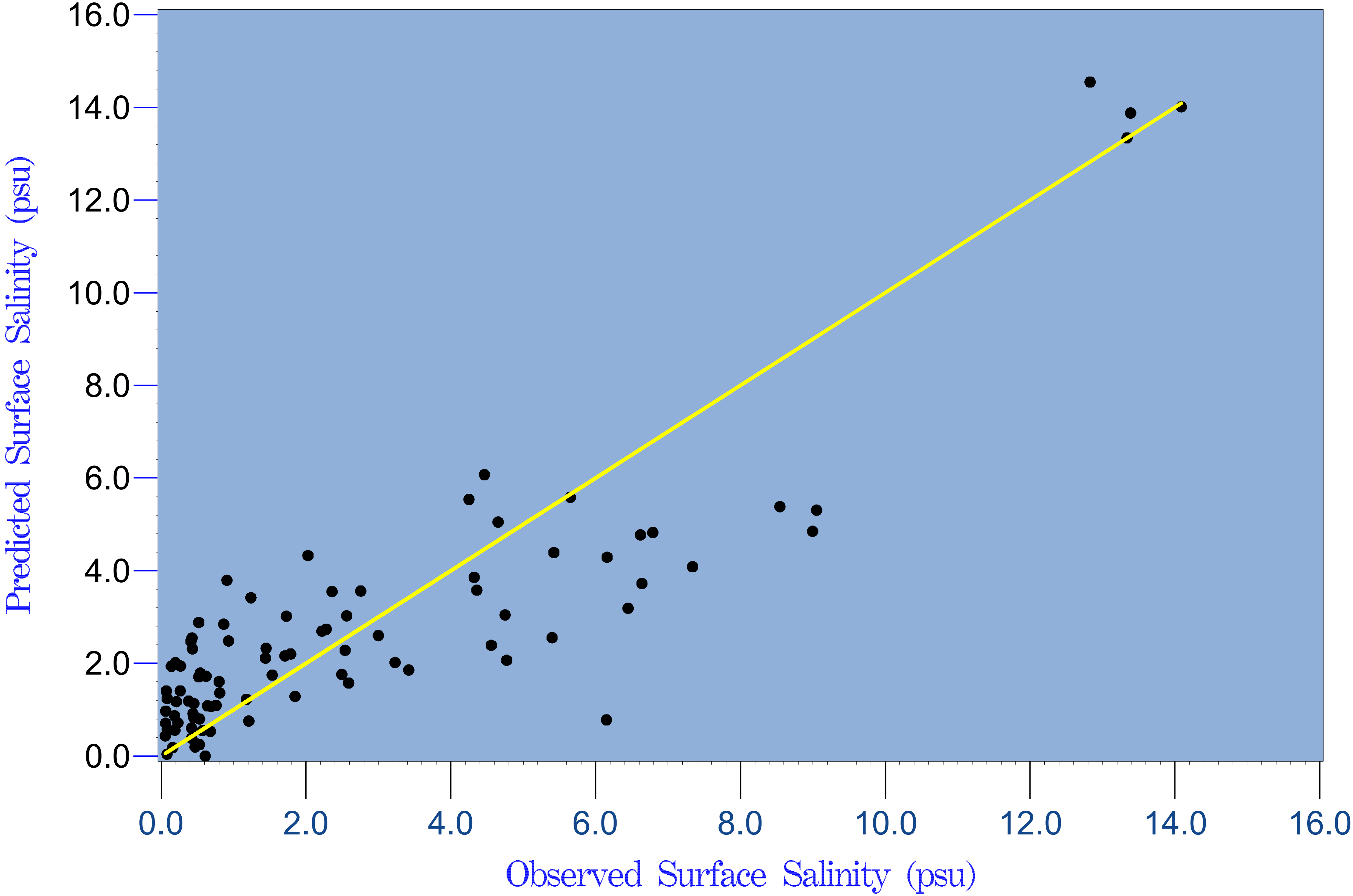


Figure 4.4.7 Predicted versus observed of modeled Shell Creek surface salinity Group A (0-90 cfs)

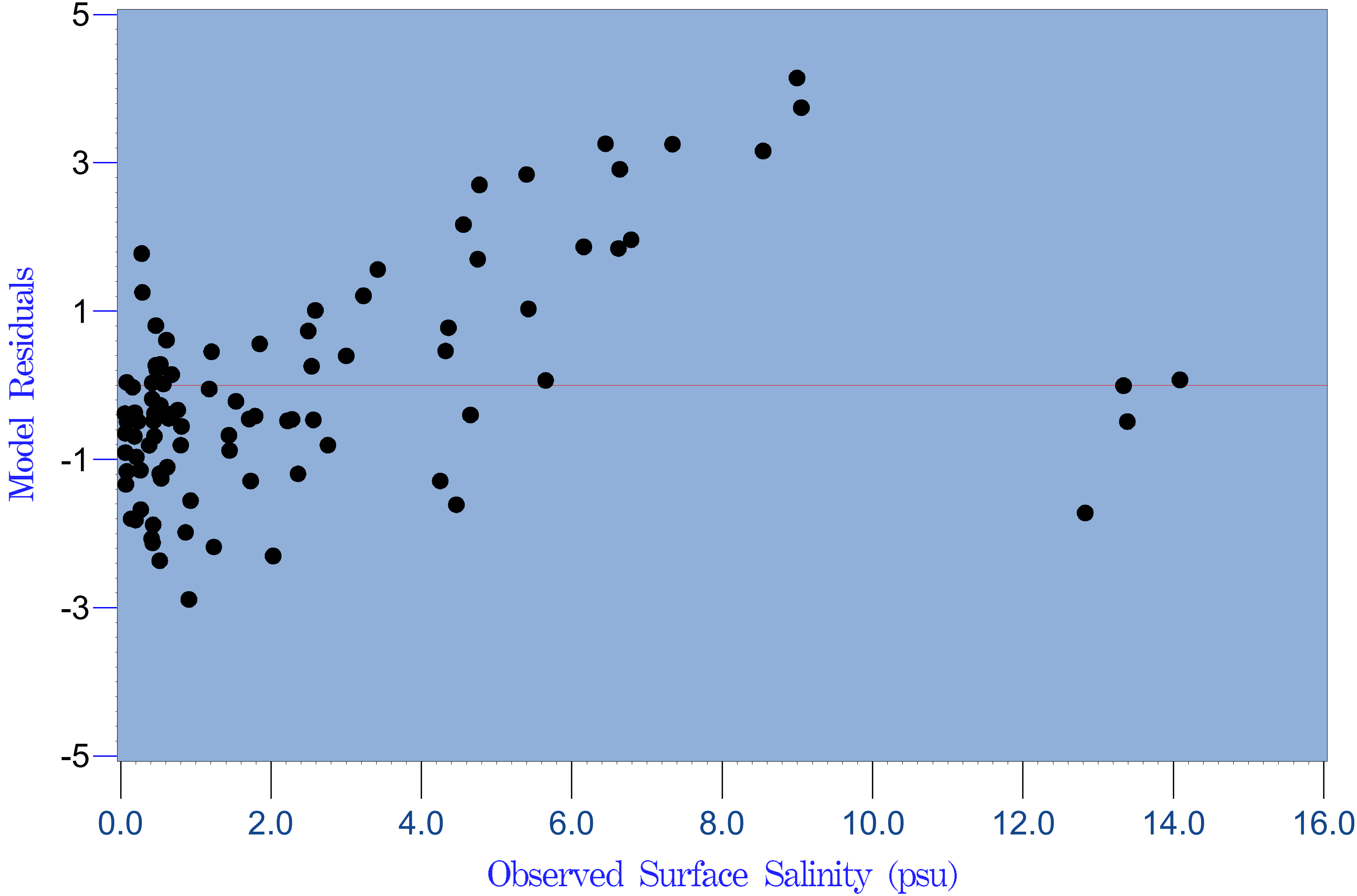


Figure 4.4.8 Model residuals versus observed of Shell Creek surface salinity Group A (0-90 cfs)

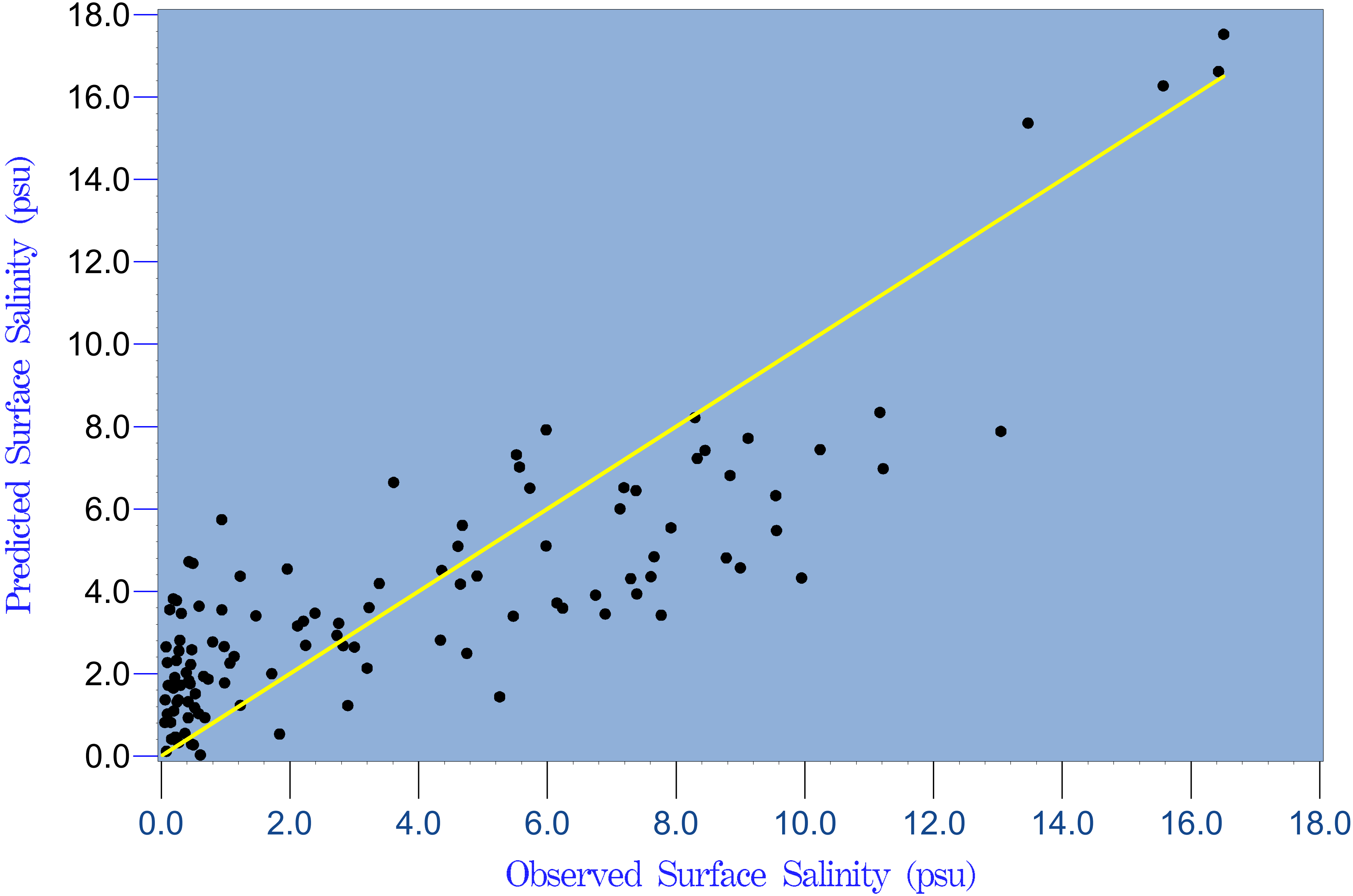


Figure 4.4.9 Predicted versus observed of modeled Shell Creek bottom salinity Group A (0-120 cfs)

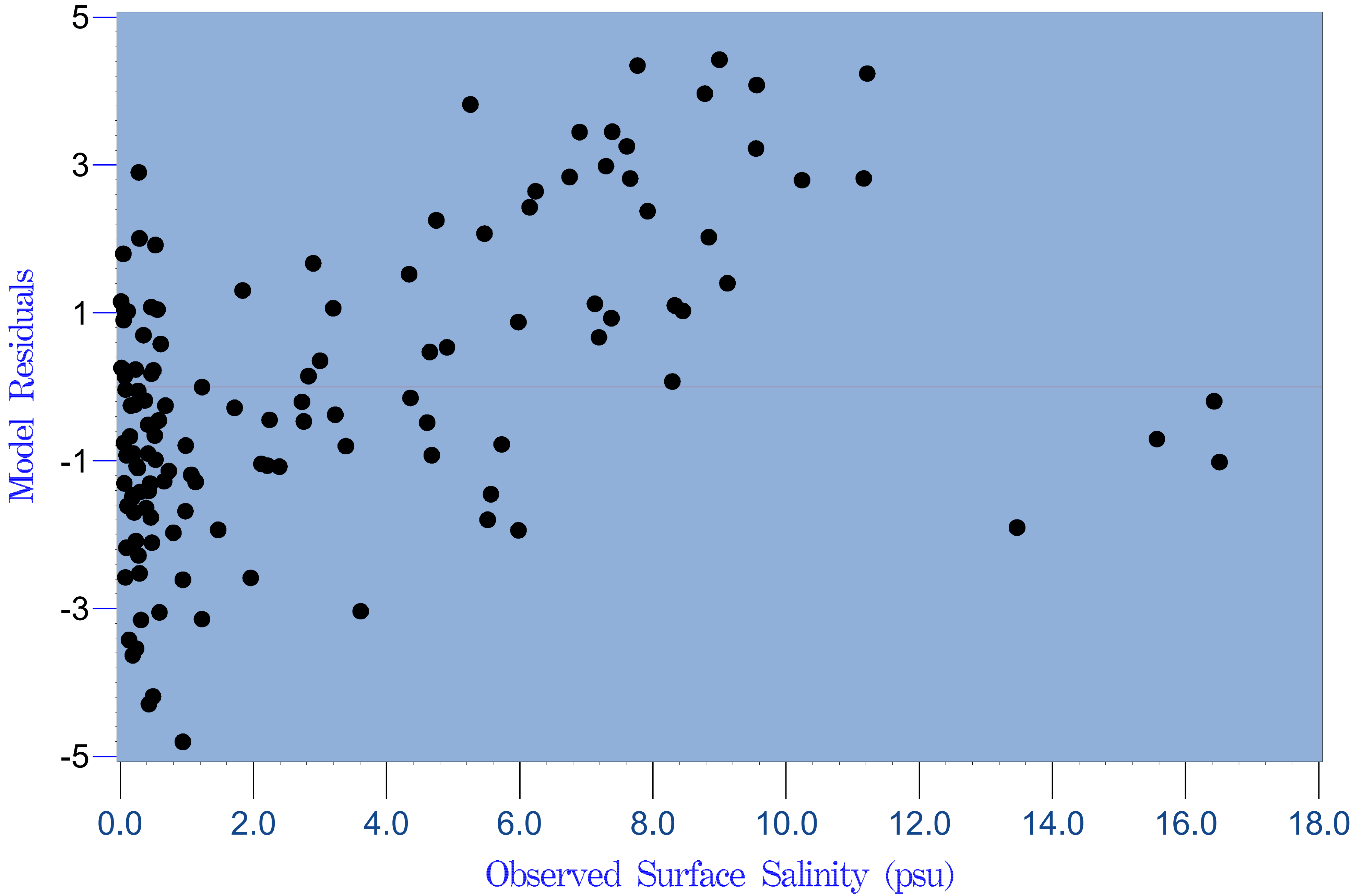


Figure 4.4.10 Model residuals versus observed of Shell Creek bottom salinity Group A (0-120 cfs)

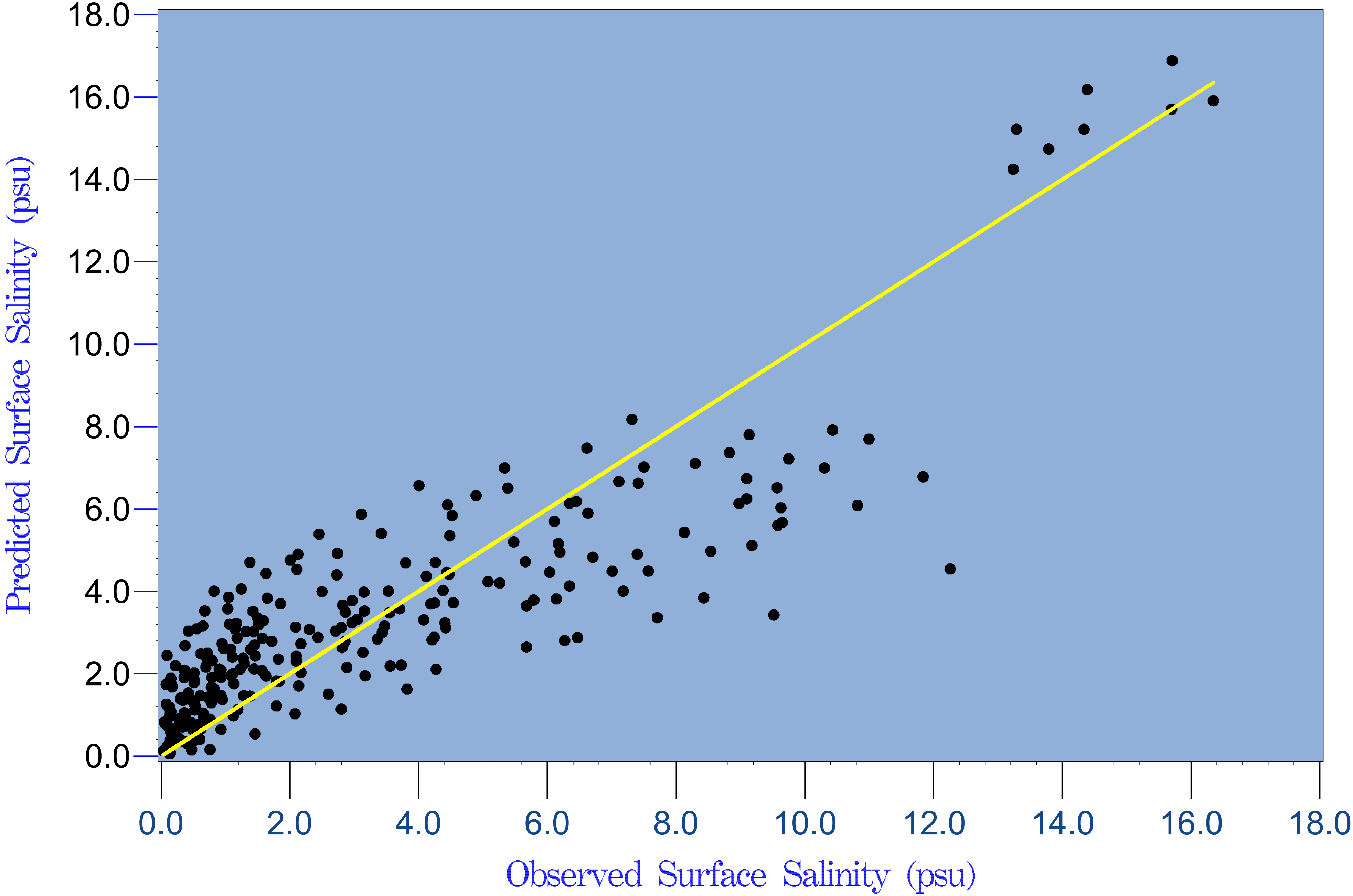


Figure 4.4.11 Predicted versus observed of modeled Shell Creek surface salinity Group B (0-140 cfs)

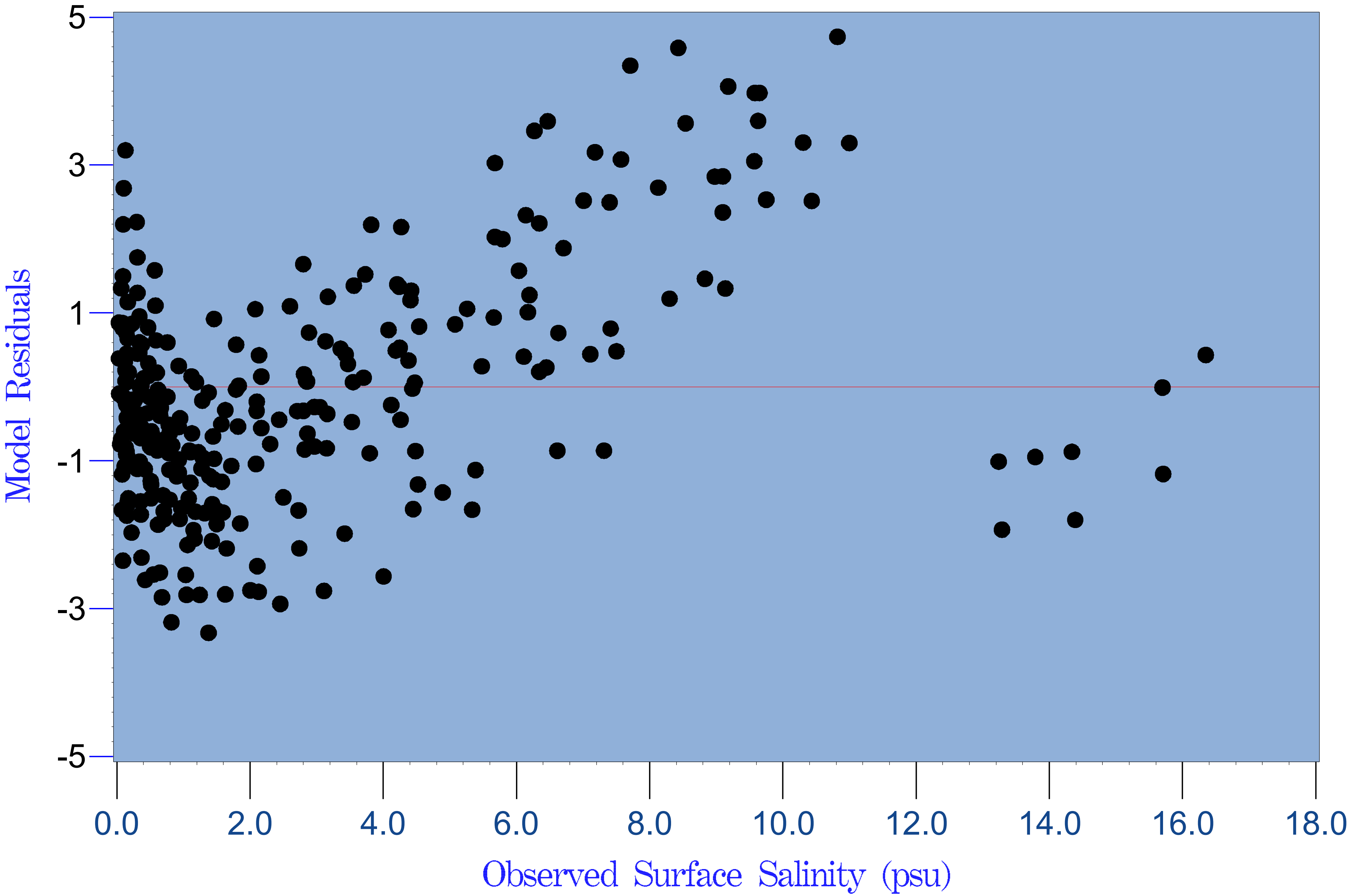


Figure 4.4.12 Model residuals versus observed of Shell Creek surface salinity Group B (0-140 cfs)

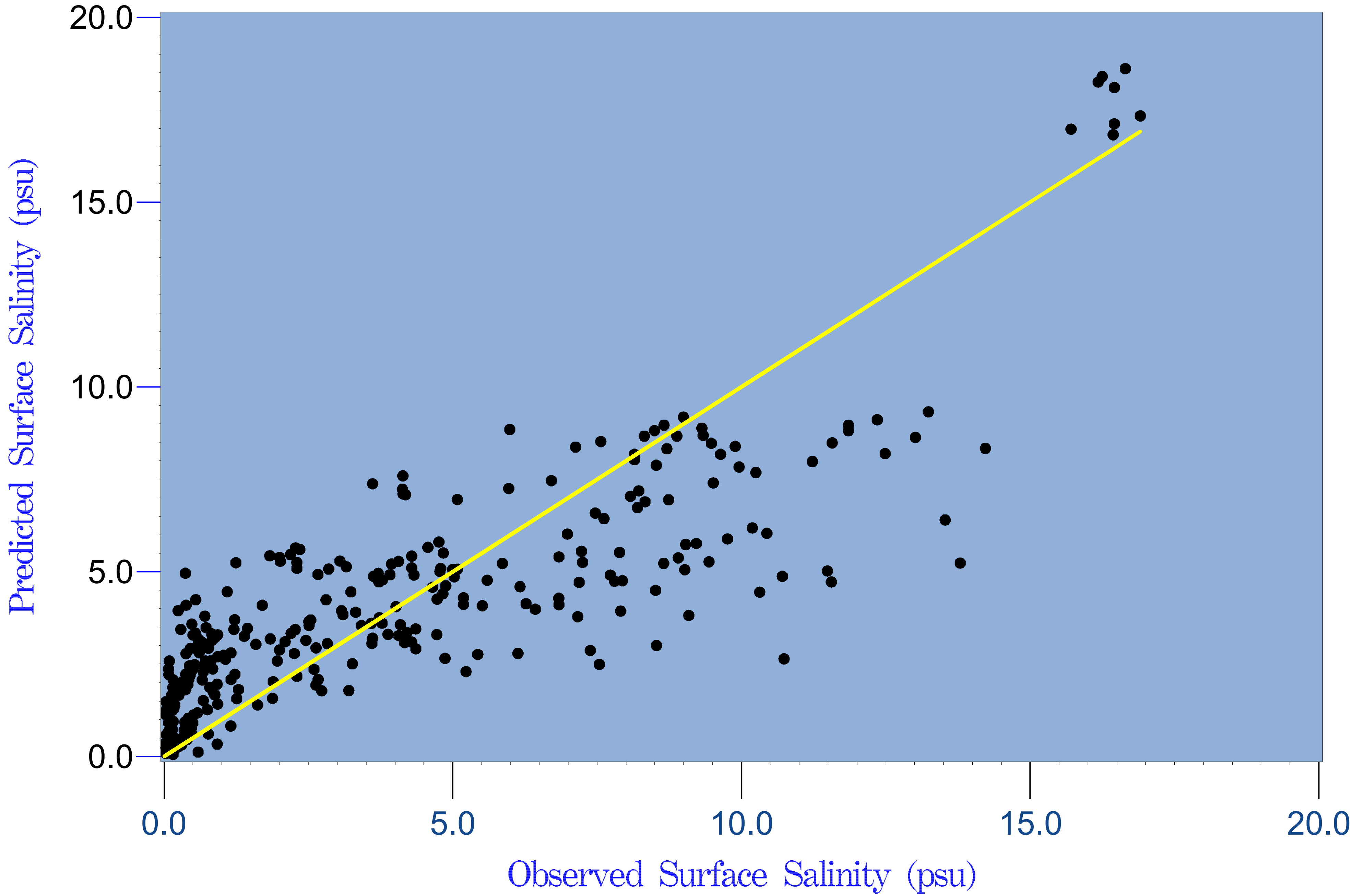


Figure 4.4.13 Predicted versus observed of modeled Shell Creek bottom salinity Group B (0-200 cfs)

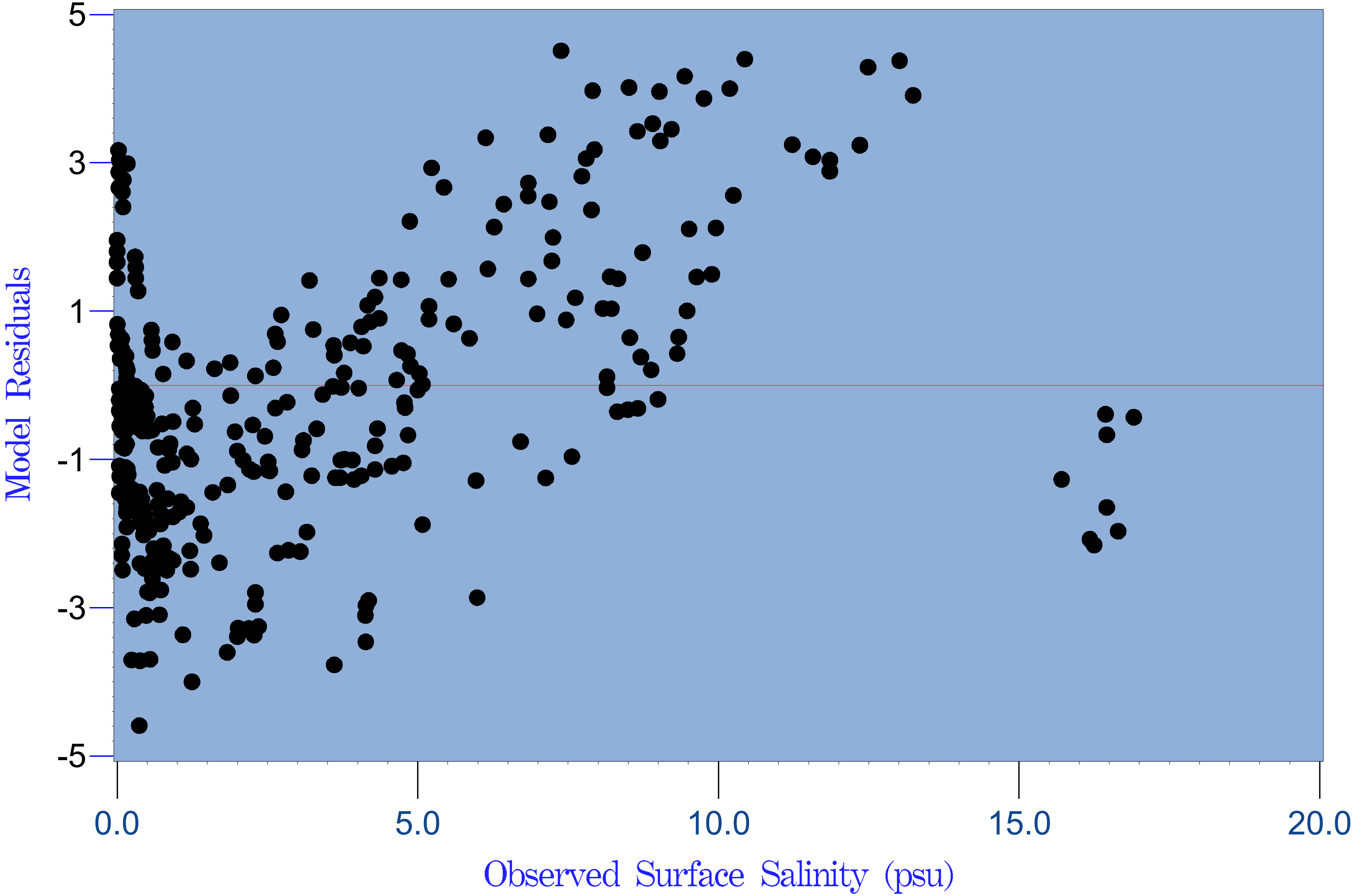


Figure 4.4.14 Model residuals versus observed of Shell Creek bottom salinity Group B (0-200 cfs)

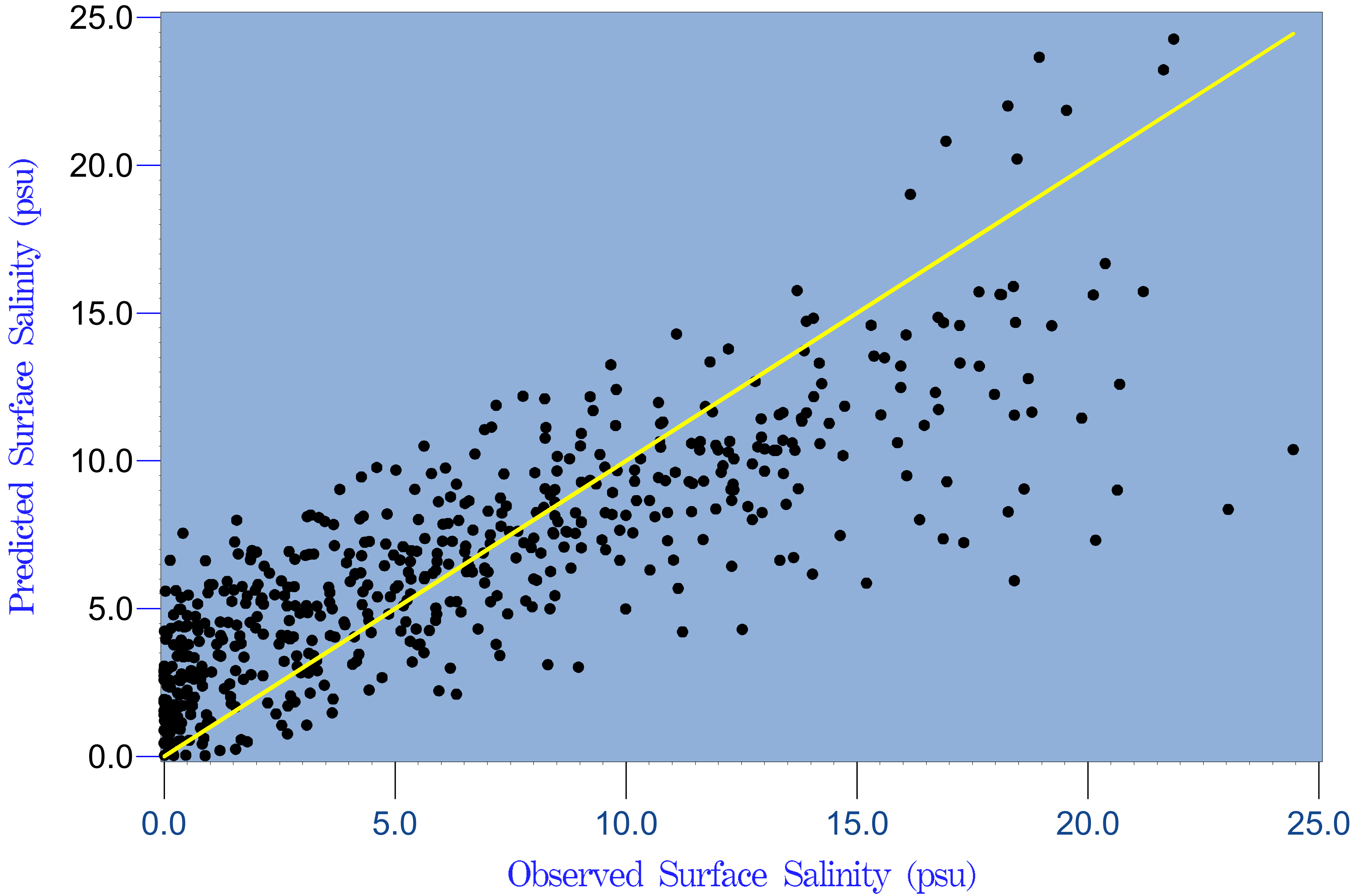


Figure 4.4.15 Predicted versus observed of modeled Shell Creek surface salinity Group C (0-450 cfs)

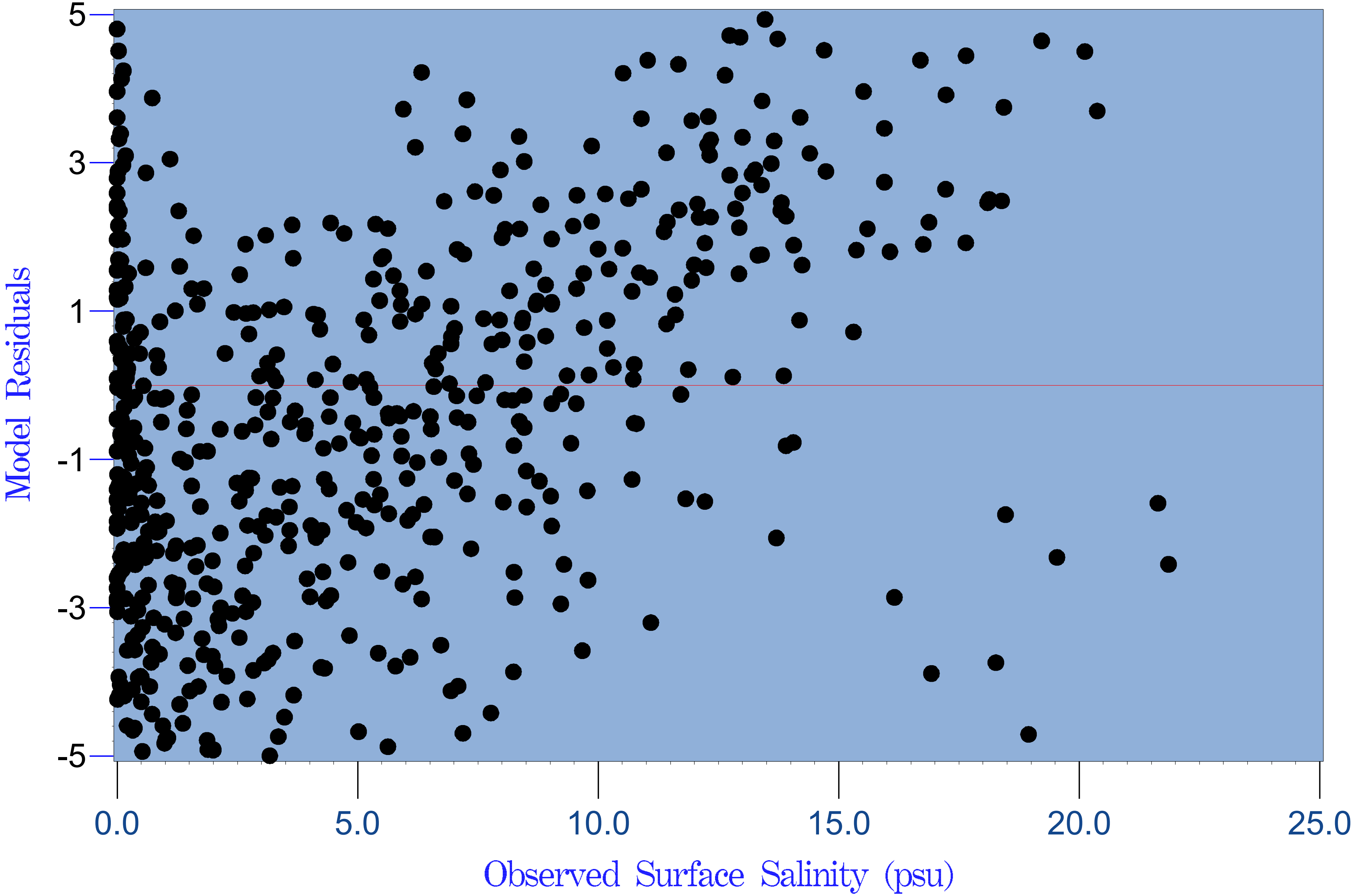


Figure 4.4.16 Model residuals versus observed of Shell Creek surface salinity Group C (0-450 cfs)

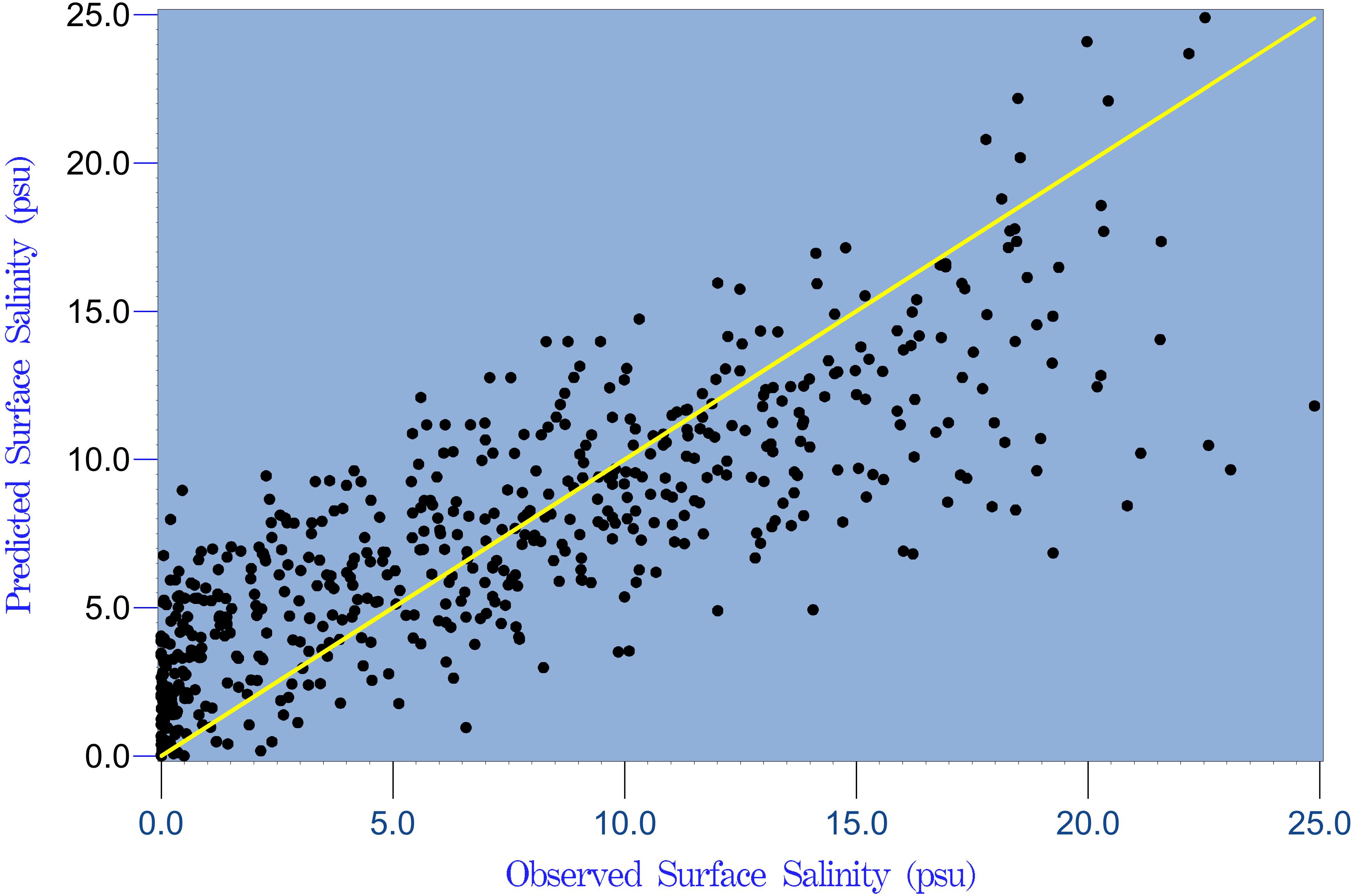


Figure 4.4.17 Predicted versus observed of modeled Shell Creek bottom salinity Group C (0-450 cfs)

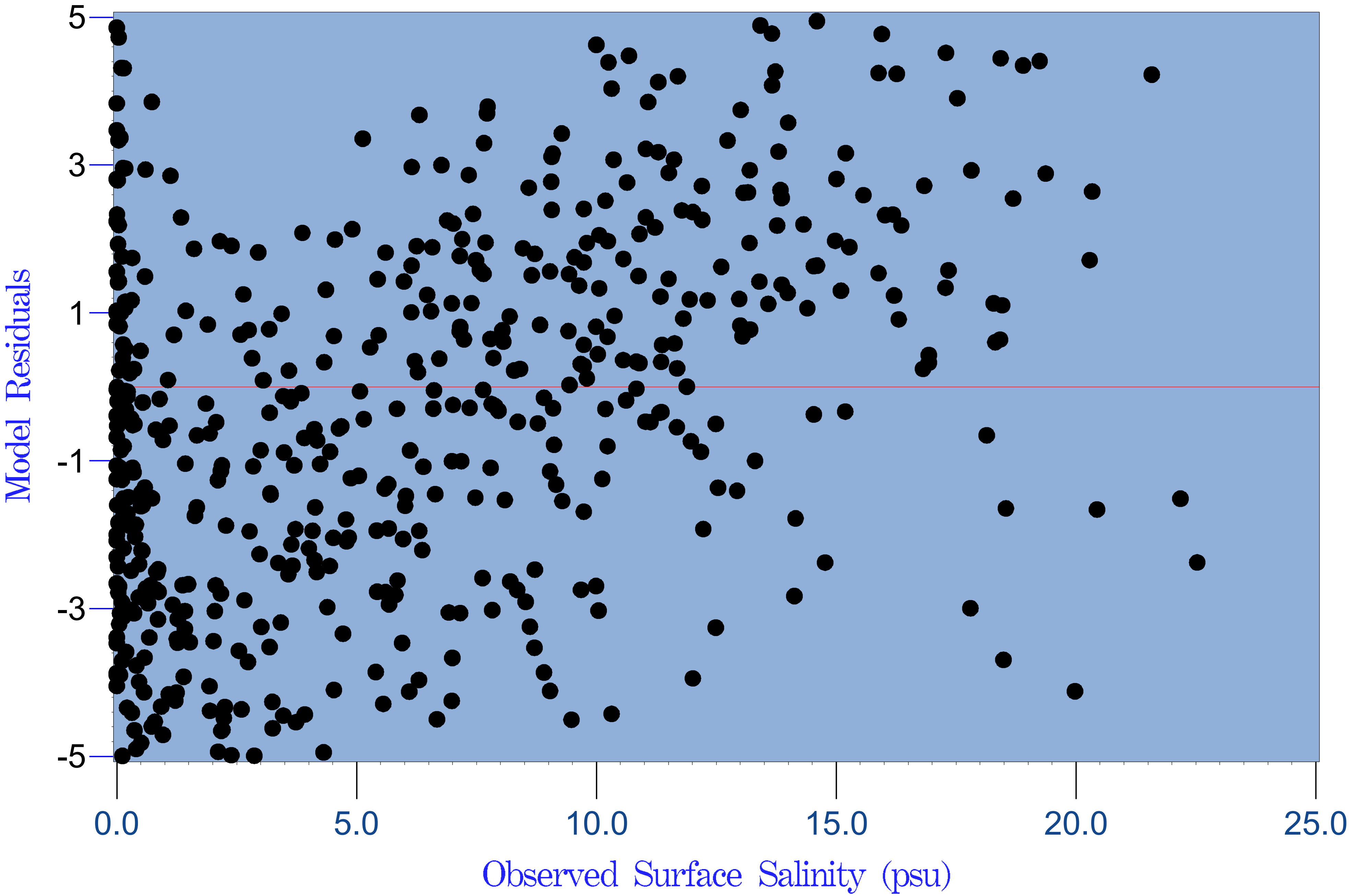


Figure 4.4.18 Model residuals versus observed of Shell Creek bottom salinity Group C (0-450 cfs)

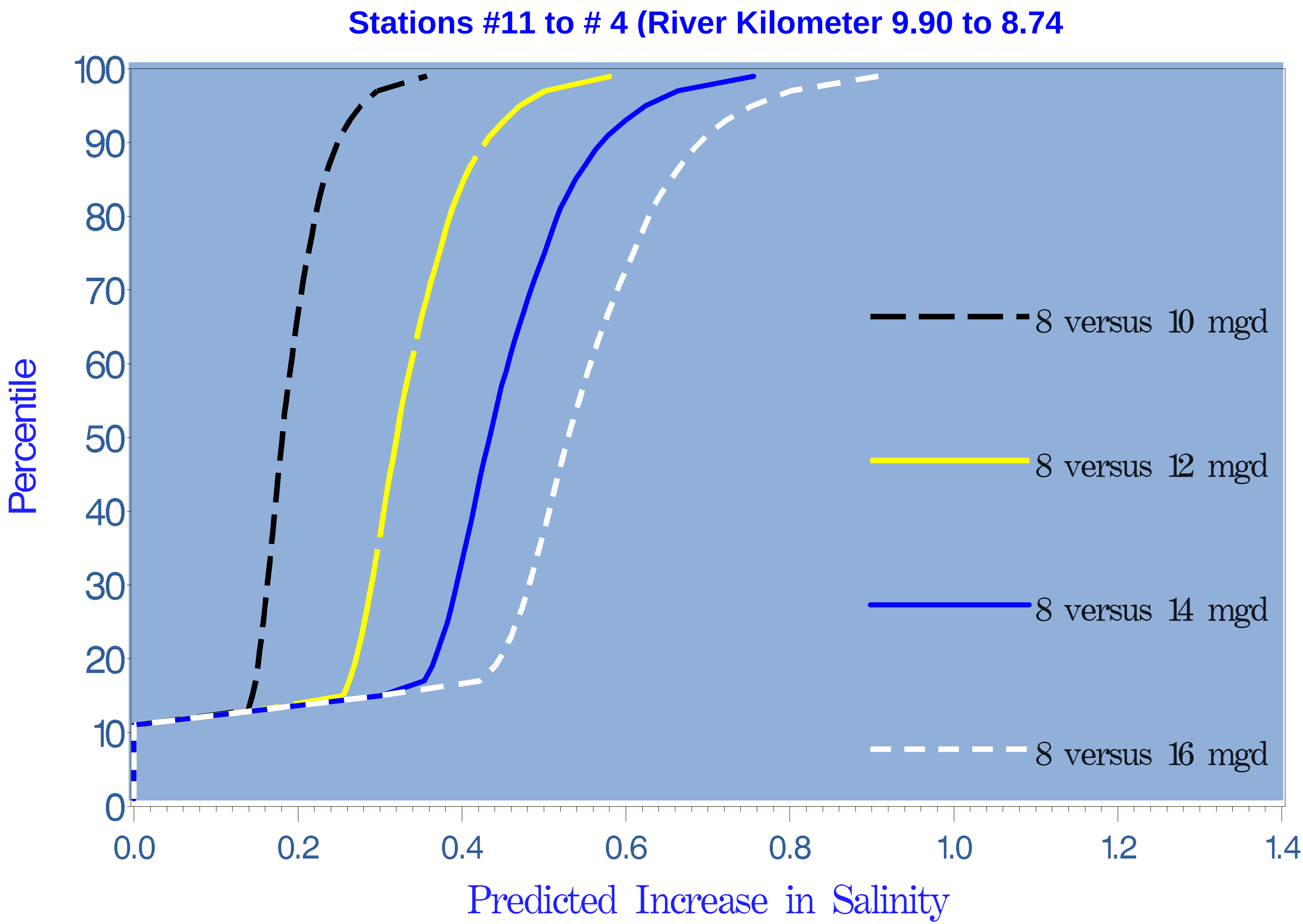


Figure 4.4.19 CDF of predicted change in Segment A surface salinities due to different increased withdrawals

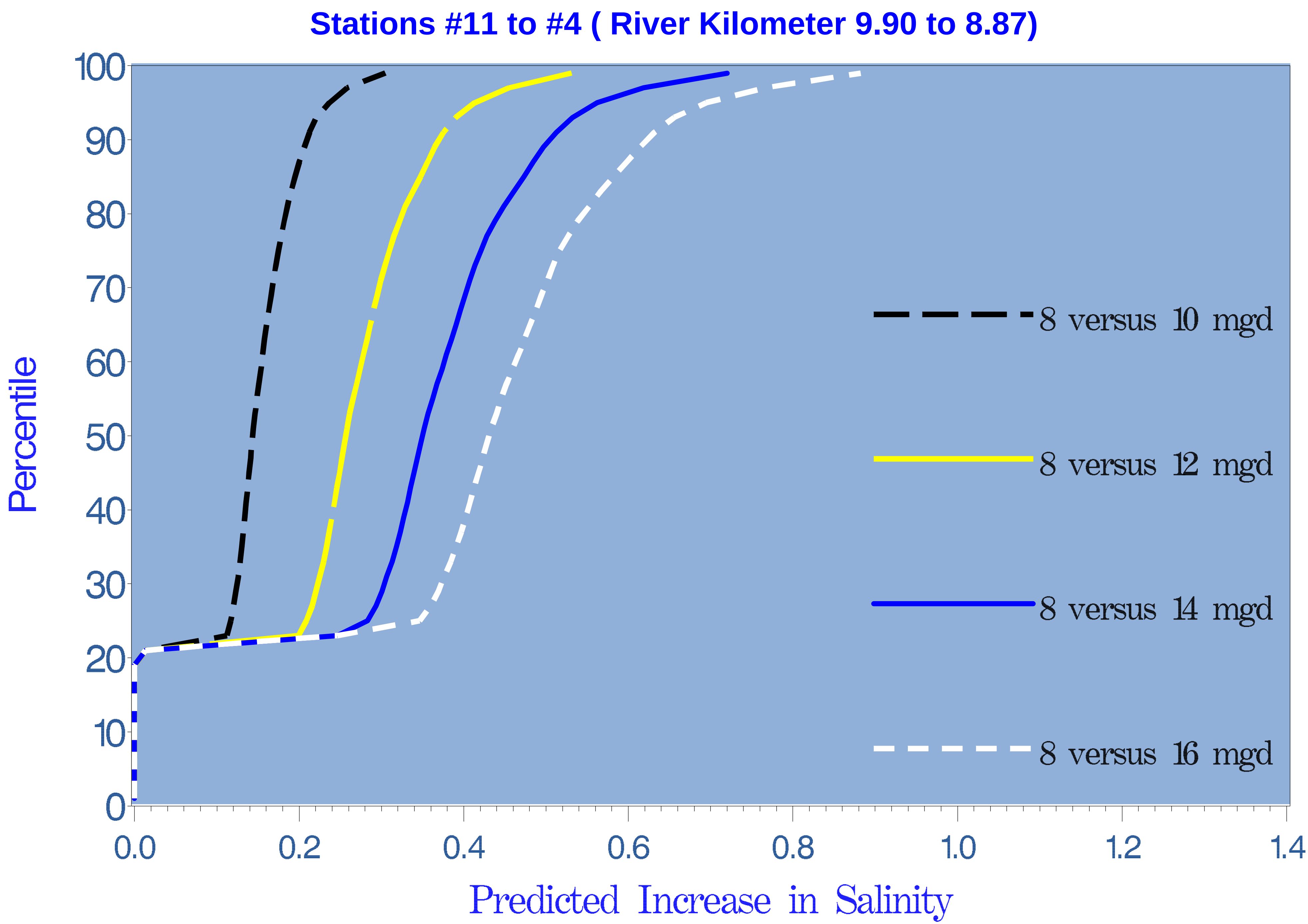


Figure 4.4.20 CDF of predicted change in Segment A bottom salinities due to different increased withdrawals

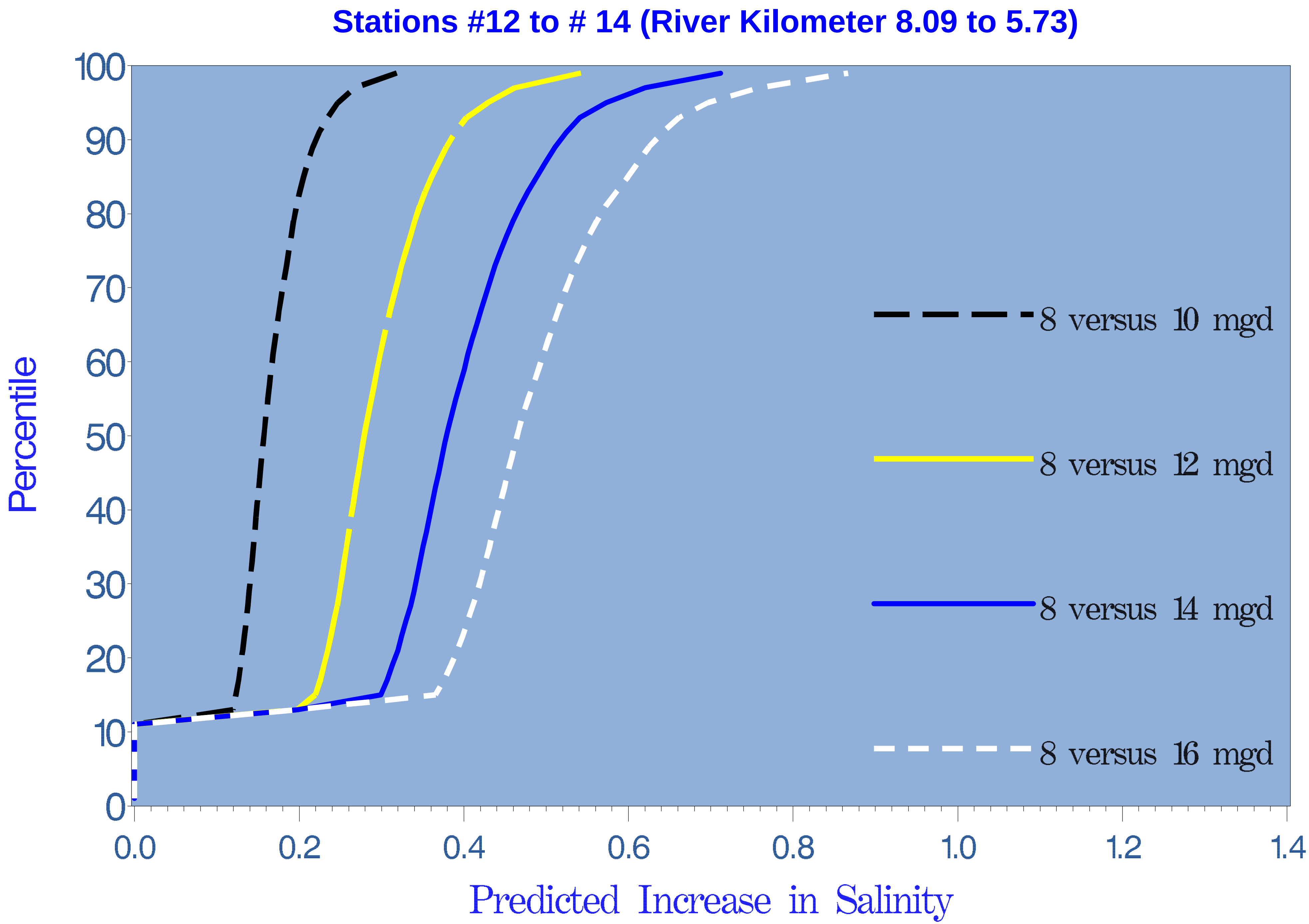


Figure 4.4.21 CDF of predicted change in Segment B surface salinities due to different increased withdrawals

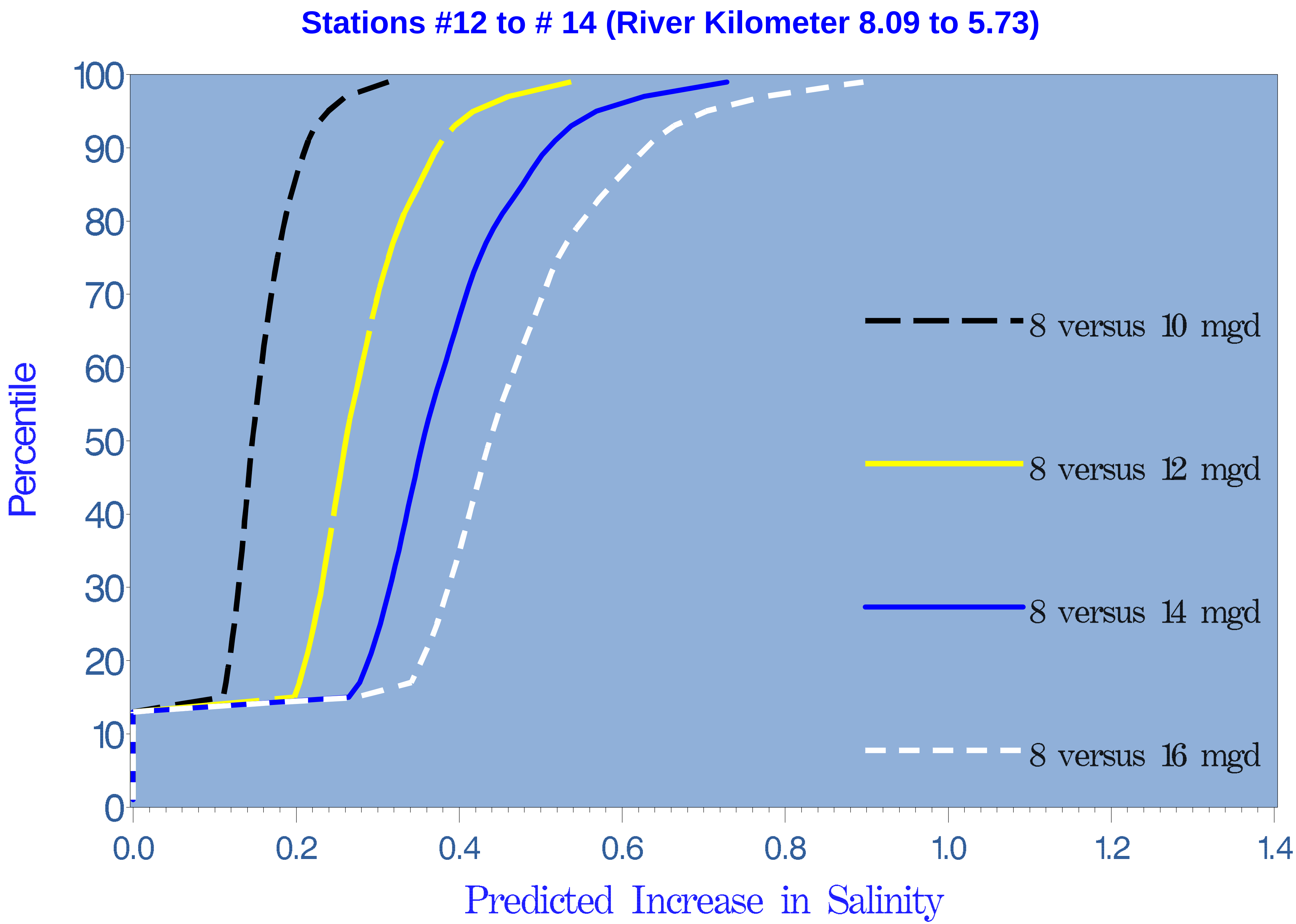


Figure 4.4.22 CDF of predicted change in Segment B bottom salinities due to different increased withdrawals

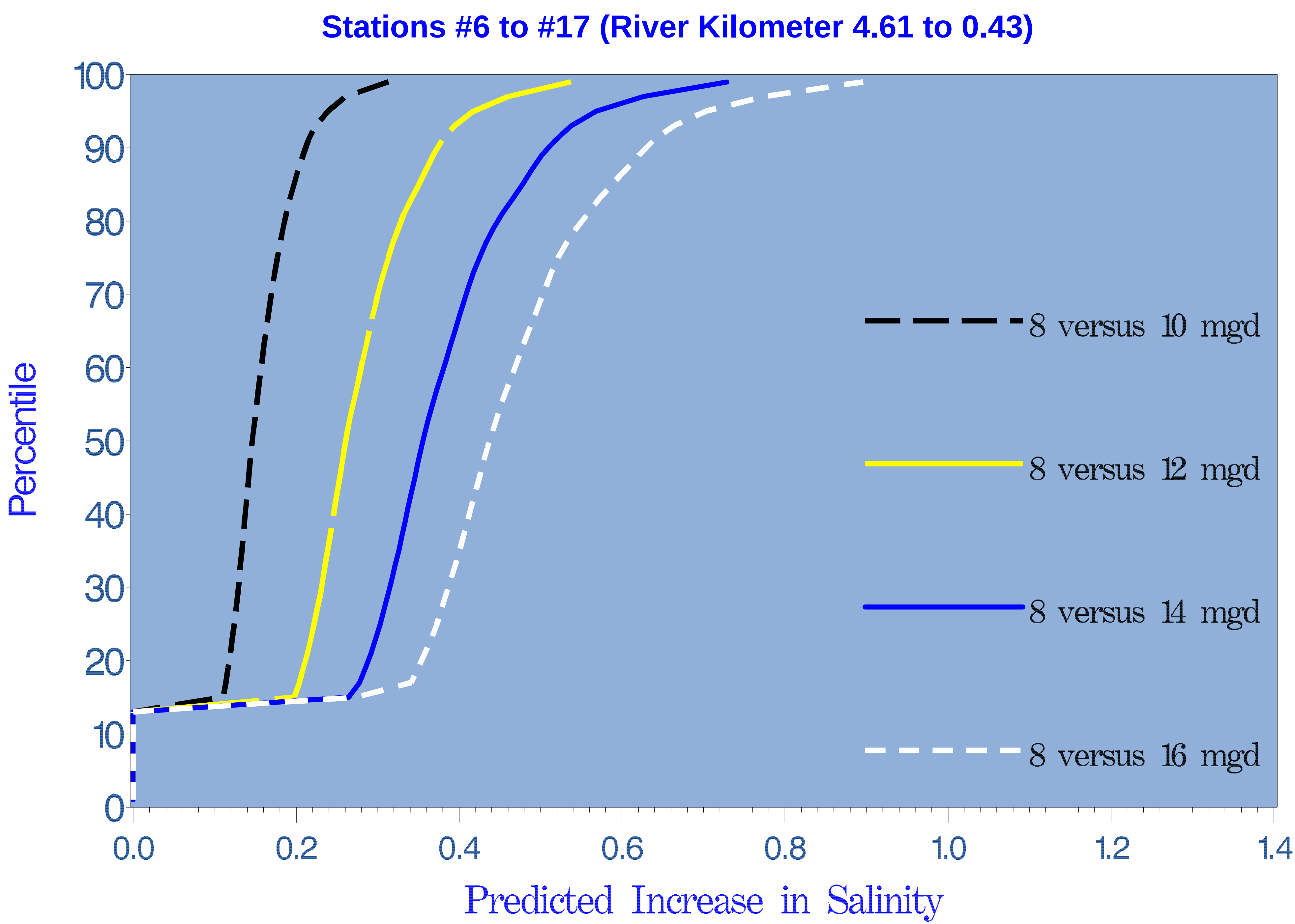


Figure 4.4.23 CDF of predicted change in Segment C surface salinities due to different increased withdrawals

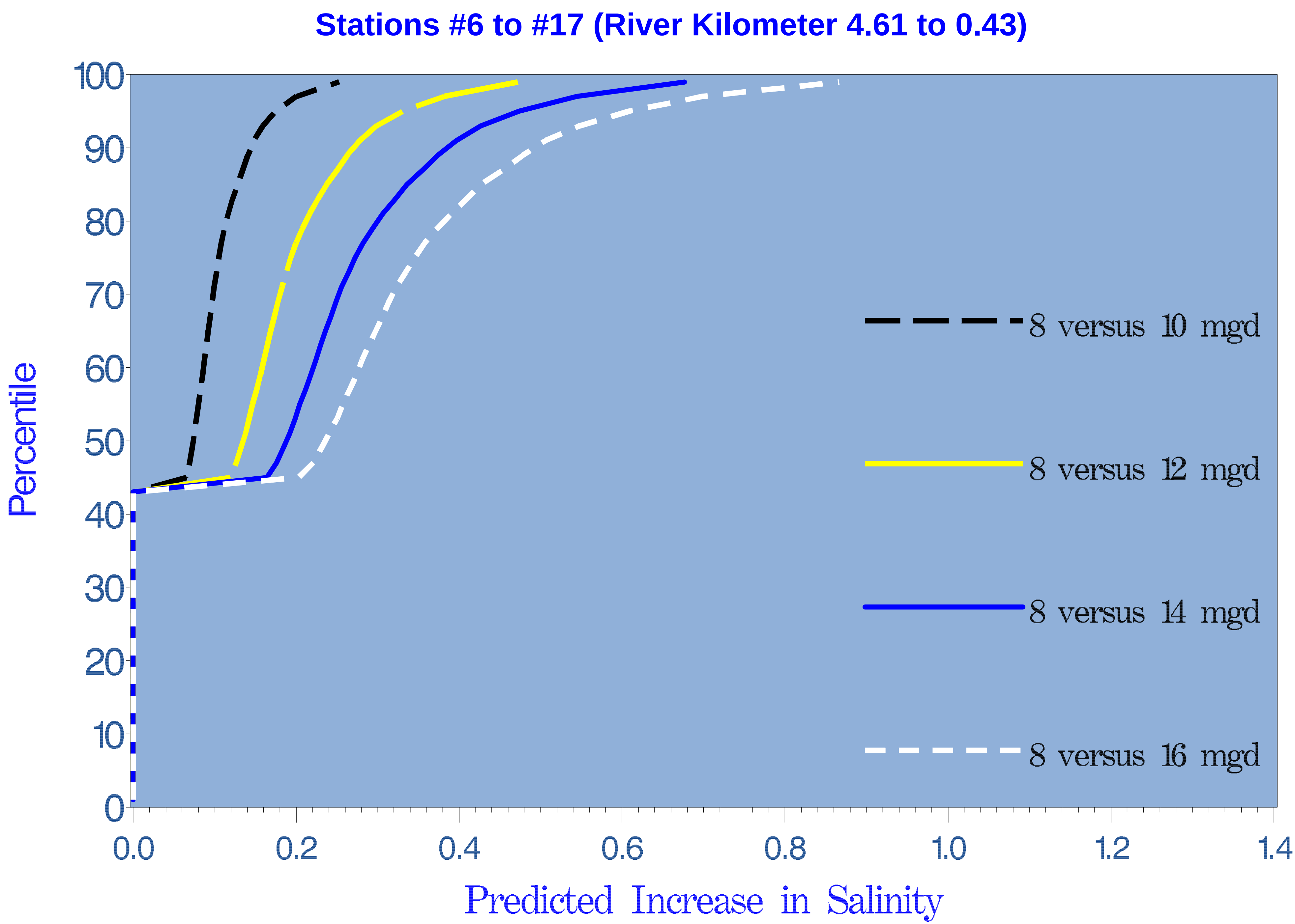


Figure 4.4.24 CDF of predicted change in Segment C bottom salinities due to different increased withdrawals

Appendix E

Statistical Models

Use STEPWISE to screen interactions of variables with Group A surface salinity
Modeled Flows 0 to 90 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Number of Observations Read	98
Number of Observations Used	90
Number of Observations with Missing Values	8

Stepwise Selection: Step 1

Variable LF3 Entered: R-Square = 0.6776 and C(p) = 64.4650

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	663.86436	663.86436	184.94	<.0001
Error	88	315.88626	3.58962		
Corrected Total	89	979.75062			

Variable	**Parameter Estimate**	**Standard Error**	**Type II SS**	**F Value**	**Pr > F**
Intercept	5.01904	0.26360	1301.37769	362.54	<.0001
LF3	-0.81856	0.06019	663.86436	184.94	<.0001

Bounds on condition number: 1, 1

Use STEPWISE to screen interactions of variables with Group A surface salinity
Modeled Flows 0 to 90 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 2

Variable LTF30 Entered: R-Square = 0.7626 and C(p) = 26.7744

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	2	747.19074	373.59537	139.76	<.0001
Error	87	232.55989	2.67310		
Corrected Total	89	979.75062			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	11.72906	1.22316	245.79656	91.95	<.0001
LF3	-0.54497	0.07141	155.69330	58.24	<.0001
LTF30	-1.31855	0.23616	83.32637	31.17	<.0001

Bounds on condition number: 1.89, 7.56

Use STEPWISE to screen interactions of variables with Group A surface salinity
Modeled Flows 0 to 90 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 3

Variable SHELL Entered: R-Square = 0.7788 and C(p) = 21.2322

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	763.02484	254.34161	100.93	<.0001
Error	86	216.72579	2.52007		
Corrected Total	89	979.75062			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	11.64414	1.18811	242.05335	96.05	<.0001
SHELL	-0.01982	0.00791	15.83410	6.28	0.0141
LF3	-0.46990	0.07553	97.55471	38.71	<.0001
LTF30	-1.17884	0.23598	62.88751	24.95	<.0001

Bounds on condition number: 2.2426, 17.943

Use STEPWISE to screen interactions of variables with Group A surface salinity
Modeled Flows 0 to 90 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 4

Variable LTF60 Entered: R-Square = 0.7931 and C(p) = 16.5455

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	4	777.06291	194.26573	81.47	<.0001
Error	85	202.68771	2.38456		
Corrected Total	89	979.75062			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	12.12188	1.17238	254.92374	106.91	<.0001
SHELL	-0.02073	0.00770	17.27721	7.25	0.0086
LF3	-0.42956	0.07532	77.54919	32.52	<.0001
LTF30	-2.38490	0.54752	45.24327	18.97	<.0001
LTF60	1.04865	0.43220	14.03807	5.89	0.0174

Bounds on condition number: 11.388, 99.038

Use STEPWISE to screen interactions of variables with Group A surface salinity
Modeled Flows 0 to 90 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 5

Variable RK Entered: R-Square = 0.8009 and C(p) = 14.9007

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	784.71476	156.94295	67.59	<.0001
Error	84	195.03586	2.32186		
Corrected Total	89	979.75062			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	16.80732	2.82839	81.98866	35.31	<.0001
RK	-0.50273	0.27693	7.65185	3.30	0.0730
SHELL	-0.02073	0.00760	17.27721	7.44	0.0078
LF3	-0.42956	0.07433	77.54919	33.40	<.0001
LTF30	-2.38490	0.54027	45.24327	19.49	<.0001
LTF60	1.04865	0.42648	14.03807	6.05	0.0160

Bounds on condition number: 11.388, 128.8

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Use STEPWISE to screen interactions of variables with Group A surface salinity
Modeled Flows 0 to 90 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Summary of Stepwise Selection									
Step	Variable Entered	Variable Removed	Label	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	LF3		Log Average 3-Day Shell Creek Flow (cfs)	1	0.6776	0.6776	64.4650	184.94	<.0001
2	LTF30		Log Average 30-Day Total River Flow (cfs)	2	0.0850	0.7626	26.7744	31.17	<.0001
3	SHELL		Shell Flow (cfs)	3	0.0162	0.7788	21.2322	6.28	0.0141
4	LTF60		Log Average 60-Day Total River Flow (cfs)	4	0.0143	0.7931	16.5455	5.89	0.0174
5	RK		River Kilometer	5	0.0078	0.8009	14.9007	3.30	0.0730

Use SAS General Linear Model (GLM) to develop best-fit modle using smallest number of variables for Group A modeling of surface salinity
Modeled Flows 0 to 90 cfs

The GLM Procedure

Dependent Variable: SAL   Salinity

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	766.1824127	255.3941376	100.70	<.0001
Error	90	228.2489475	2.5360994		
Corrected Total	93	994.4313602			

R-Square	Coeff Var	Root MSE	SAL Mean
0.770473	61.02173	1.592514	2.609748

Source	DF	Type I SS	Mean Square	F Value	Pr > F
RK	1	6.7090765	6.7090765	2.65	0.1073
LF3	1	673.2682479	673.2682479	265.47	<.0001
LTF30	1	86.2050883	86.2050883	33.99	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RK	1	6.7090765	6.7090765	2.65	0.1073
LF3	1	155.1336131	155.1336131	61.17	<.0001
LTF30	1	86.2050883	86.2050883	33.99	<.0001

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	16.09862947	2.89434685	5.56	<.0001
RK	-0.46061646	0.28319867	-1.63	0.1073
LF3	-0.54348718	0.06948955	-7.82	<.0001
LTF30	-1.33566468	0.22909422	-5.83	<.0001

Use STEPWISE to screen interactions of variables with Group A bottom salinity
Modeled Flows 0 to 120 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Number of Observations Read	134
Number of Observations Used	126
Number of Observations with Missing Values	8

Stepwise Selection: Step 1

Variable LTF30 Entered: R-Square = 0.6596 and C(p) = 55.4510

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	1325.17291	1325.17291	240.28	<.0001
Error	124	683.88372	5.51519		
Corrected Total	125	2009.05663			

Variable	**Parameter Estimate**	**Standard Error**	**Type II SS**	**F Value**	**Pr > F**
Intercept	22.66132	1.26284	1775.96811	322.01	<.0001
LTF30	-3.26325	0.21052	1325.17291	240.28	<.0001

Bounds on condition number: 1, 1

Use STEPWISE to screen interactions of variables with Group A bottom salinity
Modeled Flows 0 to 120 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 2

Variable LF3 Entered: R-Square = 0.7102 and C(p) = 31.0796

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1426.80666	713.40333	150.71	<.0001
Error	123	582.24998	4.73374		
Corrected Total	125	2009.05663			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	19.31165	1.37528	933.38267	197.18	<.0001
LF3	-0.41042	0.08858	101.63374	21.47	<.0001
LTF30	-2.46250	0.26058	422.72625	89.30	<.0001

Bounds on condition number: 1.7851, 7.1404

Use STEPWISE to screen interactions of variables with Group A bottom salinity
Modeled Flows 0 to 120 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 3

Variable SHELL Entered: R-Square = 0.7308 and C(p) = 22.3524

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1468.14844	489.38281	110.38	<.0001
Error	122	540.90820	4.43367		
Corrected Total	125	2009.05663			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	18.82837	1.34036	874.88012	197.33	<.0001
SHELL	-0.02067	0.00677	41.34178	9.32	0.0028
LF3	-0.31173	0.09161	51.33546	11.58	0.0009
LTF30	-2.21409	0.26499	309.53558	69.81	<.0001

Bounds on condition number: 2.0389, 17.211

Use STEPWISE to screen interactions of variables with Group A bottom salinity
Modeled Flows 0 to 120 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 4

Variable RK Entered: R-Square = 0.7435 and C(p) = 17.6901

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	4	1493.82440	373.45610	87.70	<.0001
Error	121	515.23224	4.25812		
Corrected Total	125	2009.05663			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	26.08217	3.23289	277.15554	65.09	<.0001
RK	-0.77831	0.31695	25.67596	6.03	0.0155
SHELL	-0.02067	0.00663	41.34178	9.71	0.0023
LF3	-0.31173	0.08978	51.33546	12.06	0.0007
LTF30	-2.21409	0.25969	309.53558	72.69	<.0001

Bounds on condition number: 2.0389, 26.949

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Use STEPWISE to screen interactions of variables with Group A bottom salinity
Modeled Flows 0 to 120 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Summary of Stepwise Selection									
Step	Variable Entered	Variable Removed	Label	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	LTF30		Log Average 30-Day Total River Flow (cfs)	1	0.6596	0.6596	55.4510	240.28	<.0001
2	LF3		Log Average 3-Day Shell Creek Flow (cfs)	2	0.0506	0.7102	31.0796	21.47	<.0001
3	SHELL		Shell Flow (cfs)	3	0.0206	0.7308	22.3524	9.32	0.0028
4	RK		River Kilometer	4	0.0128	0.7435	17.6901	6.03	0.0155

Use SAS General Linear Model (GLM) to develop best-fit modle using smallest number of variables for Group A modeling of bottom salinity
Modeled Flows 0 to 120 cfs

The GLM Procedure

Dependent Variable: SAL Salinity

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1467.967308	489.322436	107.92	<.0001
Error	126	571.288308	4.534034		
Corrected Total	129	2039.255616			

R-Square	Coeff Var	Root MSE	SAL Mean
0.719854	63.84112	2.129327	3.335354

Source	DF	Type I SS	Mean Square	F Value	Pr > F
RK	1	26.524011	26.524011	5.85	0.0170
LF3	1	1008.656328	1008.656328	222.46	<.0001
LTF30	1	432.786969	432.786969	95.45	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RK	1	26.5240113	26.5240113	5.85	0.0170
LF3	1	99.3450119	99.3450119	21.91	<.0001
LTF30	1	432.7869692	432.7869692	95.45	<.0001

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	26.70375760	3.28807980	8.12	<.0001
RK	-0.77878922	0.32199025	-2.42	0.0170
LF3	-0.40550727	0.08662994	-4.68	<.0001
LTF30	-2.48728795	0.25458416	-9.77	<.0001

Use STEPWISE to screen interactions of variables with Group B surface salinity
Modeled Flows 0 to 140 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Number of Observations Read	293
Number of Observations Used	277
Number of Observations with Missing Values	16

Stepwise Selection: Step 1

Variable LTF30 Entered: R-Square = 0.6538 and C(p) = 238.1496

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	2244.05630	2244.05630	519.30	<.0001
Error	275	1188.36898	4.32134		
Corrected Total	276	3432.42528			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	19.51084	0.73416	3051.99810	706.26	<.0001
LTF30	-2.73429	0.11999	2244.05630	519.30	<.0001

Bounds on condition number: 1, 1

Use STEPWISE to screen interactions of variables with Group B surface salinity
Modeled Flows 0 to 140 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 2

Variable LF3 Entered: R-Square = 0.7291 and C(p) = 128.9600

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	2	2502.56048	1251.28024	368.71	<.0001
Error	274	929.86480	3.39367		
Corrected Total	276	3432.42528			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	16.21787	0.75209	1578.01931	464.99	<.0001
LF3	-0.45413	0.05203	258.50418	76.17	<.0001
LTF30	-1.92398	0.14116	630.43770	185.77	<.0001

Bounds on condition number: 1.7624, 7.0496

Use STEPWISE to screen interactions of variables with Group B surface salinity
Modeled Flows 0 to 140 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 3

Variable RK Entered: R-Square = 0.7594 and C(p) = 86.2815

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2606.43323	868.81108	287.15	<.0001
Error	273	825.99205	3.02561		
Corrected Total	276	3432.42528			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	21.12543	1.09810	1119.79818	370.11	<.0001
RK	-0.70376	0.12011	103.87275	34.33	<.0001
LF3	-0.45430	0.04913	258.70549	85.51	<.0001
LTF30	-1.92263	0.13329	629.55077	208.07	<.0001

Bounds on condition number: 1.7624, 13.574

Use STEPWISE to screen interactions of variables with Group B surface salinity
Modeled Flows 0 to 140 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 4

Variable SHELL Entered: R-Square = 0.7745 and C(p) = 65.9543

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	2658.34163	664.58541	233.52	<.0001
Error	272	774.08365	2.84590		
Corrected Total	276	3432.42528			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	20.34091	1.08072	1008.17719	354.26	<.0001
RK	-0.70323	0.11649	103.71727	36.44	<.0001
SHELL	-0.01479	0.00346	51.90840	18.24	<.0001
LF3	-0.39402	0.04970	178.90765	62.87	<.0001
LTF30	-1.65705	0.14345	379.75957	133.44	<.0001

Bounds on condition number: 2.1702, 27.921

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Use STEPWISE to screen interactions of variables with Group B surface salinity
Modeled Flows 0 to 140 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Summary of Stepwise Selection									
Step	Variable Entered	Variable Removed	Label	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	LTF30		Log Average 30-Day Total River Flow (cfs)	1	0.6538	0.6538	238.150	519.30	<.0001
2	LF3		Log Average 3-Day Shell Creek Flow (cfs)	2	0.0753	0.7291	128.960	76.17	<.0001
3	RK		River Kilometer	3	0.0303	0.7594	86.2815	34.33	<.0001
4	SHELL		Shell Flow (cfs)	4	0.0151	0.7745	65.9543	18.24	<.0001

Use SAS General Linear Model (GLM) to develop best-fit modle using smallest number of variables for Group B modeling of surface salinity
Modeled Flows 0 to 140 cfs

The GLM Procedure

Dependent Variable: SAL Salinity

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2625.560354	875.186785	294.84	<.0001
Error	281	834.093289	2.968304		
Corrected Total	284	3459.653643			

R-Square	Coeff Var	Root MSE	SAL Mean
0.758908	57.56584	1.722877	2.992880

Source	DF	Type I SS	Mean Square	F Value	Pr > F
RK	1	109.227454	109.227454	36.80	<.0001
LF3	1	1880.735026	1880.735026	633.61	<.0001
LTF30	1	635.597875	635.597875	214.13	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RK	1	107.7097029	107.7097029	36.29	<.0001
LF3	1	259.0886072	259.0886072	87.29	<.0001
LTF30	1	635.5978748	635.5978748	214.13	<.0001

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	21.16576786	1.07798706	19.63	<.0001
RK	-0.70647846	0.11728046	-6.02	<.0001
LF3	-0.45430155	0.04862664	-9.34	<.0001
LTF30	-1.92932214	0.13184622	-14.63	<.0001

Use STEPWISE to screen interactions of variables with Group B bottome salinity
Modeled Flows 0 to 200 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Number of Observations Read	345
Number of Observations Used	325
Number of Observations with Missing Values	20

Stepwise Selection: Step 1

Variable LTF30 Entered: R-Square = 0.6692 and C(p) = 117.9043

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	3720.06191	3720.06191	653.46	<.0001
Error	323	1838.79780	5.69287		
Corrected Total	324	5558.85971			

Variable	**Parameter Estimate**	**Standard Error**	**Type II SS**	**F Value**	**Pr > F**
Intercept	23.35088	0.78047	5095.93333	895.14	<.0001
LTF30	-3.19343	0.12492	3720.06191	653.46	<.0001

Bounds on condition number: 1, 1

Use STEPWISE to screen interactions of variables with Group B bottome salinity
Modeled Flows 0 to 200 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 2

Variable LF3 Entered: R-Square = 0.7100 and C(p) = 65.8046

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	3946.71346	1973.35673	394.15	<.0001
Error	322	1612.14625	5.00667		
Corrected Total	324	5558.85971			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	20.78264	0.82548	3173.51084	633.86	<.0001
LF3	-0.40947	0.06086	226.65155	45.27	<.0001
LTF30	-2.52713	0.15340	1358.76932	271.39	<.0001

Bounds on condition number: 1.7145, 6.8581

Use STEPWISE to screen interactions of variables with Group B bottome salinity
Modeled Flows 0 to 200 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 3

Variable SHELL Entered: R-Square = 0.7290 and C(p) = 42.6372

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	4052.15264	1350.71755	287.77	<.0001
Error	321	1506.70707	4.69379		
Corrected Total	324	5558.85971			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	19.79263	0.82611	2694.34103	574.02	<.0001
SHELL	-0.01492	0.00315	105.43918	22.46	<.0001
LF3	-0.32852	0.06135	134.58733	28.67	<.0001
LTF30	-2.21205	0.16273	867.33405	184.78	<.0001

Bounds on condition number: 2.058, 17.074

Use STEPWISE to screen interactions of variables with Group B bottome salinity
Modeled Flows 0 to 200 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 4

Variable LTF60 Entered: R-Square = 0.7314 and C(p) = 41.3657

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	4065.85890	1016.46472	217.86	<.0001
Error	320	1493.00081	4.66563		
Corrected Total	324	5558.85971			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	19.81729	0.82376	2700.23405	578.75	<.0001
SHELL	-0.01611	0.00321	117.19135	25.12	<.0001
LF3	-0.33226	0.06120	137.49512	29.47	<.0001
LTF30	-1.68282	0.34880	108.59830	23.28	<.0001
LTF60	-0.49343	0.28789	13.70626	2.94	0.0875

Bounds on condition number: 9.5123, 82.478

Use STEPWISE to screen interactions of variables with Group B bottome salinity
Modeled Flows 0 to 200 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 5

Variable RK Entered: R-Square = 0.7336 and C(p) = 40.4686

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	5	4077.99646	815.59929	175.69	<.0001
Error	319	1480.86325	4.64220		
Corrected Total	324	5558.85971			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	21.36628	1.26208	1330.47534	286.60	<.0001
RK	-0.22204	0.13732	12.13756	2.61	0.1069
SHELL	-0.01610	0.00321	117.13285	25.23	<.0001
LF3	-0.33232	0.06105	137.54395	29.63	<.0001
LTF30	-1.68264	0.34793	108.57460	23.39	<.0001
LTF60	-0.49335	0.28716	13.70167	2.95	0.0868

Bounds on condition number: 9.5123, 108.1

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Use STEPWISE to screen interactions of variables with Group B bottome salinity
Modeled Flows 0 to 200 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Summary of Stepwise Selection									
Step	Variable Entered	Variable Removed	Label	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	LTF30		Log Average 30-Day Total River Flow (cfs)	1	0.6692	0.6692	117.904	653.46	<.0001
2	LF3		Log Average 3-Day Shell Creek Flow (cfs)	2	0.0408	0.7100	65.8046	45.27	<.0001
3	SHELL		Shell Flow (cfs)	3	0.0190	0.7290	42.6372	22.46	<.0001
4	LTF60		Log Average 60-Day Total River Flow (cfs)	4	0.0025	0.7314	41.3657	2.94	0.0875
5	RK		River Kilometer	5	0.0022	0.7336	40.4686	2.61	0.1069

Use SAS General Linear Model (GLM) to develop best-fit modle using smallest number of variables for Group B modeling of bottm salinity Modeled Flows 0 to 200 cfs

The GLM Procedure

Dependent Variable: SAL   Salinity

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	3979.115670	1326.371890	269.15	<.0001
Error	329	1621.321684	4.928029		
Corrected Total	332	5600.437354			

R-Square	Coeff Var	Root MSE	SAL Mean
0.710501	60.35560	2.219917	3.678062

Source	DF	Type I SS	Mean Square	F Value	Pr > F
RK	1	12.457500	12.457500	2.53	0.1128
LF3	1	2593.835702	2593.835702	526.34	<.0001
LTF30	1	1372.822468	1372.822468	278.57	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RK	1	11.832025	11.832025	2.40	0.1222
LF3	1	225.152405	225.152405	45.69	<.0001
LTF30	1	1372.822468	1372.822468	278.57	<.0001

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	22.34188507	1.27232677	17.56	<.0001
RK	-0.21657143	0.13976817	-1.55	0.1222
LF3	-0.40787312	0.06034252	-6.76	<.0001
LTF30	-2.53714374	0.15201083	-16.69	<.0001

Use STEPWISE to screen interactions of variables with Group C surface salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Number of Observations Read	635
Number of Observations Used	610
Number of Observations with Missing Values	25

Stepwise Selection: Step 1

Variable LTF30 Entered: R-Square = 0.5616 and C(p) = 375.0424

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	11324	11324	778.79	<.0001
Error	608	8840.62570	14.54050		
Corrected Total	609	20165			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	31.56793	0.93425	16601	1141.74	<.0001
LTF30	-3.98211	0.14269	11324	778.79	<.0001

Bounds on condition number: 1, 1

Use STEPWISE to screen interactions of variables with Group C surface salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 2

Variable RK Entered: R-Square = 0.6713 and C(p) = 131.4823

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	2	13537	6768.43703	619.88	<.0001
Error	607	6627.77055	10.91890		
Corrected Total	609	20165			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	34.58818	0.83692	18649	1707.99	<.0001
RK	-1.24739	0.08762	2212.85516	202.66	<.0001
LTF30	-3.97602	0.12365	11289	1033.92	<.0001

Bounds on condition number: 1, 4

Use STEPWISE to screen interactions of variables with Group C surface salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 3

Variable SHELL Entered: R-Square = 0.7065 and C(p) = 54.8498

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	14245	4748.48924	486.15	<.0001
Error	606	5919.17687	9.76762		
Corrected Total	609	20165			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	32.16943	0.84097	14293	1463.28	<.0001
RK	-1.25225	0.08288	2230.03535	228.31	<.0001
SHELL	-0.01109	0.00130	708.59368	72.55	<.0001
LTF30	-3.33116	0.13932	5584.04017	571.69	<.0001

Bounds on condition number: 1.4191, 11.515

Use STEPWISE to screen interactions of variables with Group C surface salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 4

Variable LF3 Entered: R-Square = 0.7081 and C(p) = 53.2097

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	4	14278	3569.56780	366.88	<.0001
Error	605	5886.37342	9.72954		
Corrected Total	609	20165			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	31.74407	0.87071	12932	1329.16	<.0001
RK	-1.25243	0.08271	2230.65455	229.27	<.0001
SHELL	-0.01035	0.00136	561.47508	57.71	<.0001
LF3	-0.13241	0.07211	32.80346	3.37	0.0668
LTF30	-3.19283	0.15815	3965.82223	407.61	<.0001

Bounds on condition number: 1.8357, 24.842

Use STEPWISE to screen interactions of variables with Group C surface salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 5

Variable LF30 Entered: R-Square = 0.7101 and C(p) = 50.6550

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	5	14319	2863.86299	295.92	<.0001
Error	604	5845.32964	9.67770		
Corrected Total	609	20165			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	31.99952	0.87720	12878	1330.72	<.0001
RK	-1.25176	0.08249	2228.25158	230.25	<.0001
SHELL	-0.01034	0.00136	560.83077	57.95	<.0001
LF3	-0.25644	0.09381	72.32273	7.47	0.0064
LF30	0.27630	0.13417	41.04378	4.24	0.0399
LTF30	-3.35466	0.17621	3507.40206	362.42	<.0001

Bounds on condition number: 3.6831, 58.116

Use STEPWISE to screen interactions of variables with Group C surface salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 6

Variable LF10 Entered: R-Square = 0.7157 and C(p) = 40.2074

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	6	14431	2405.24776	252.98	<.0001
Error	603	5733.15804	9.50772		
Corrected Total	609	20165			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	32.21594	0.87174	12985	1365.73	<.0001
RK	-1.25316	0.08177	2233.18804	234.88	<.0001
SHELL	-0.00951	0.00137	459.53611	48.33	<.0001
LF3	0.48215	0.23427	40.27153	4.24	0.0400
LF10	-1.54805	0.45069	112.17159	11.80	0.0006
LF30	1.07473	0.26780	153.12444	16.11	<.0001
LTF30	-3.41081	0.17542	3594.31538	378.04	<.0001

Bounds on condition number: 51.207, 544.11

Use STEPWISE to screen interactions of variables with Group C surface salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 7

Variable LF5 Entered: R-Square = 0.7197 and C(p) = 33.2236

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	7	14512	2073.20628	220.81	<.0001
Error	602	5652.20068	9.38904		
Corrected Total	609	20165			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	32.55169	0.87380	13030	1387.79	<.0001
RK	-1.25228	0.08126	2229.99881	237.51	<.0001
SHELL	-0.00826	0.00142	315.57312	33.61	<.0001
LF3	-0.82546	0.50249	25.33736	2.70	0.1010
LF5	2.01876	0.68749	80.95736	8.62	0.0034
LF10	-2.77430	0.61236	192.71684	20.53	<.0001
LF30	1.57241	0.31551	233.19419	24.84	<.0001
LTF30	-3.49664	0.17676	3674.19027	391.33	<.0001

Bounds on condition number: 165.37, 2650.6

Use STEPWISE to screen interactions of variables with Group C surface salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 8

Variable LF60 Entered: R-Square = 0.7252 and C(p) = 22.9306

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	8	14623	1827.90267	198.25	<.0001
Error	601	5541.42324	9.22034		
Corrected Total	609	20165			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	32.75858	0.86797	13134	1424.43	<.0001
RK	-1.25370	0.08052	2235.02902	242.40	<.0001
SHELL	-0.00698	0.00146	210.59193	22.84	<.0001
LF3	-0.82207	0.49796	25.12951	2.73	0.0993
LF5	2.39931	0.69008	111.46181	12.09	0.0005
LF10	-3.63317	0.65547	283.27831	30.72	<.0001
LF30	2.23280	0.36614	342.88660	37.19	<.0001
LF60	-0.95451	0.27538	110.77744	12.01	0.0006
LTF30	-2.95140	0.23543	1449.04654	157.16	<.0001

Bounds on condition number: 169.67, 3319.9

Use STEPWISE to screen interactions of variables with Group C surface salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 9

Variable LFCUB Entered: R-Square = 0.7320 and C(p) = 9.7105

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	14760	1640.04188	182.08	<.0001
Error	600	5404.26767	9.00711		
Corrected Total	609	20165			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	33.89751	0.90616	12604	1399.34	<.0001
RK	-1.25157	0.07959	2227.31077	247.28	<.0001
SHELL	-0.00564	0.00148	130.52840	14.49	0.0002
LF3	-5.65227	1.33206	162.17542	18.01	<.0001
LF5	6.59233	1.27271	241.66190	26.83	<.0001
LF10	-4.46177	0.68176	385.78048	42.83	<.0001
LF30	2.65627	0.37780	445.24366	49.43	<.0001
LF60	-1.23234	0.28133	172.82517	19.19	<.0001
LFCUB	0.36423	0.09334	137.15557	15.23	0.0001
LTF30	-2.99079	0.23291	1485.18627	164.89	<.0001

Bounds on condition number: 669.64, 13227

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Use STEPWISE to screen interactions of variables with Group C surface salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Summary of Stepwise Selection									
Step	Variable Entered	Variable Removed	Label	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	LTF30		Log Average 30-Day Total River Flow (cfs)	1	0.5616	0.5616	375.042	778.79	<.0001
2	RK		River Kilometer	2	0.1097	0.6713	131.482	202.66	<.0001
3	SHELL		Shell Flow (cfs)	3	0.0351	0.7065	54.8498	72.55	<.0001
4	LF3		Log Average 3-Day Shell Creek Flow (cfs)	4	0.0016	0.7081	53.2097	3.37	0.0668
5	LF30		Log Average 30-Day Shell Creek Flow (cfs)	5	0.0020	0.7101	50.6550	4.24	0.0399
6	LF10		Log Average 10-Day Shell Creek Flow (cfs)	6	0.0056	0.7157	40.2074	11.80	0.0006
7	LF5		Log Average 5-Day Shell Creek Flow (cfs)	7	0.0040	0.7197	33.2236	8.62	0.0034
8	LF60		Log Average 60-Day Shell Creek Flow (cfs)	8	0.0055	0.7252	22.9306	12.01	0.0006
9	LFCUB		Log Cubic Term of Estiamted Flow (cfs)	9	0.0068	0.7320	9.7105	15.23	0.0001

Use SAS General Linear Model (GLM) to develop best-fit modle using smallest number of variables for Group C modeling of surface salinity
Modeled Flows 0 to 450 cfs

The GLM Procedure

Dependent Variable: SAL Salinity

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	13817.56265	4605.85422	439.42	<.0001
Error	616	6456.67128	10.48161		
Corrected Total	619	20274.23393			

R-Square	Coeff Var	Root MSE	SAL Mean
0.681533	55.05017	3.237531	5.881056

Source	DF	Type I SS	Mean Square	F Value	Pr > F
RK	1	2314.632922	2314.632922	220.83	<.0001
LF3	1	5986.667195	5986.667195	571.16	<.0001
LTF30	1	5516.262528	5516.262528	526.28	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RK	1	2283.931302	2283.931302	217.90	<.0001
LF3	1	179.930919	179.930919	17.17	<.0001
LTF30	1	5516.262528	5516.262528	526.28	<.0001

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	33.31052018	0.87705637	37.98	<.0001
RK	-1.25702621	0.08515630	-14.76	<.0001
LF3	-0.29592783	0.07142445	-4.14	<.0001
LTF30	-3.57132632	0.15567578	-22.94	<.0001

Use STEPWISE to screen interactions of variables with Group C bottom salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Number of Observations Read	635
Number of Observations Used	610
Number of Observations with Missing Values	25

Stepwise Selection: Step 1

Variable LTF30 Entered: R-Square = 0.5364 and C(p) = 341.0004

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	12686	12686	703.43	<.0001
Error	608	10965	18.03503		
Corrected Total	609	23652			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	34.01360	1.03891	19332	1071.89	<.0001
LTF30	-4.20979	0.15873	12686	703.43	<.0001

Bounds on condition number: 1, 1

Use STEPWISE to screen interactions of variables with Group C bottom salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 2

Variable RK Entered: R-Square = 0.6634 and C(p) = 83.6216

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	15690	7844.83189	598.07	<.0001
Error	607	7961.95402	13.11689		
Corrected Total	609	23652			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	37.56251	0.91652	22032	1679.68	<.0001
RK	-1.45456	0.09613	3003.34174	228.97	<.0001
LTF30	-4.20568	0.13537	12662	965.29	<.0001

Bounds on condition number: 1, 4

Use STEPWISE to screen interactions of variables with Group C bottom salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity
Stepwise Selection: Step 3

Variable SHELL Entered: R-Square = 0.6863 and C(p) = 38.6971

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	16233	5411.00051	442.01	<.0001
Error	606	7418.61629	12.24194		
Corrected Total	609	23652			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	35.45094	0.94044	17396	1420.98	<.0001
RK	-1.45545	0.09287	3007.00185	245.63	<.0001
SHELL	-0.00972	0.00146	543.33773	44.38	<.0001
LTF30	-3.64318	0.15566	6705.79678	547.77	<.0001

Bounds on condition number: 1.4169, 11.501

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Use STEPWISE to screen interactions of variables with Group C bottom salinity
Modeled Flows 0 to 450 cfs

The STEPWISE Procedure
Model: MODEL1
Dependent Variable: SAL Salinity

Summary of Stepwise Selection									
Step	Variable Entered	Variable Removed	Label	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	LTF30		Log Average 30-Day Total River Flow (cfs)	1	0.5364	0.5364	341.000	703.43	<.0001
2	RK		River Kilometer	2	0.1270	0.6634	83.6216	228.97	<.0001
3	SHELL		Shell Flow (cfs)	3	0.0230	0.6863	38.6971	44.38	<.0001

Use SAS General Linear Model (GLM) to develop best-fit modle using smallest number of variables for Group C modeling of bottom salinity
Modeled Flows 0 to 450 cfs

The GLM Procedure

Dependent Variable: SAL Salinity

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	15849.02953	5283.00984	411.15	<.0001
Error	616	7915.18822	12.84933		
Corrected Total	619	23764.21775			

R-Square	Coeff Var	Root MSE	SAL Mean
0.666928	52.23238	3.584596	6.862786

Source	DF	Type I SS	Mean Square	F Value	Pr > F
RK	1	3107.577718	3107.577718	241.85	<.0001
LF3	1	5875.587396	5875.587396	457.27	<.0001
LTF30	1	6865.864415	6865.864415	534.34	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
RK	1	3082.721541	3082.721541	239.91	<.0001
LF3	1	59.074886	59.074886	4.60	0.0324
LTF30	1	6865.864415	6865.864415	534.34	<.0001

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	36.82586598	0.96938118	37.99	<.0001
RK	-1.46172258	0.09437090	-15.49	<.0001
LF3	-0.16928505	0.07895096	-2.14	0.0324
LTF30	-3.97284019	0.17186750	-23.12	<.0001

Appendix F

Low Frequency Analyses

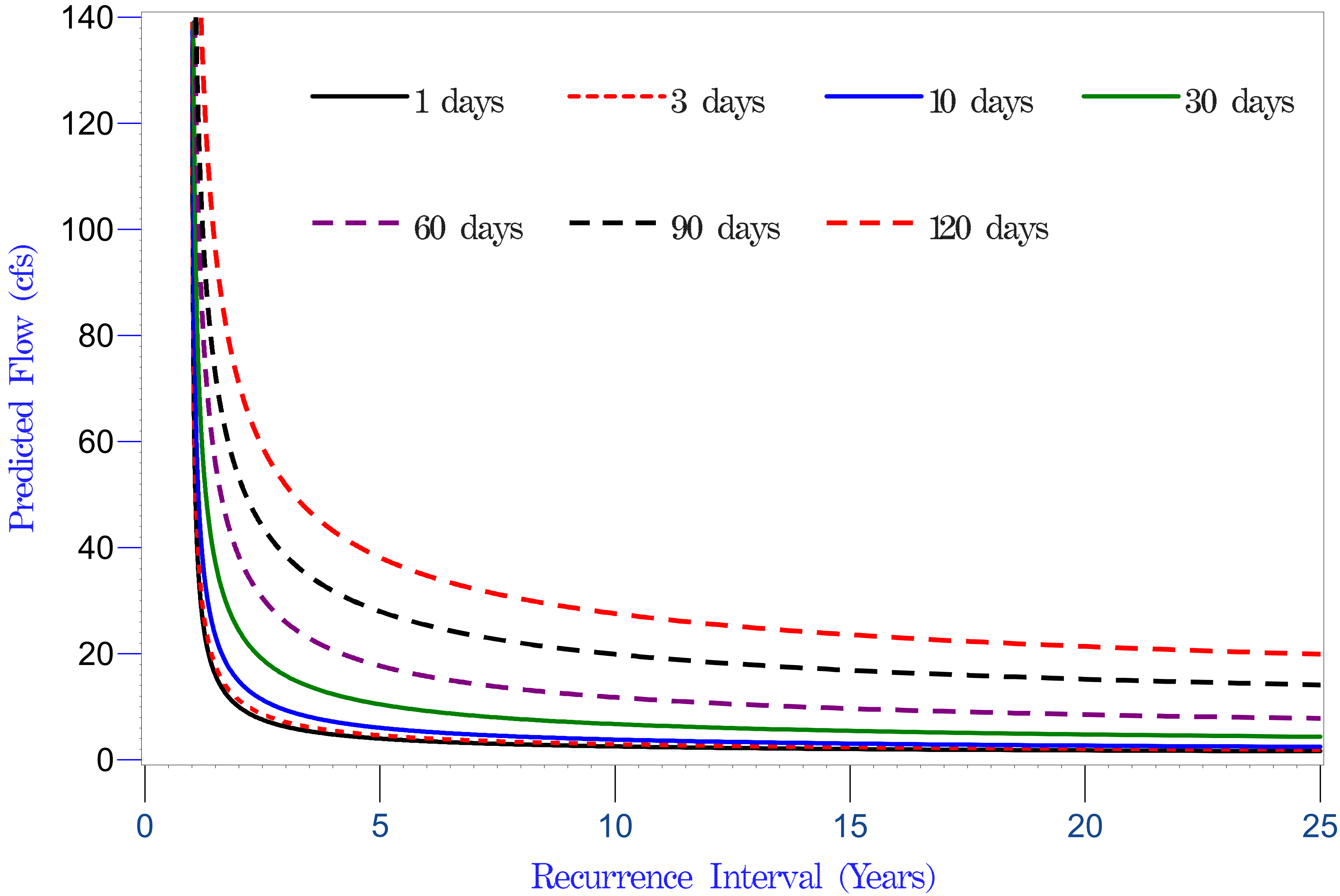


Figure 5.1 Consecutive day/low frequency analysis of Shell Creek flows without withdrawals (1966-2004)

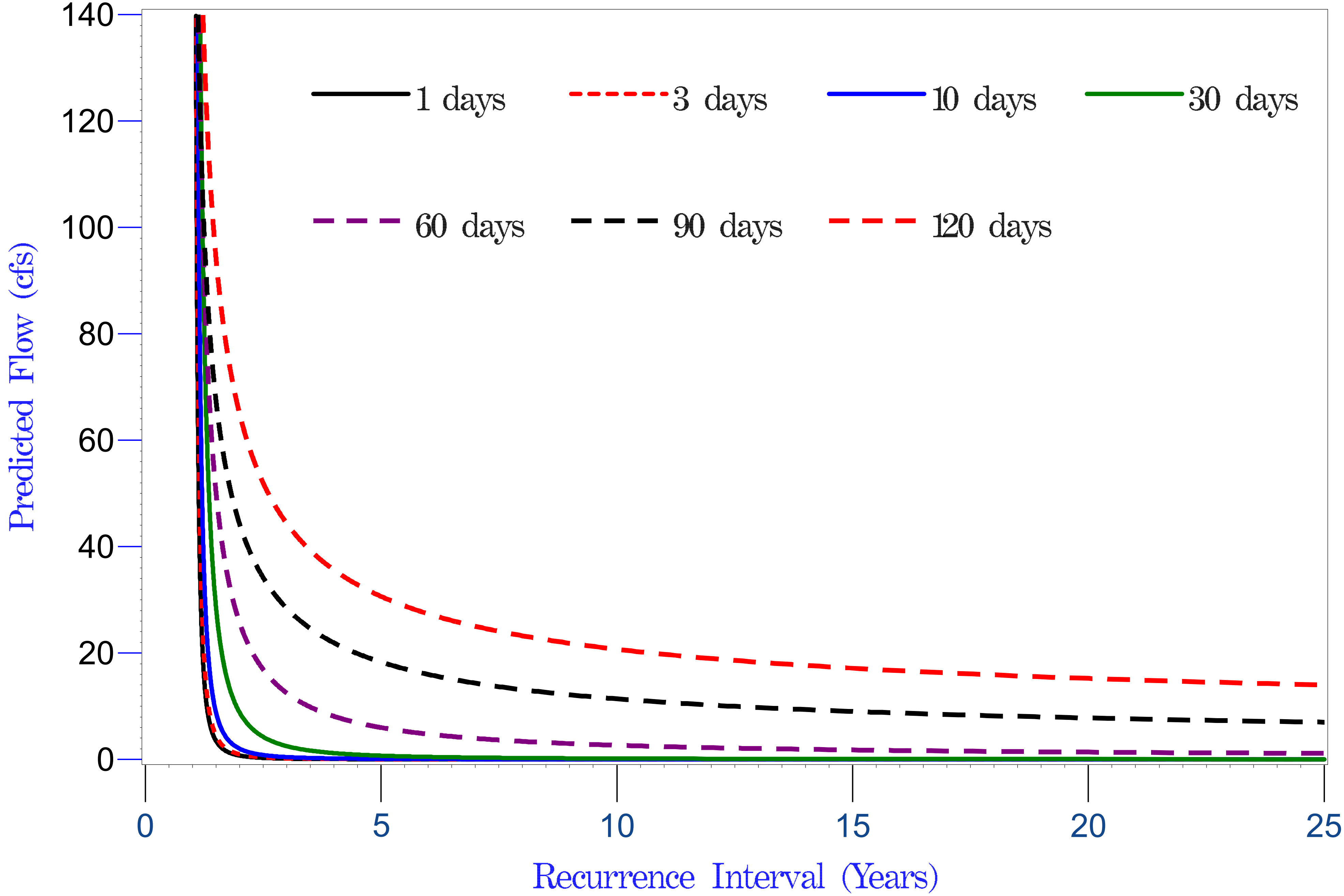


Figure 5.2 Consecutive day/low frequency analysis of Shell Creek flows with historic withdrawals (1966-2004)

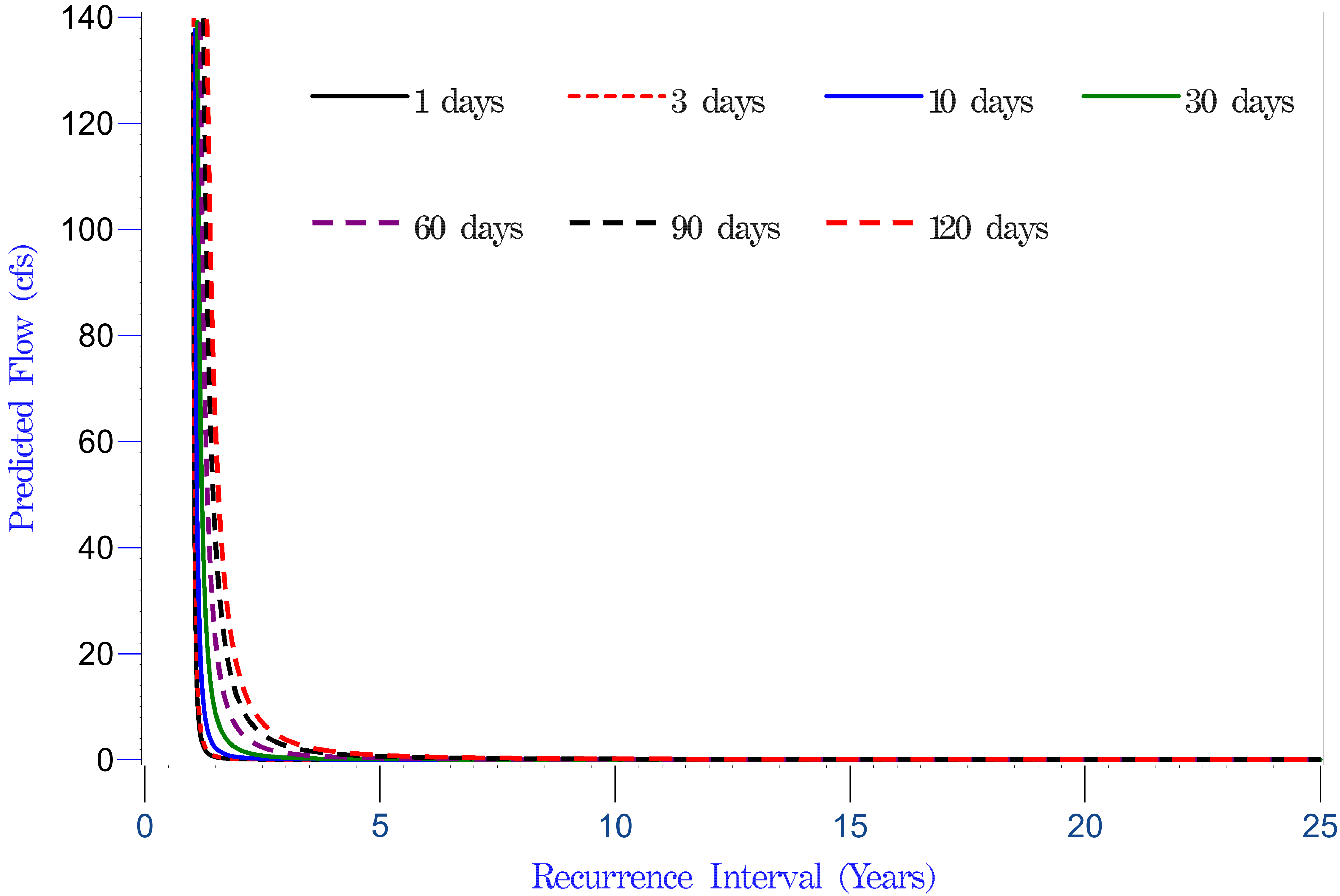


Figure 5.3 Consecutive day/low frequency analysis of Shell Creek flows with 8 mgd withdrawals (1966-2004)

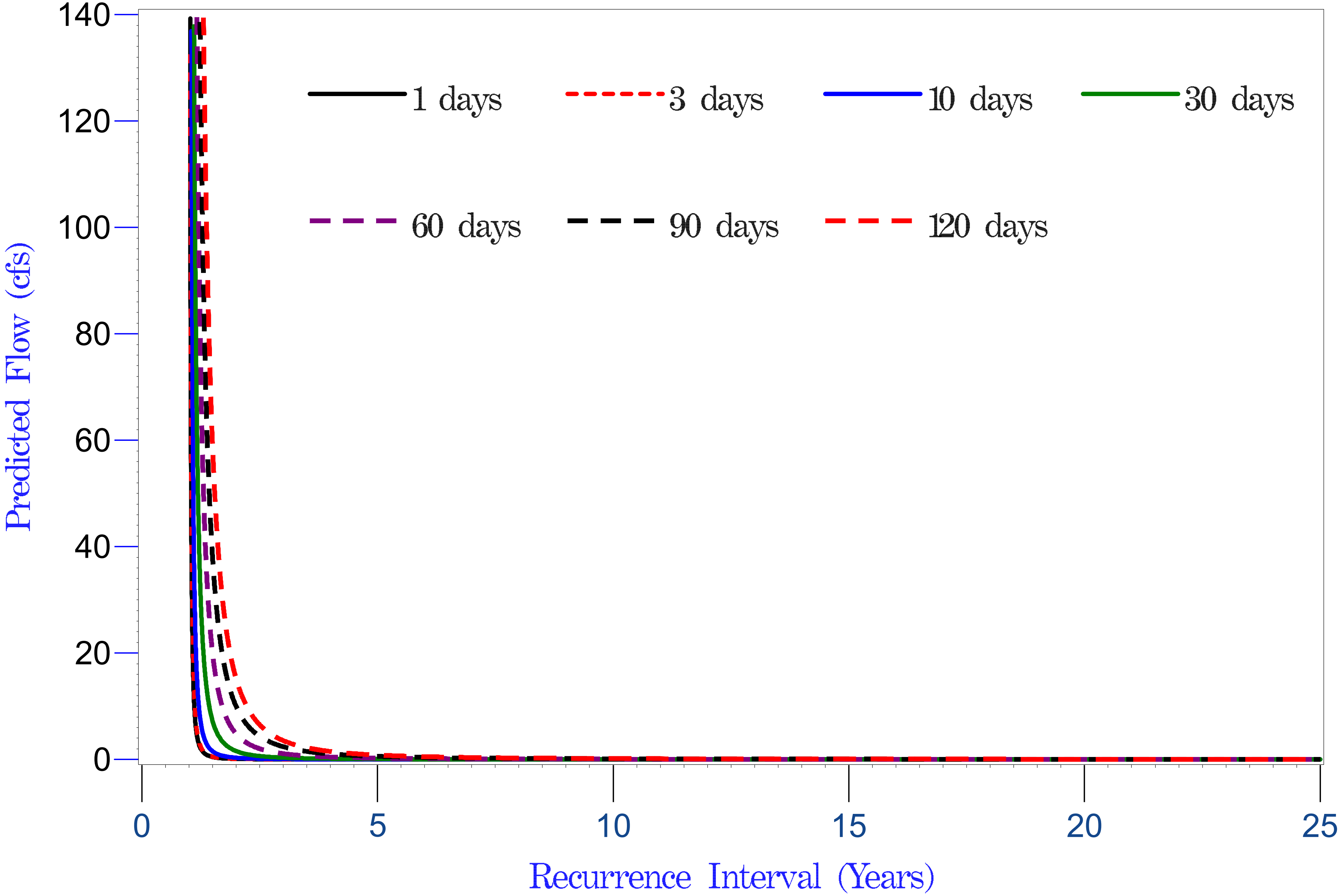


Figure 5.4 Consecutive day/low frequency analysis of Shell Creek flows with 10 mgd withdrawals (1966-2004)

Table 5.2

Lowest Average Flow (cfs)
for Indicated Recurrence Intervals (years)
(Without Withdrawals)

Consecutive Days	Variable	2 Years	3 Years	5 Years	10 Years	25 Years
1	pu	12.2	7.6	5.0	3.2	2.1
1	pl	8.2	5.0	3.1	1.9	1.2
1	p_flow	10.0	6.2	4.0	2.5	1.6
3	pu	13.6	8.6	5.7	3.7	2.5
3	pl	9.3	5.8	3.6	2.2	1.4
3	p_flow	11.3	7.1	4.6	2.9	1.9
10	pu	18.0	11.3	7.4	4.8	3.2
10	pl	12.3	7.6	4.8	2.9	1.8
10	p_flow	14.8	9.3	6.0	3.8	2.4
30	pu	29.2	18.9	12.7	8.4	5.6
30	pl	20.4	13.1	8.4	5.2	3.2
30	p_flow	24.4	15.8	10.5	6.7	4.3
60	pu	45.1	30.5	21.1	14.4	9.8
60	pl	32.7	21.8	14.5	9.3	5.9
60	p_flow	38.4	25.9	17.7	11.8	7.8
90	pu	60.9	43.9	32.3	23.5	17.1
90	pl	46.6	33.3	23.7	16.4	11.2
90	p_flow	53.2	38.4	28.0	19.9	14.1
120	pu	80.8	58.9	43.9	32.4	24.0
120	pl	62.3	45.0	32.5	22.8	15.9
120	p_flow	70.9	51.7	38.1	27.6	19.9

PU = Predicted Upper Limit
PL = Predicted Lower Limit
P_FLOW = Predicted Flow

Table 5.3

Lowest Average Flow (cfs) for Indicated Recurrence Intervals (years)
(With Actual Historic Withdrawals)

Consecutive Days	Variable	2 Years	3 Years	5 Years	10 Years	25 Years
1	pu	1.4	0.3	0.1	0.0	0.0
1	pl	0.4	0.1	0.0	0.0	0.0
1	p_flow	0.7	0.1	0.0	0.0	0.0
3	pu	1.9	0.4	0.1	0.0	0.0
3	pl	0.5	0.1	0.0	0.0	0.0
3	p_flow	1.0	0.2	0.0	0.0	0.0
10	pu	3.8	0.8	0.2	0.0	0.0
10	pl	1.1	0.2	0.0	0.0	0.0
10	p_flow	2.0	0.4	0.1	0.0	0.0
30	pu	14.9	4.2	1.2	0.3	0.1
30	pl	5.3	1.4	0.4	0.1	0.0
30	p_flow	8.8	2.5	0.7	0.2	0.0
60	pu	34.7	16.7	8.2	3.8	1.8
60	pl	19.2	9.1	4.2	1.7	0.7
60	p_flow	25.7	12.5	6.0	2.7	1.1
90	pu	53.2	34.0	22.3	14.3	9.1
90	pl	36.9	23.4	14.6	8.7	5.1
90	p_flow	44.3	28.4	18.3	11.4	7.0
120	pu	76.1	51.9	36.4	25.1	17.5
120	pl	55.5	37.4	25.2	16.4	10.6
120	p_flow	65.0	44.3	30.6	20.7	14.0

PU = Predicted Upper Limit
PL = Predicted Lower Limit
P_FLOW = Predicted Flow

Table 5.4

Lowest Average Flow (cfs)
for Indicated Recurrence Intervals (years)
(With 8 mgd Withdrawals)

Consecutive Days	Variable	2 Years	3 Years	5 Years	10 Years	25 Years
1	pu	0.2	0.0	0.0	0.0	0.0
1	pl	0.1	0.0	0.0	0.0	0.0
1	p_flow	0.1	0.0	0.0	0.0	0.0
3	pu	0.3	0.1	0.0	0.0	0.0
3	pl	0.1	0.0	0.0	0.0	0.0
3	p_flow	0.1	0.0	0.0	0.0	0.0
10	pu	0.9	0.2	0.0	0.0	0.0
10	pl	0.3	0.0	0.0	0.0	0.0
10	p_flow	0.5	0.1	0.0	0.0	0.0
30	pu	3.8	0.8	0.2	0.0	0.0
30	pl	1.0	0.2	0.0	0.0	0.0
30	p_flow	2.0	0.4	0.1	0.0	0.0
60	pu	10.3	2.3	0.6	0.1	0.0
60	pl	3.1	0.7	0.1	0.0	0.0
60	p_flow	5.6	1.3	0.3	0.1	0.0
90	pu	19.9	4.8	1.2	0.3	0.1
90	pl	6.2	1.4	0.3	0.1	0.0
90	p_flow	11.0	2.7	0.6	0.1	0.0
120	pu	29.8	6.9	1.7	0.4	0.1
120	pl	9.0	2.0	0.4	0.1	0.0
120	p_flow	16.3	3.8	0.9	0.2	0.0

PU = Predicted Upper Limit
PL = Predicted Lower Limit
P_FLOW = Predicted Flow

Table 5.5

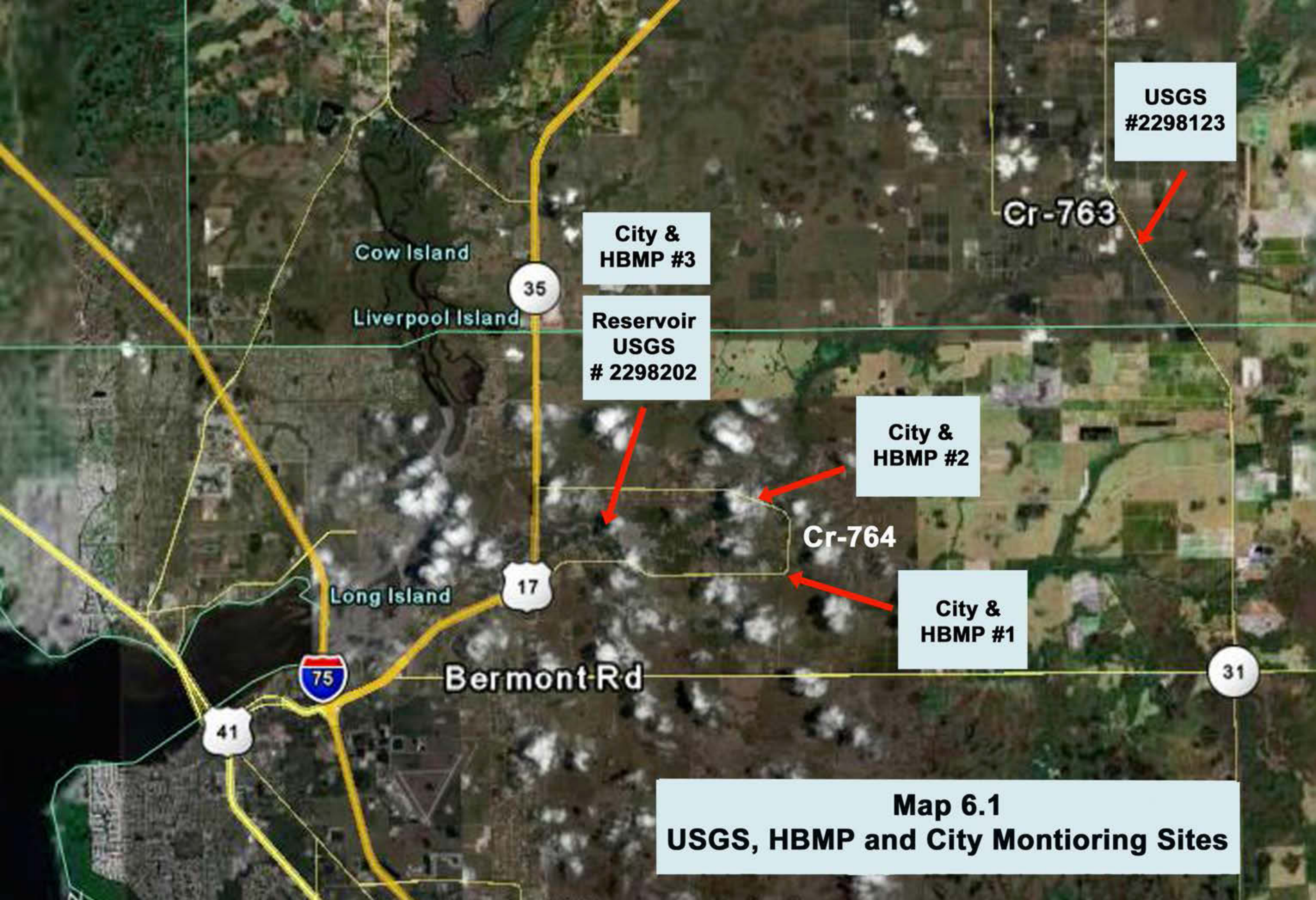
Lowest Average Flow (cfs)
for Indicated Recurrence Intervals (years)
(With 10 mgd Withdrawals)

Consecutive Days	Variable	2 Years	3 Years	5 Years	10 Years	25 Years
1	pu	0.2	0.0	0.0	0.0	0.0
1	pl	0.1	0.0	0.0	0.0	0.0
1	p_flow	0.1	0.0	0.0	0.0	0.0
3	pu	0.2	0.0	0.0	0.0	0.0
3	pl	0.1	0.0	0.0	0.0	0.0
3	p_flow	0.1	0.0	0.0	0.0	0.0
10	pu	0.6	0.1	0.0	0.0	0.0
10	pl	0.2	0.0	0.0	0.0	0.0
10	p_flow	0.3	0.1	0.0	0.0	0.0
30	pu	3.0	0.6	0.1	0.0	0.0
30	pl	0.8	0.2	0.0	0.0	0.0
30	p_flow	1.6	0.3	0.1	0.0	0.0
60	pu	8.9	2.0	0.5	0.1	0.0
60	pl	2.6	0.6	0.1	0.0	0.0
60	p_flow	4.8	1.1	0.2	0.1	0.0
90	pu	18.0	4.3	1.1	0.2	0.1
90	pl	5.6	1.3	0.3	0.1	0.0
90	p_flow	10.0	2.4	0.6	0.1	0.0
120	pu	27.8	6.4	1.6	0.3	0.1
120	pl	8.4	1.9	0.4	0.1	0.0
120	p_flow	15.2	3.5	0.8	0.2	0.0

PU = Predicted Upper Limit
PL = Predicted Lower Limit
P_FLOW = Predicted Flow

Appendix G

Water Quality



Map 6.1
USGS, HBMP and City Montioring Sites

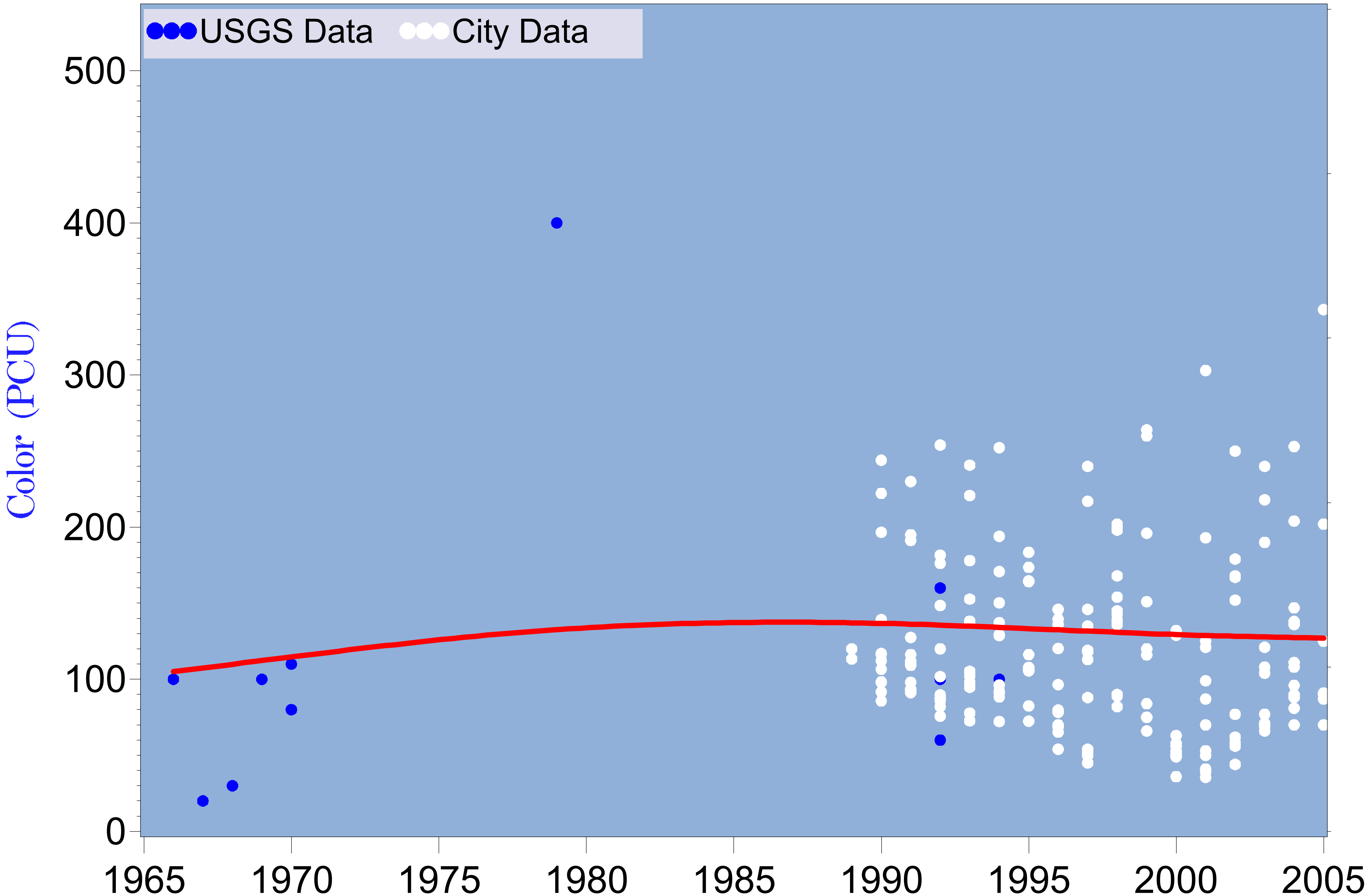


Figure 6.1 Color USGS site 2298123
Prairie Creek near Fort Ogden

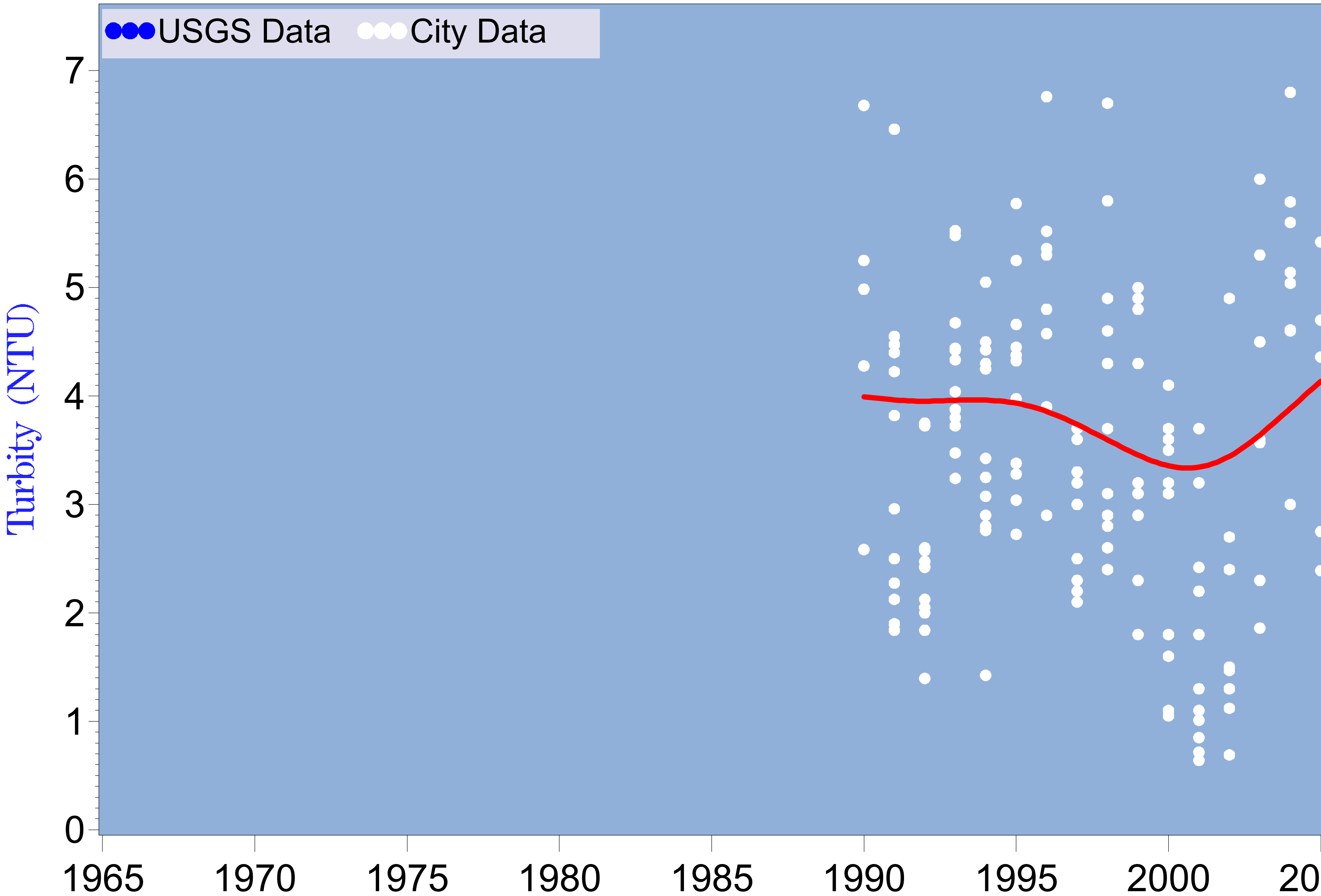


Figure 6.2 Turbidity USGS site 2298123
Prairie Creek near Fort Ogden

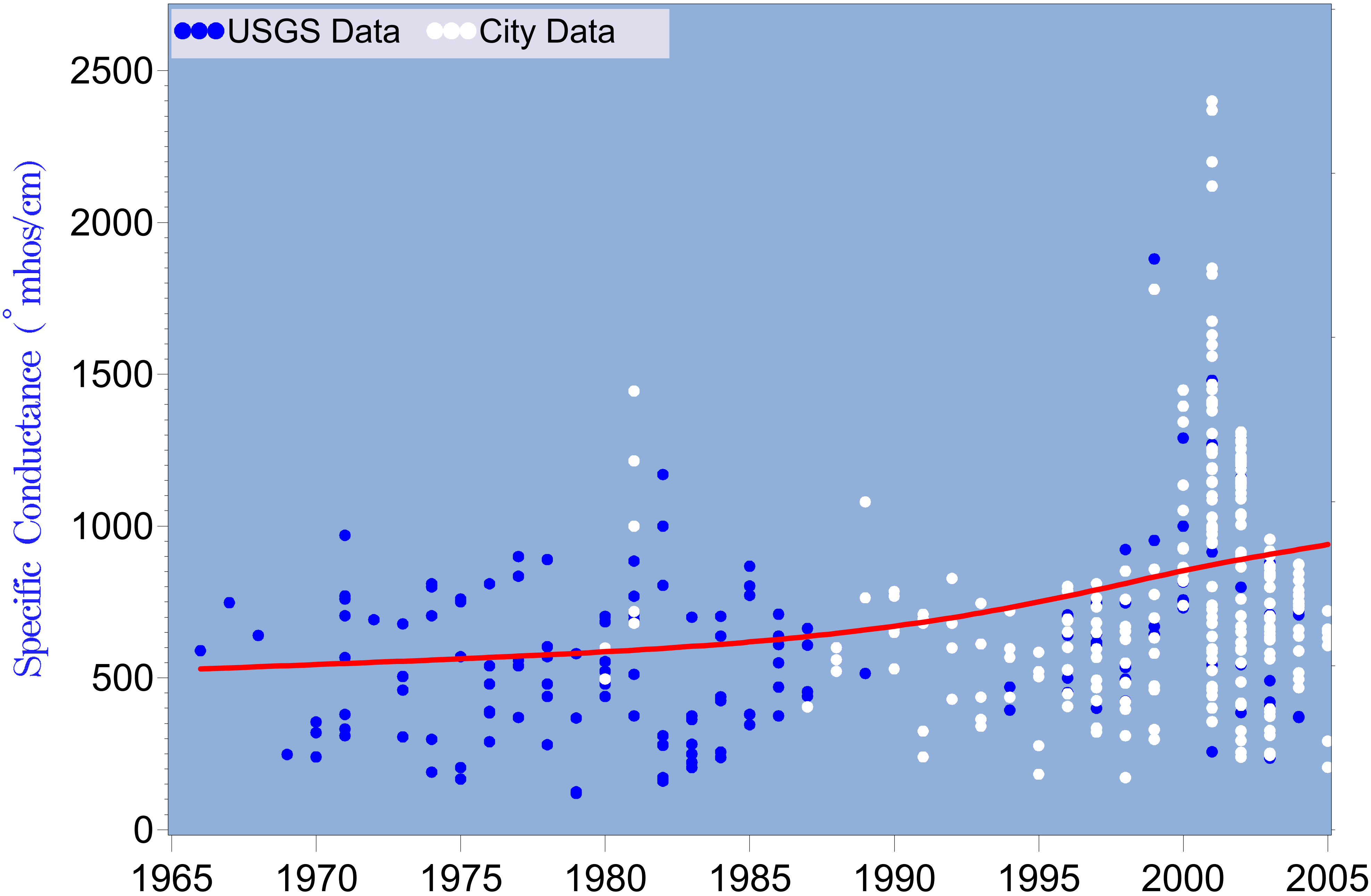


Figure 6.3 Specific conductance USGS site 2298123
Prairie Creek near Fort Ogden

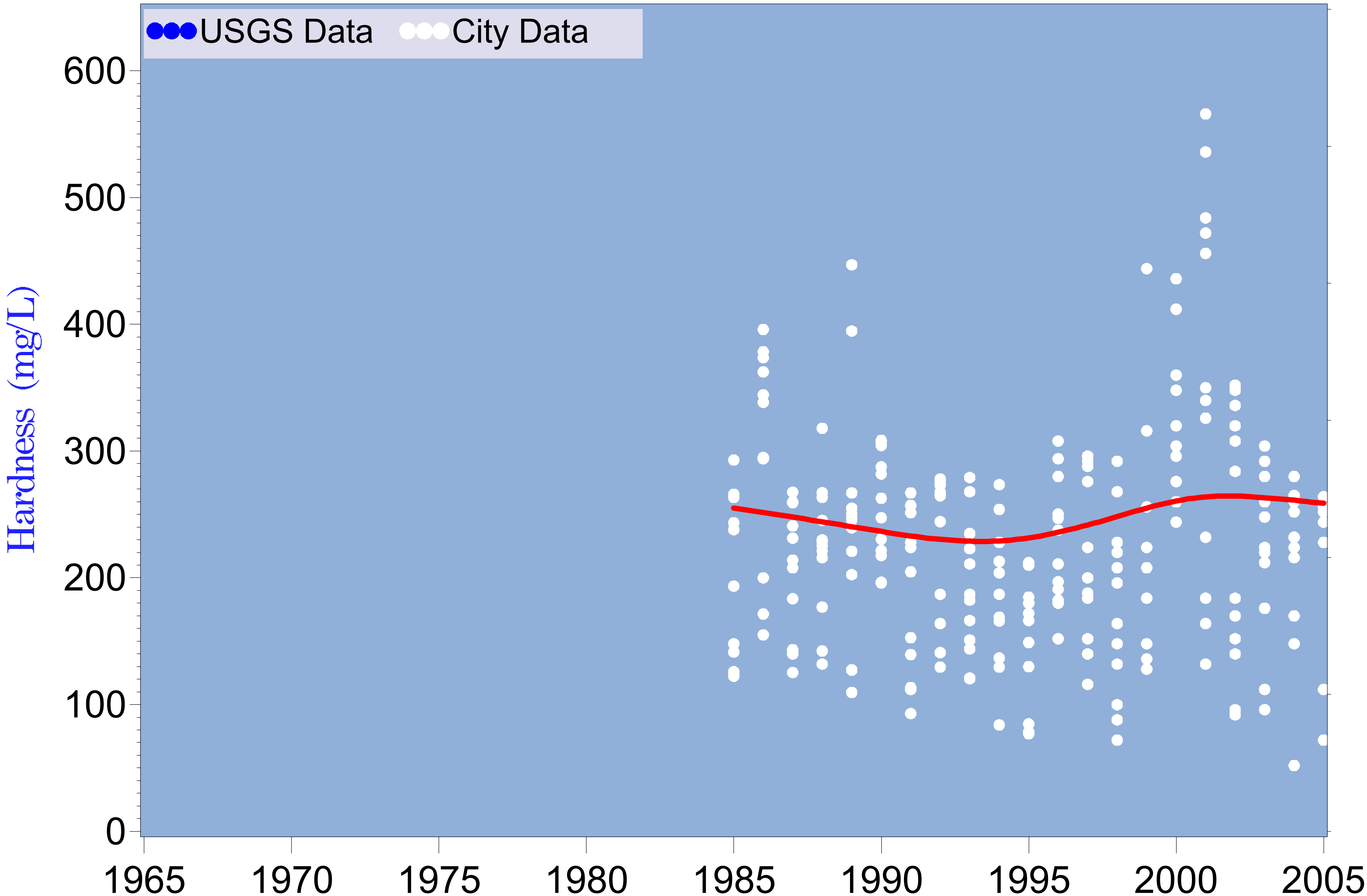


Figure 6.4 Hardness USGS site 2298123
Prairie Creek near Fort Ogden

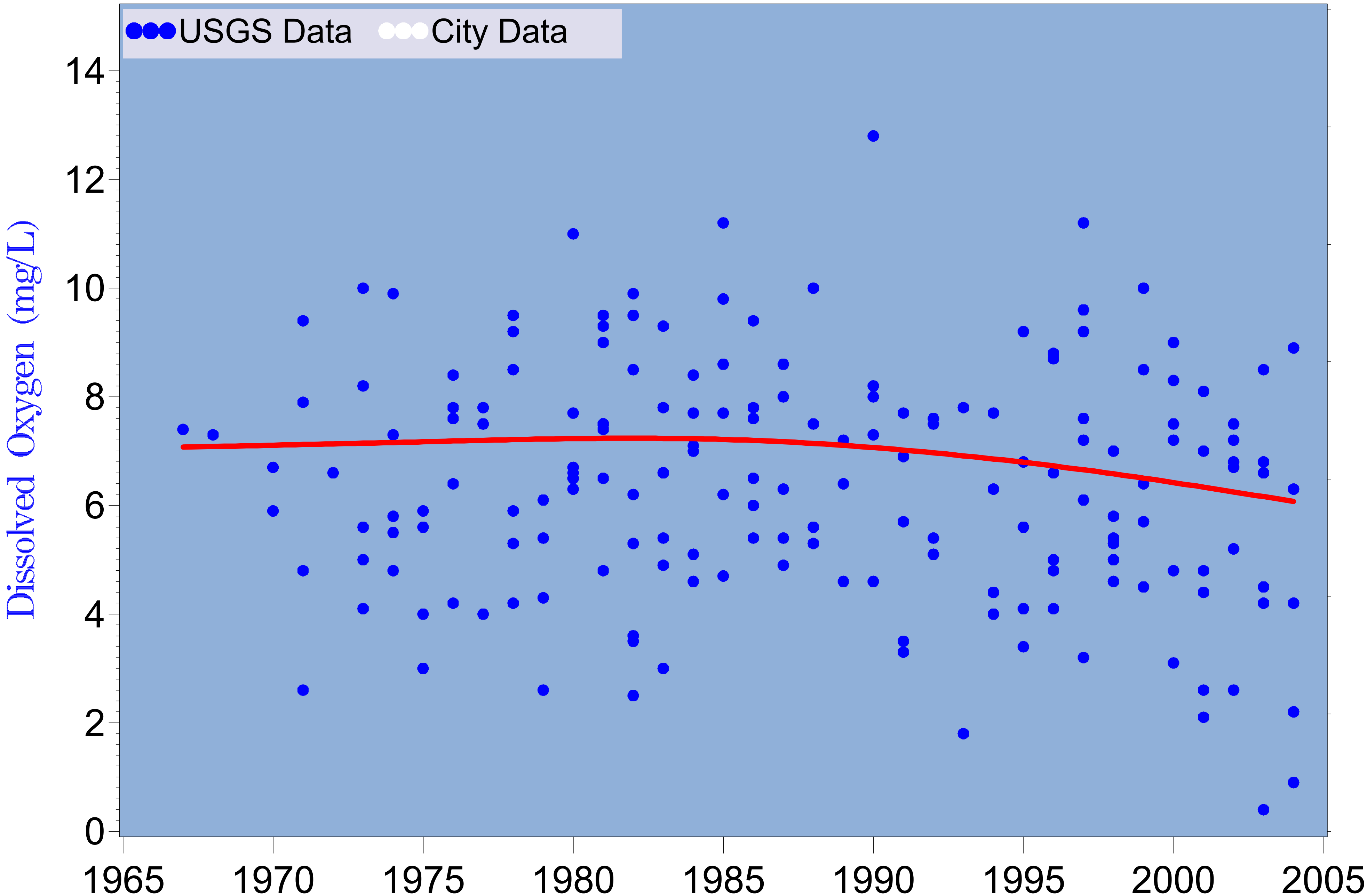


Figure 6.5 Dissolved oxygen at USGS site 2298123
Prairie Creek near Fort Ogden

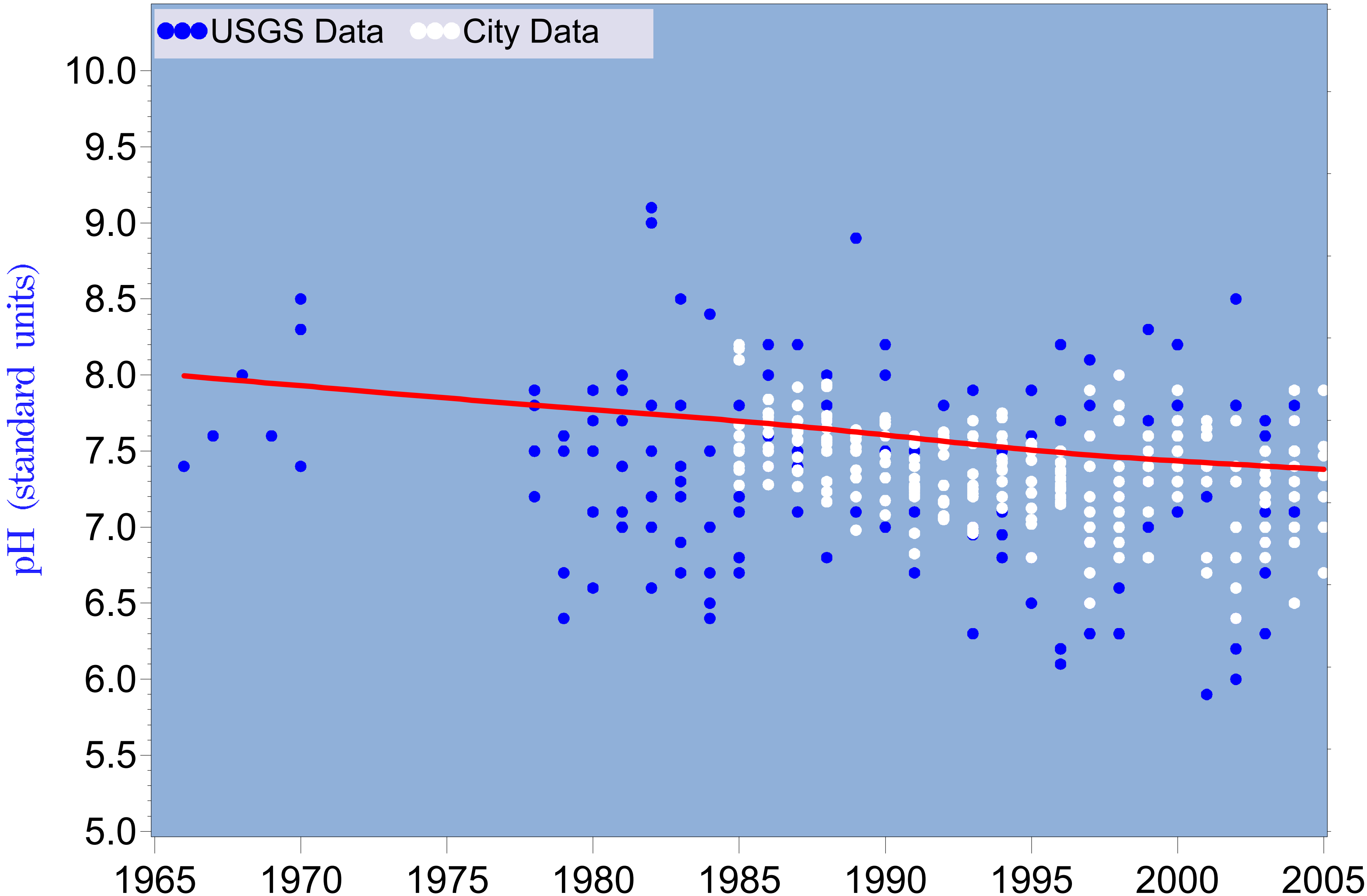


Figure 6.6 pH at USGS site 2298123
Prairie Creek near Fort Ogden

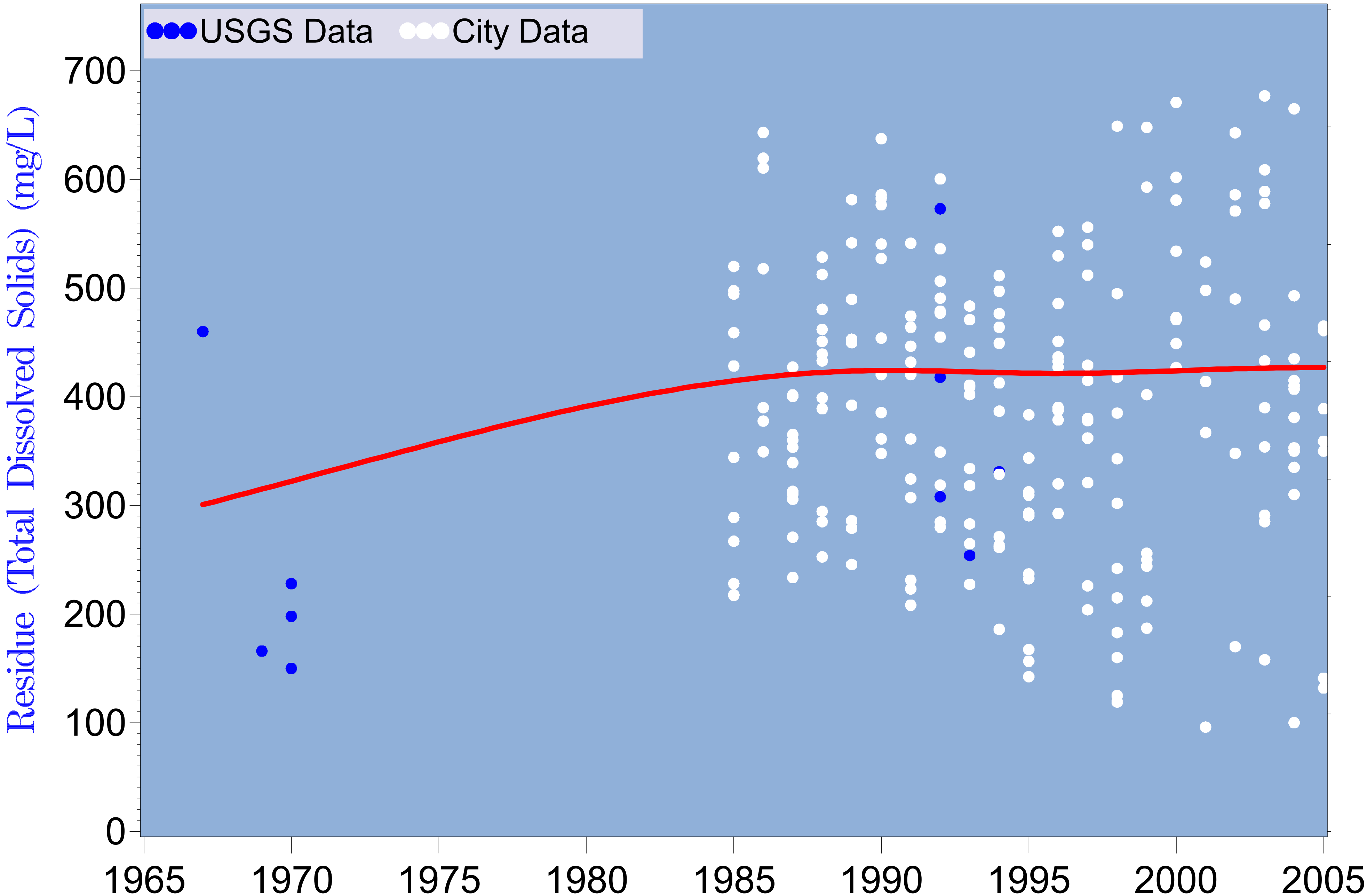


Figure 6.7 TDS at USGS site 2298123
Prairie Creek near Fort Ogden

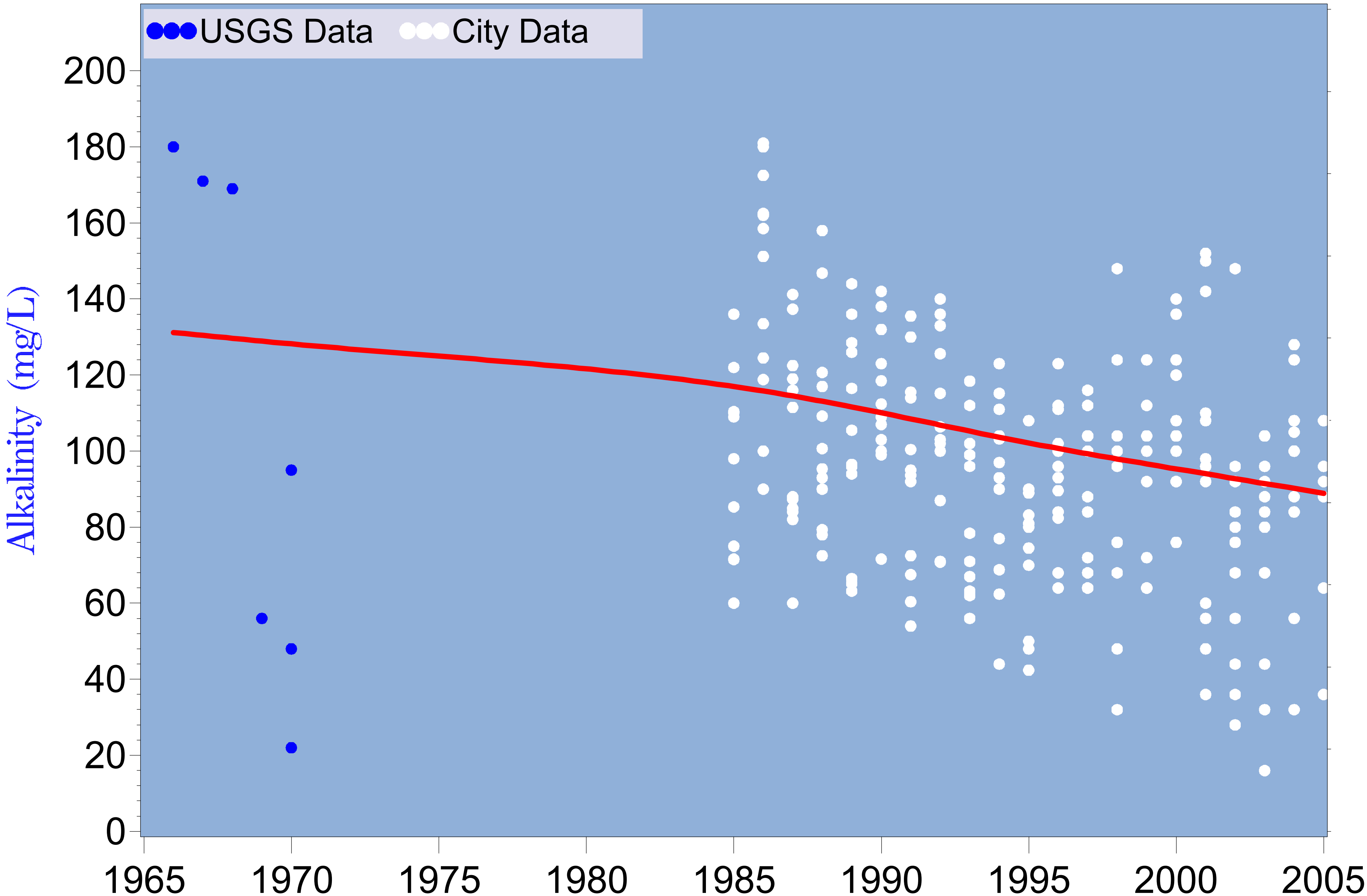


Figure 6.8 Alkalinity at USGS site 2298123
Prairie Creek near Fort Ogden

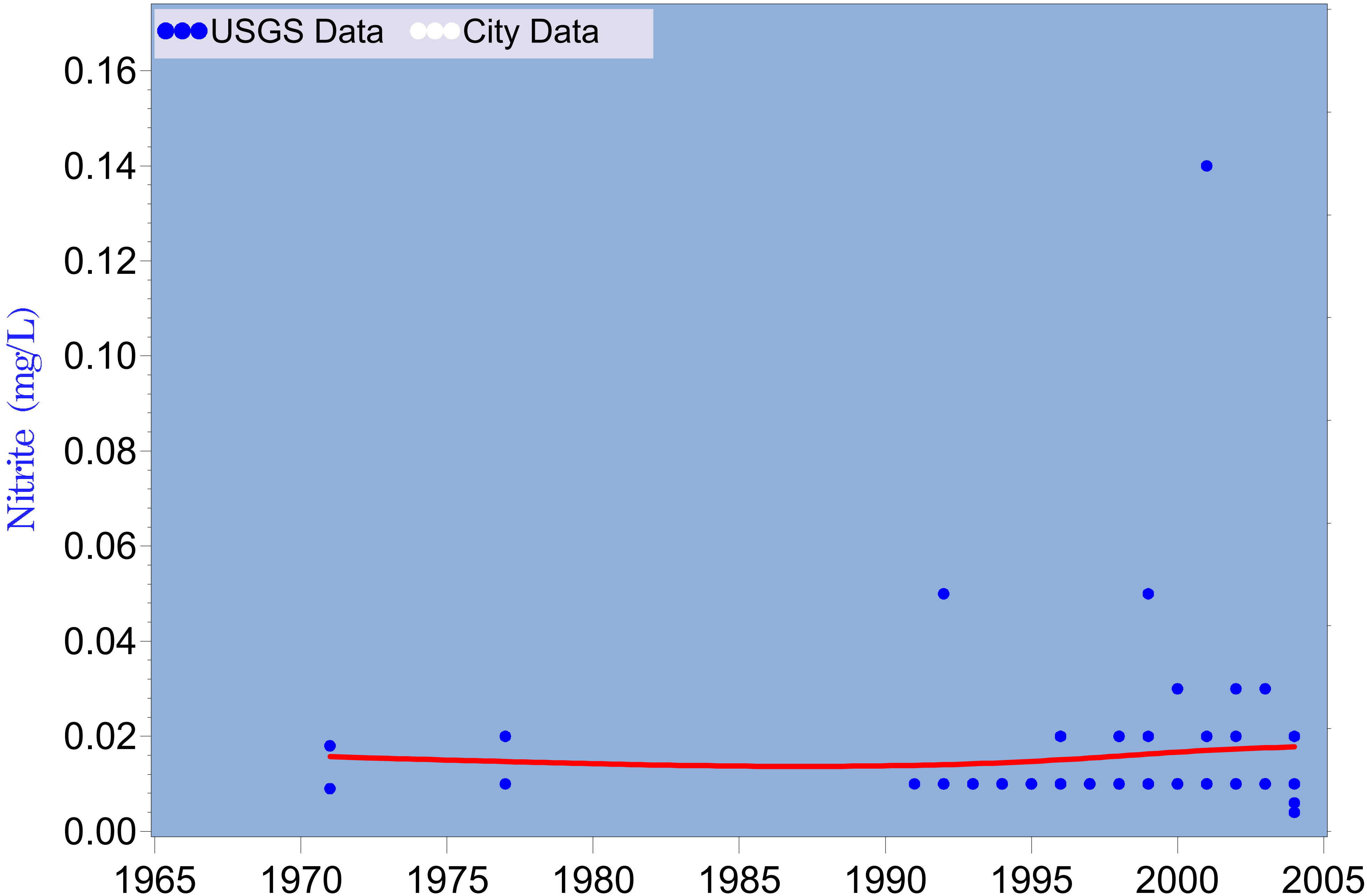


Figure 6.9 Nitrite at USGS site 2298123
Prairie Creek near Fort Ogden

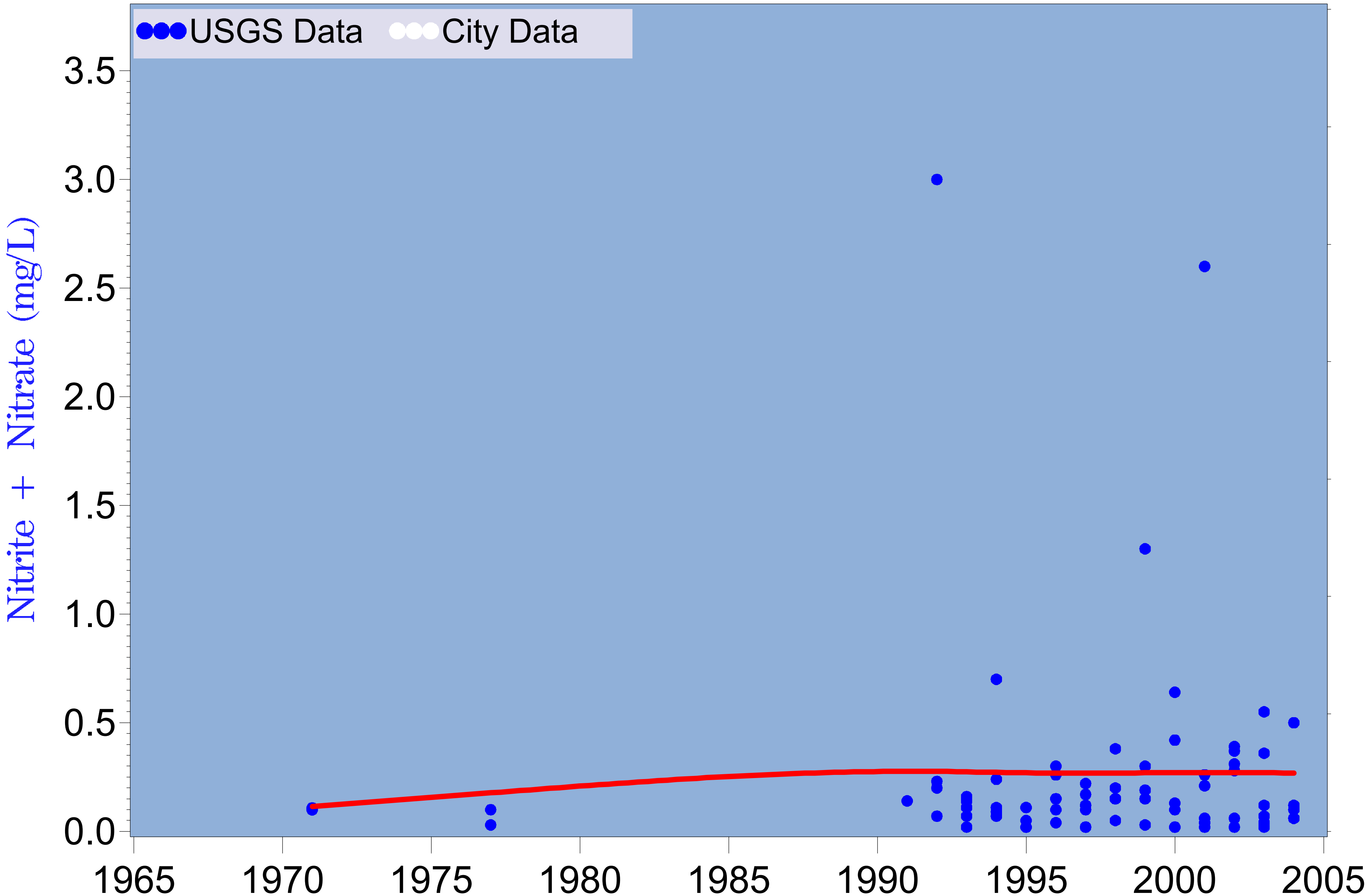


Figure 6.10 Nitrite + nitrate at USGS site 2298123
Prairie Creek near Fort Ogden

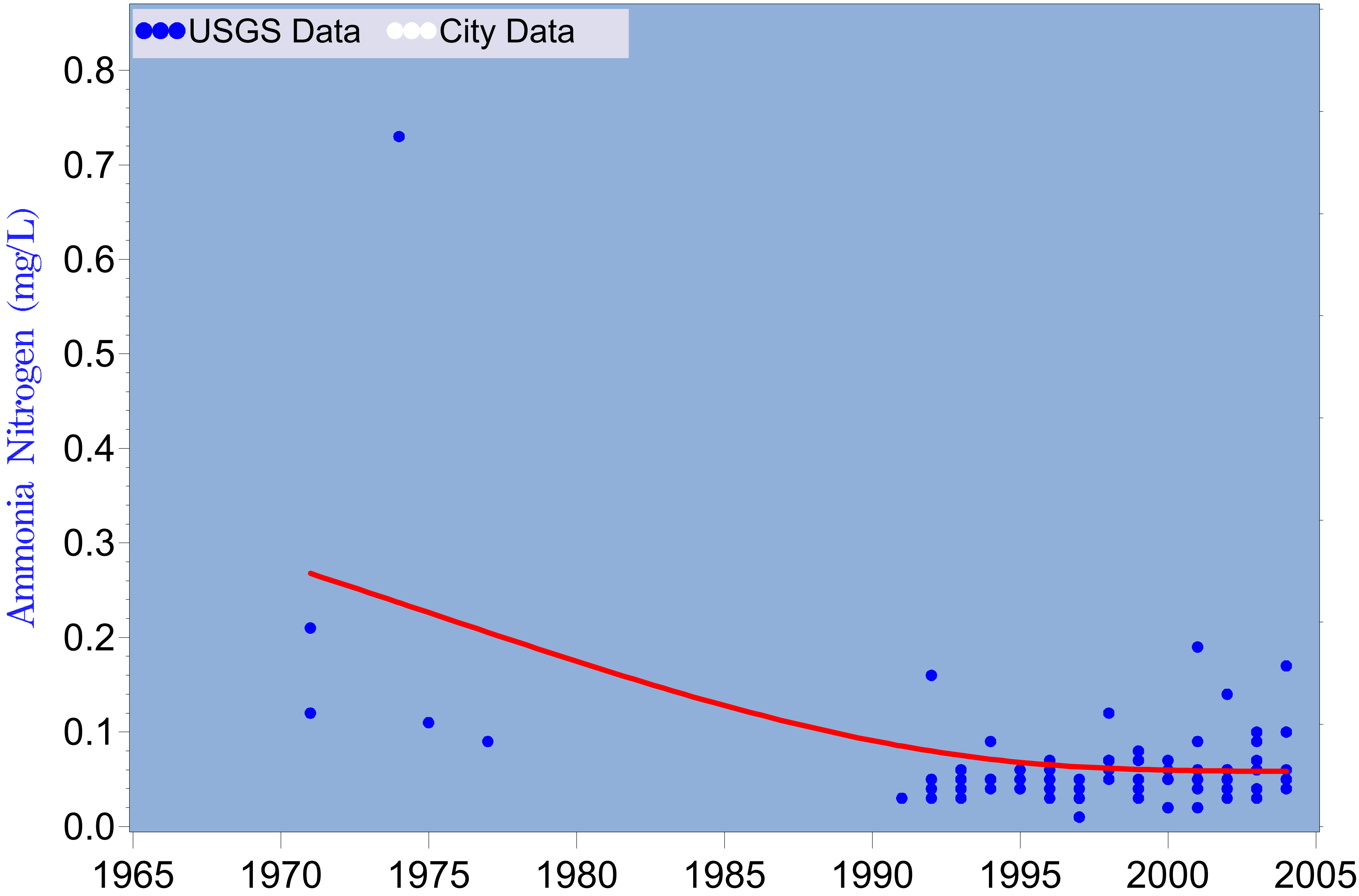


Figure 6.11 Ammonia nitrogen at USGS site 2298123
Prairie Creek near Fort Ogden

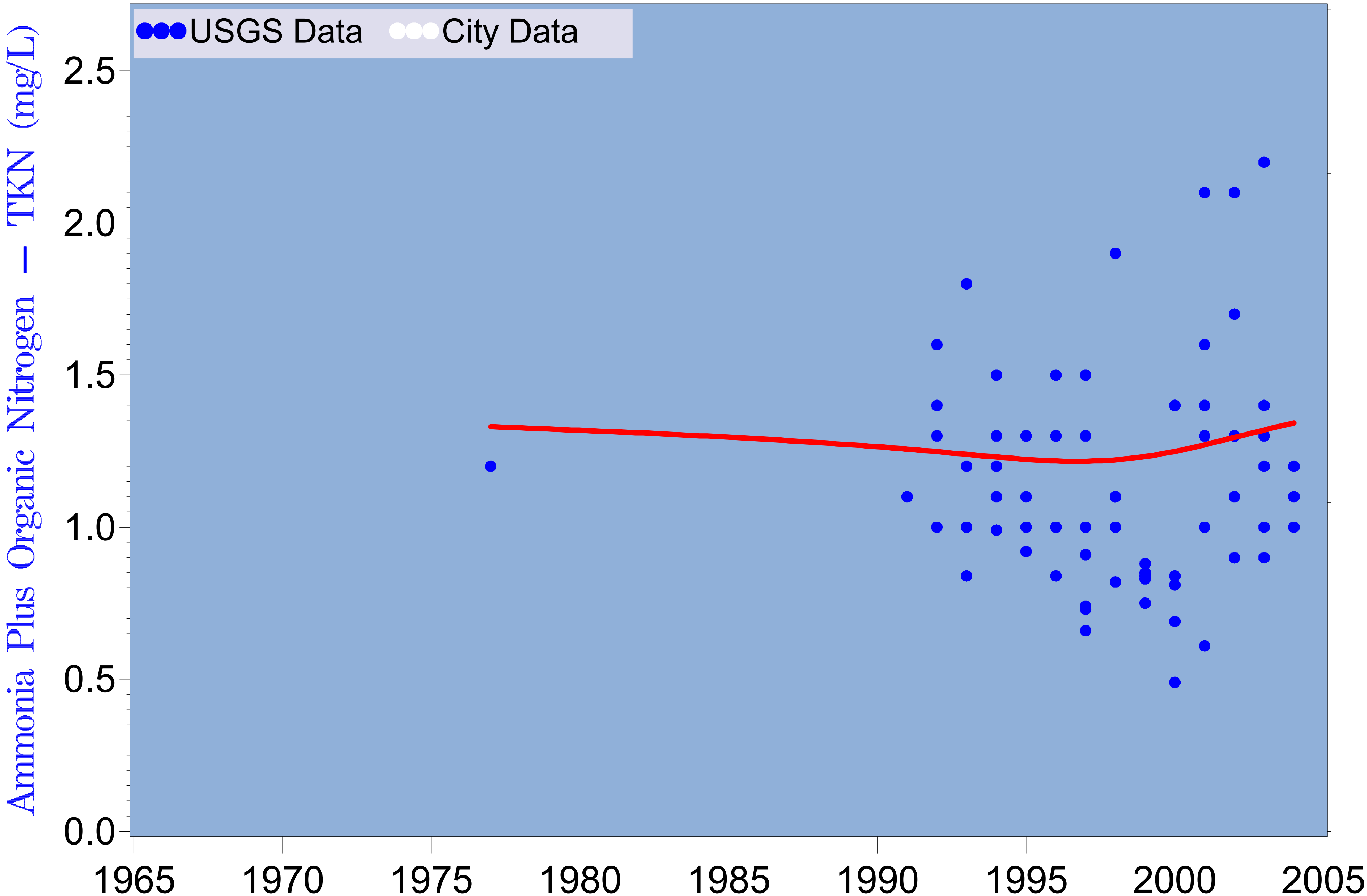


Figure 6.12 Total Kjeldahl nitrogen at USGS site 2298123
Prairie Creek near Fort Ogden

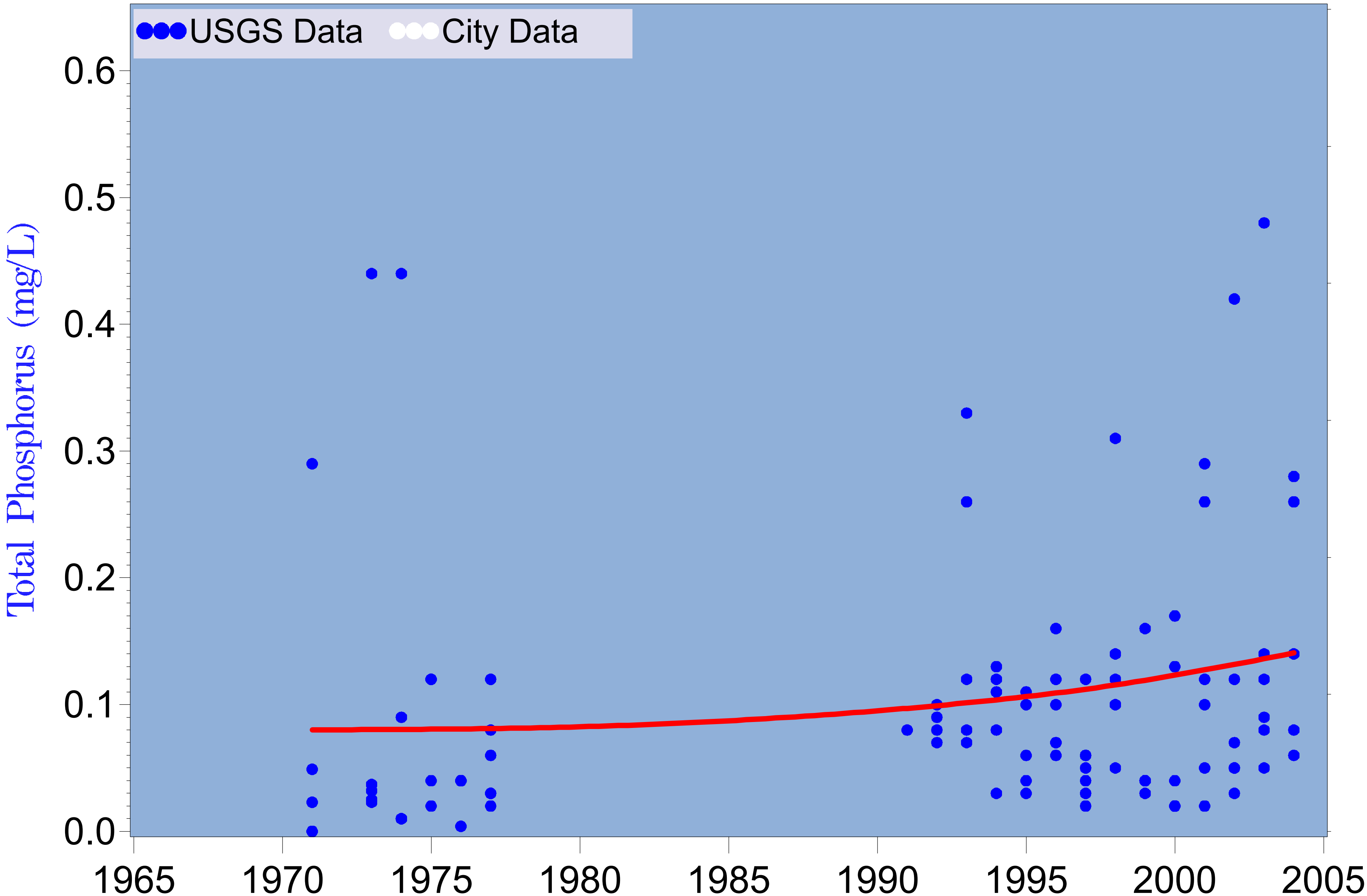


Figure 6.13 Total phosphorus at USGS site 2298123
Prairie Creek near Fort Ogden

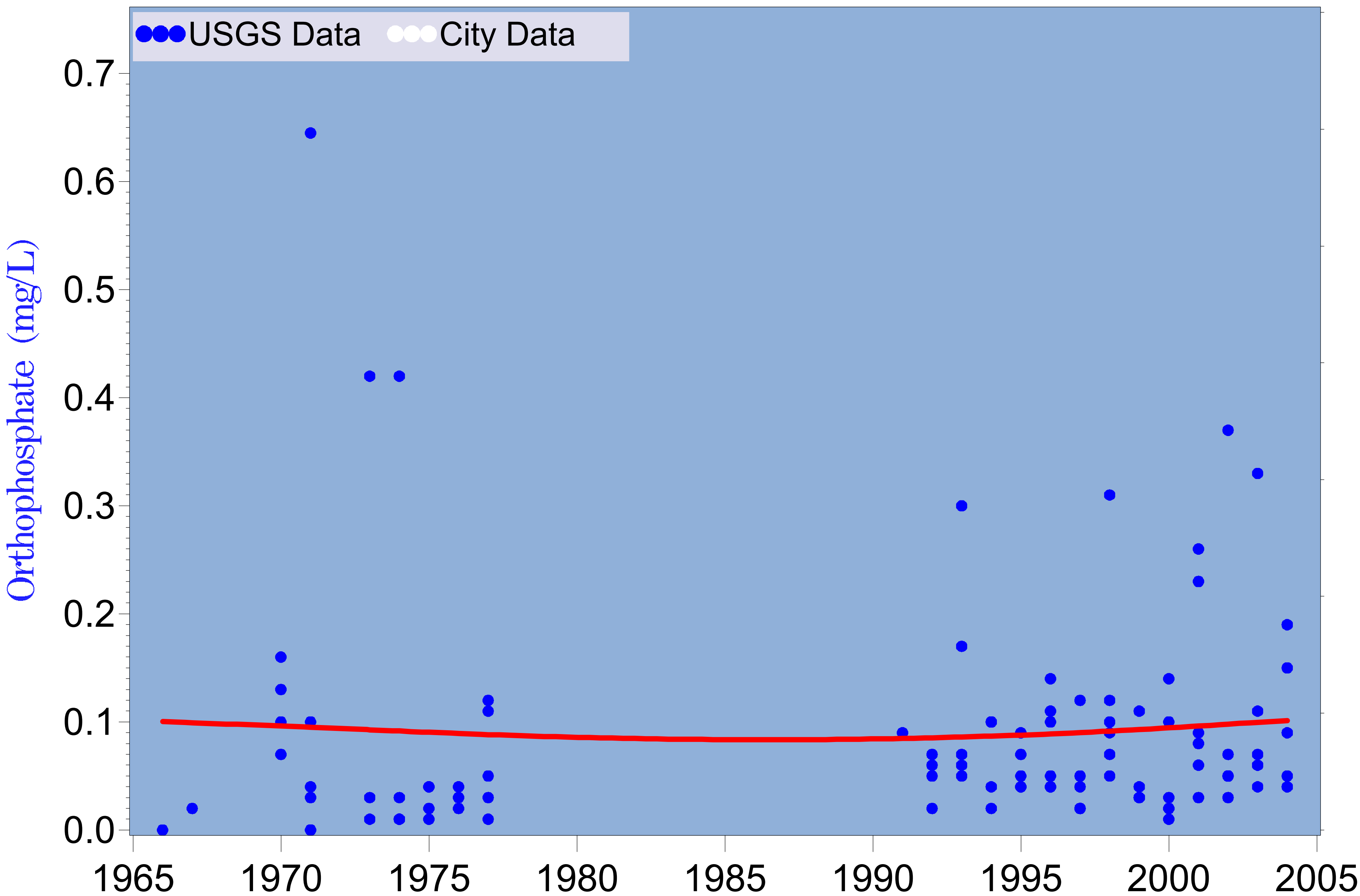


Figure 6.14 Orthophosphate at USGS site 2298123
Prairie Creek near Fort Ogden

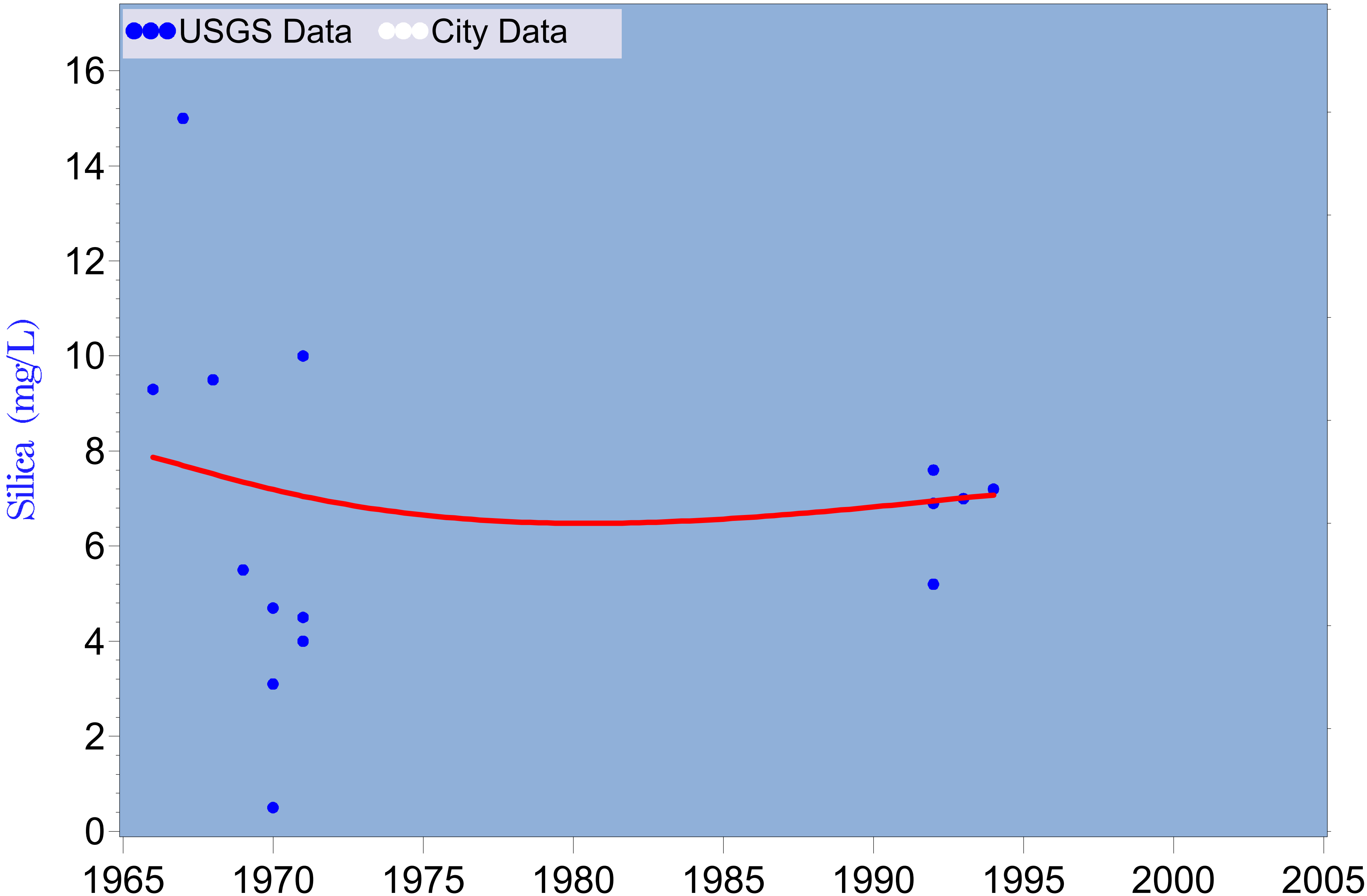


Figure 6.15 Silica at USGS site 2298123
Prairie Creek near Fort Ogden

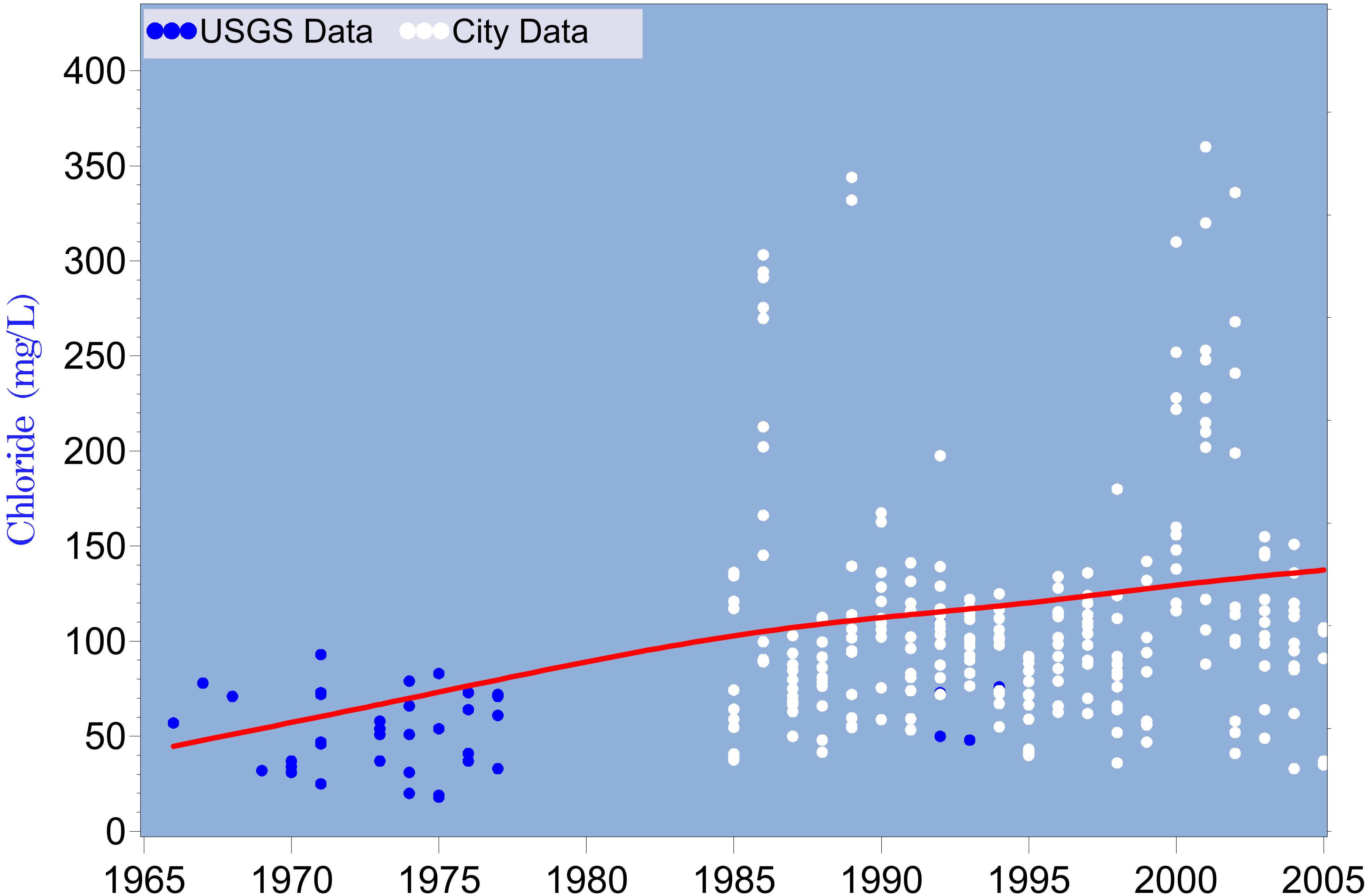


Figure 6.16 Chloride at USGS site 2298123
Prairie Creek near Fort Ogden

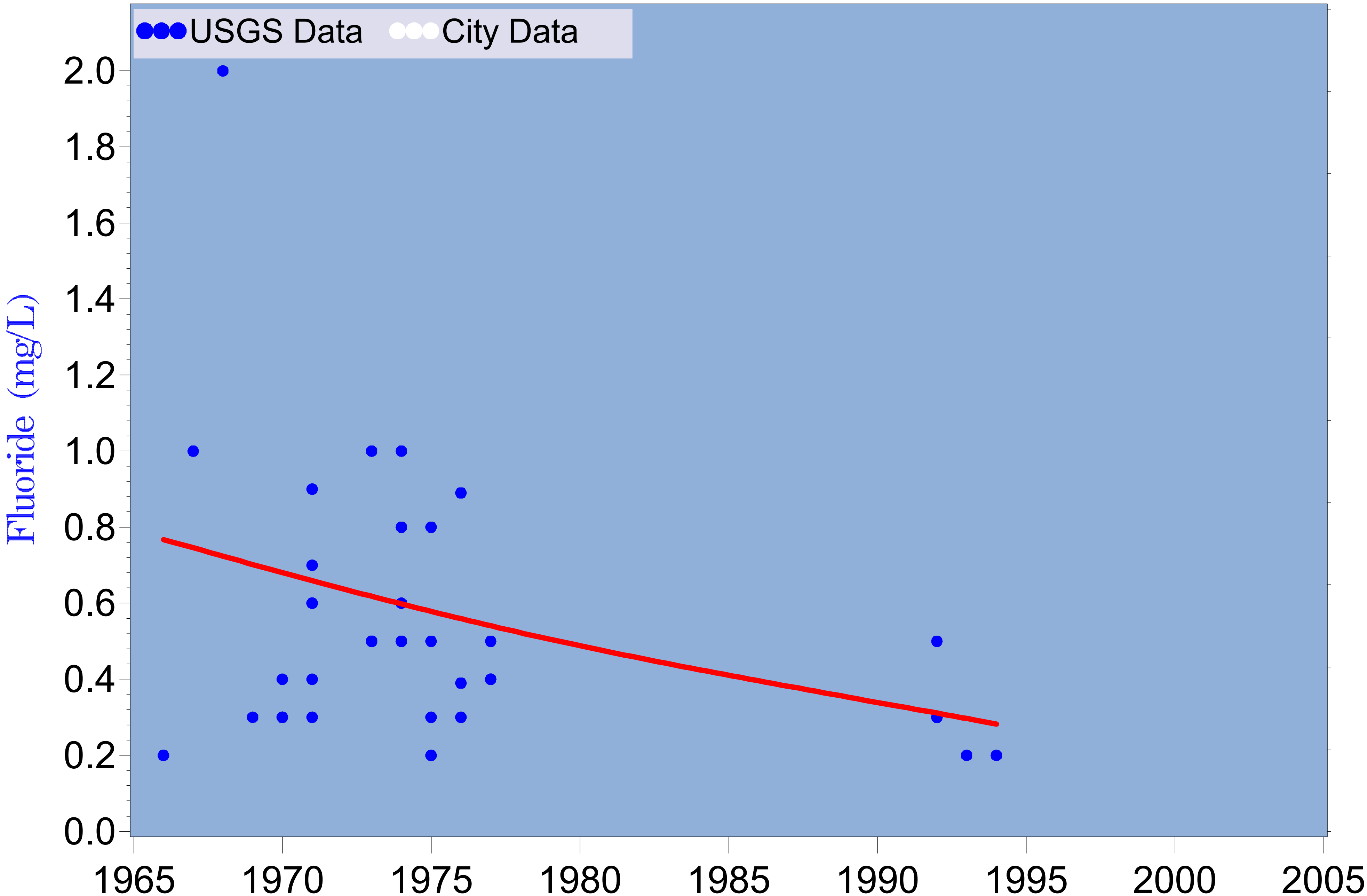


Figure 6.17 Fluoride at USGS site 2298123
Prairie Creek near Fort Ogden

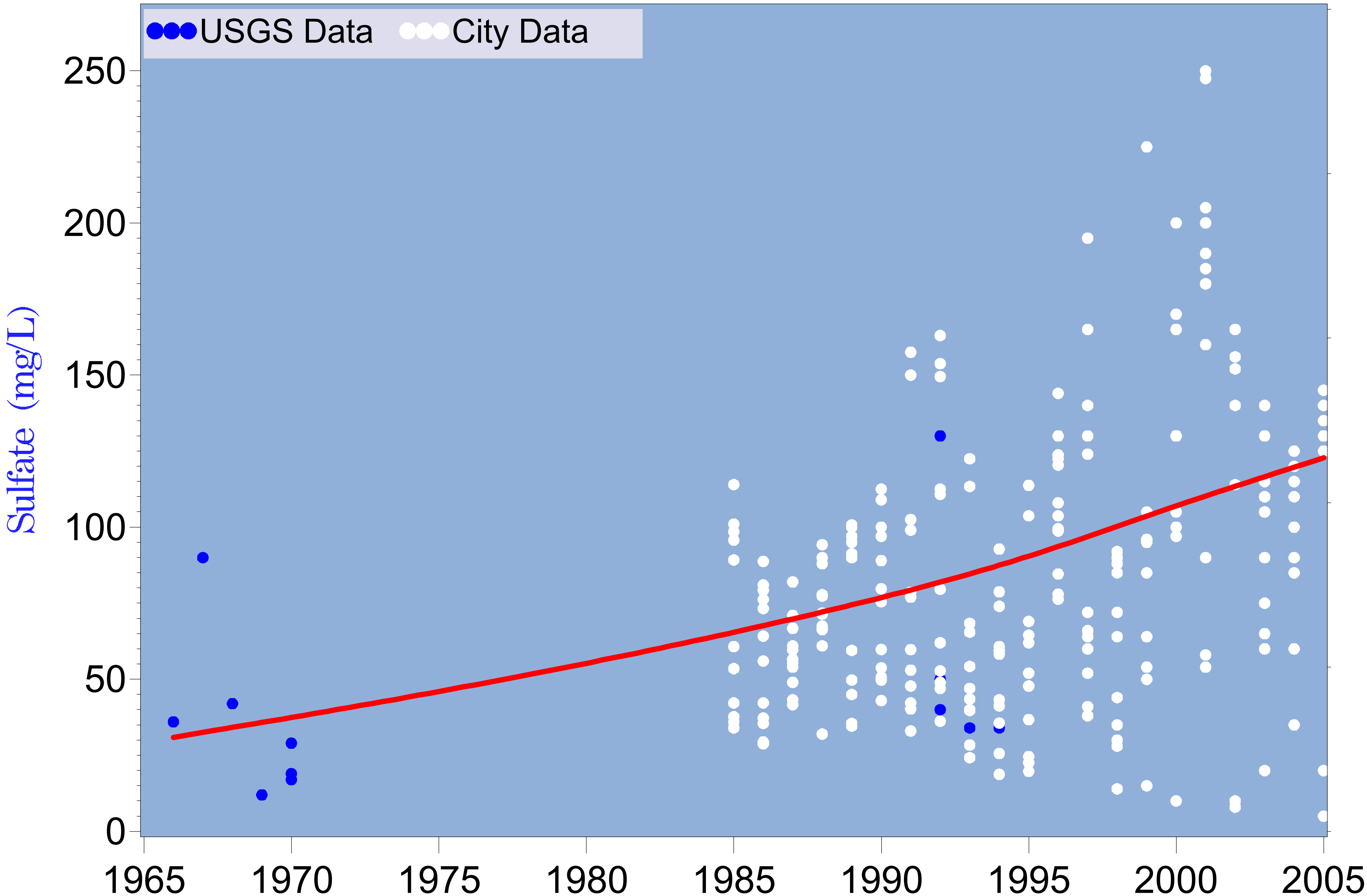


Figure 6.18 Sulfate at USGS site 2298123
Prairie Creek near Fort Ogden

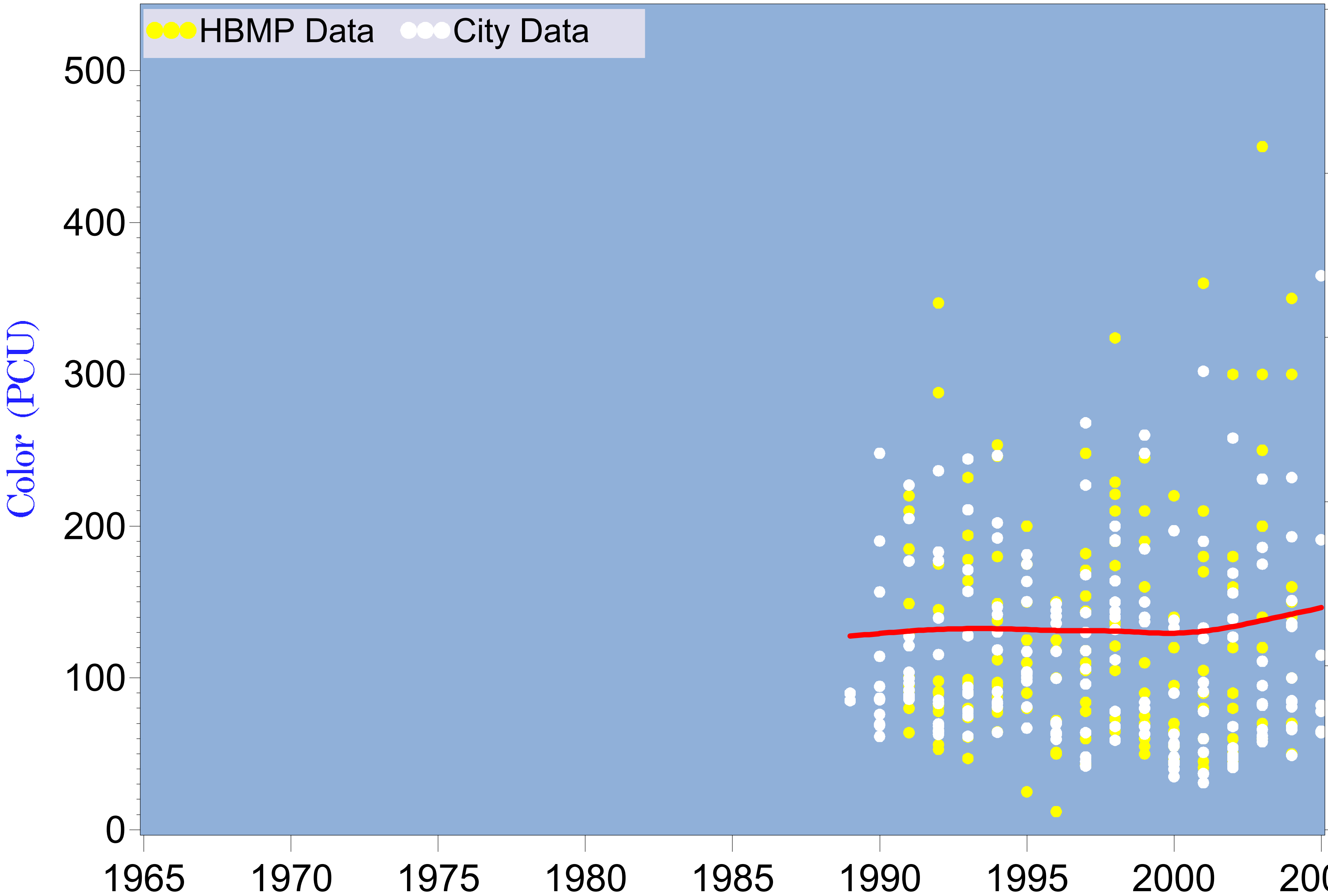


Figure 6.19 Water color at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

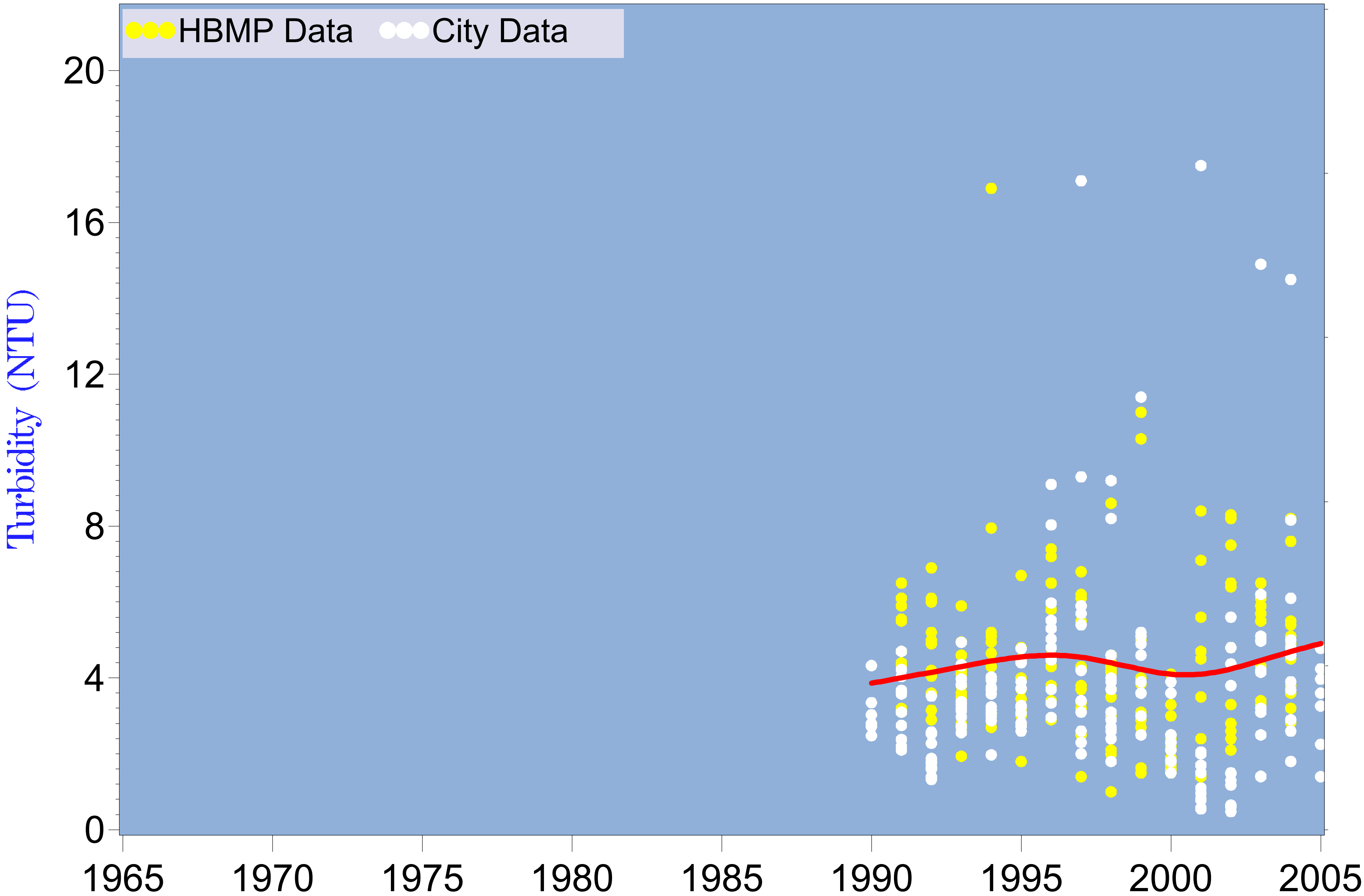


Figure 6.20 Turbidity at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

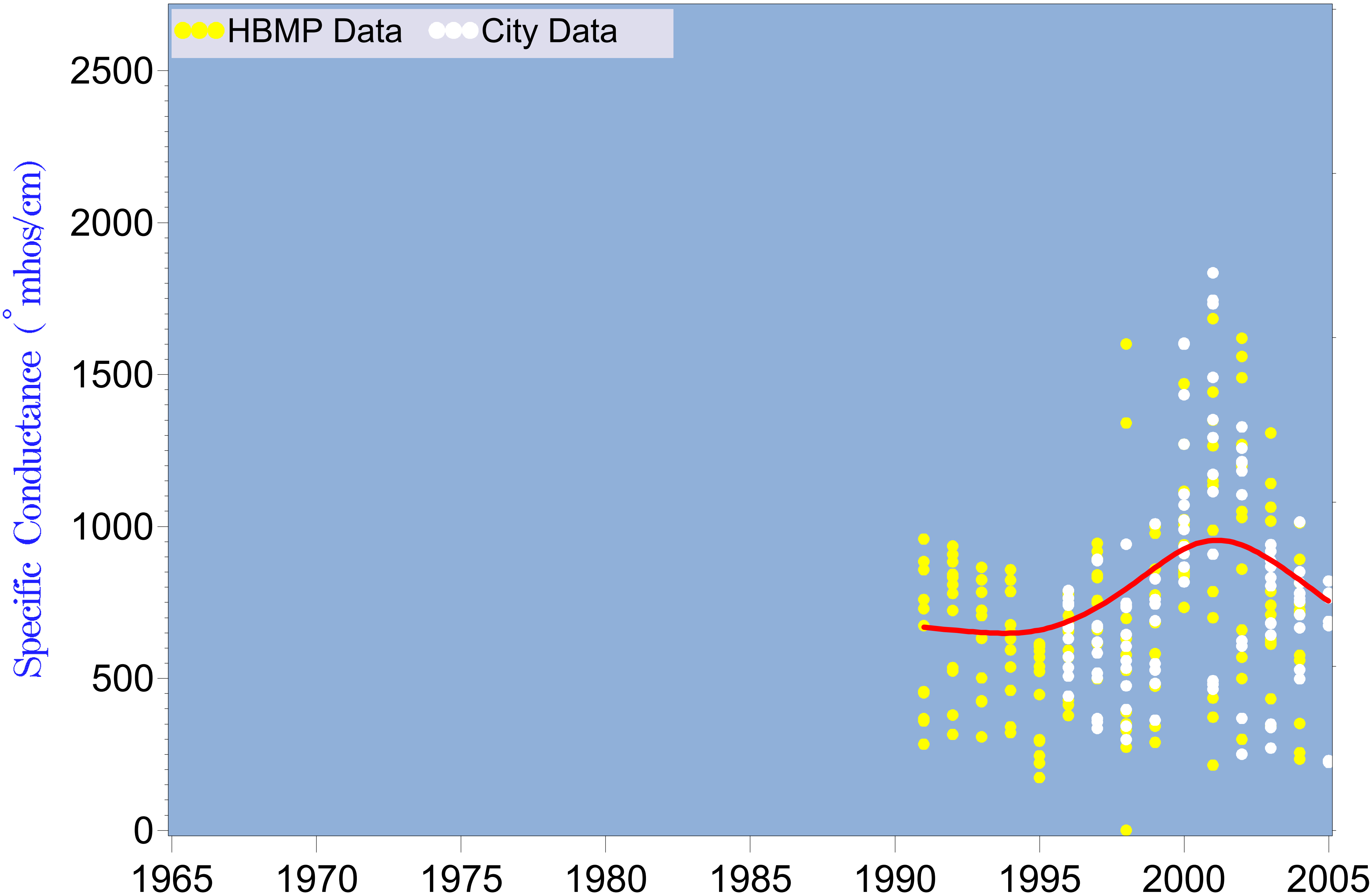


Figure 6.21 Specific conductance Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

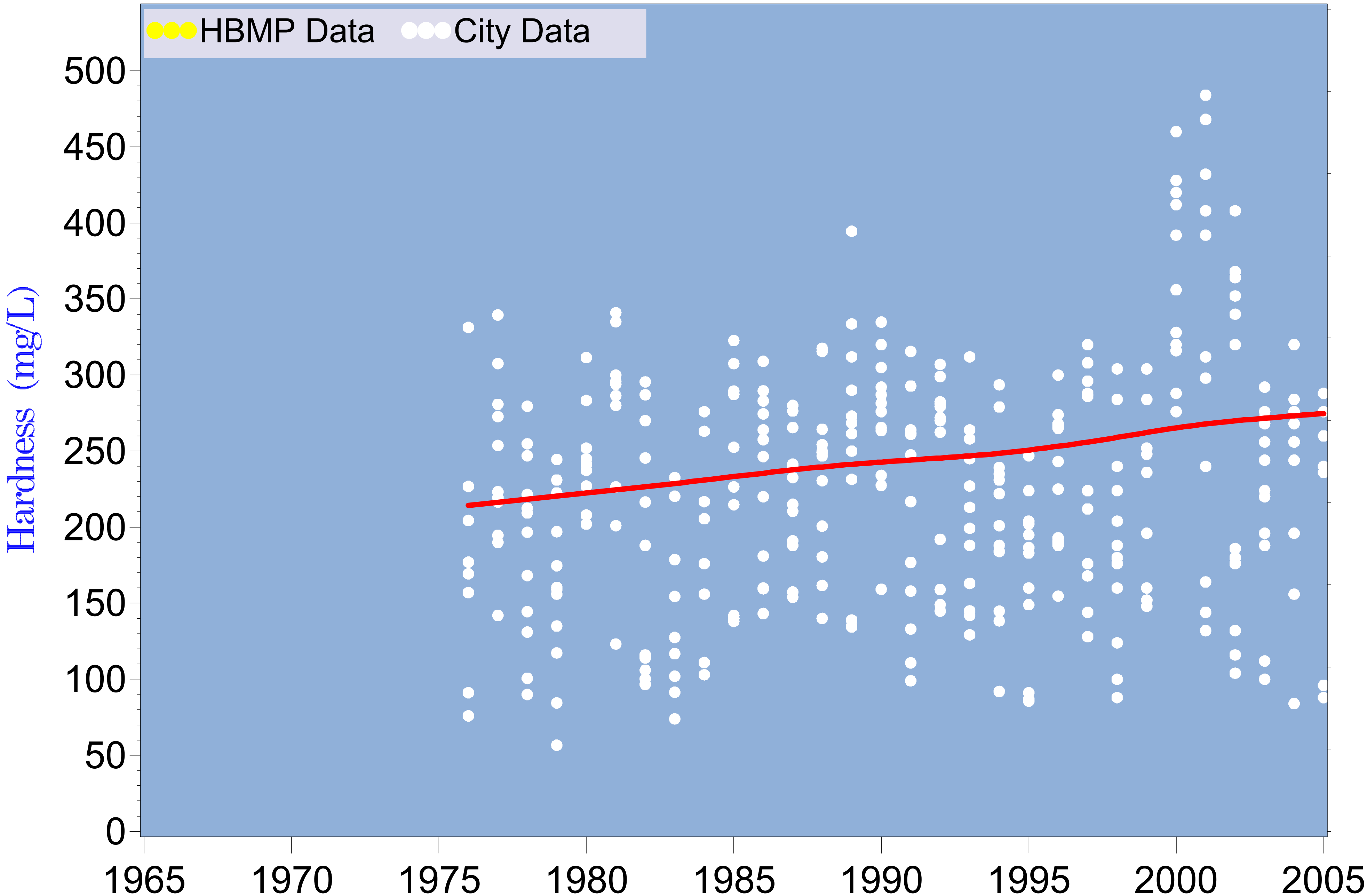


Figure 6.22 Hardness Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

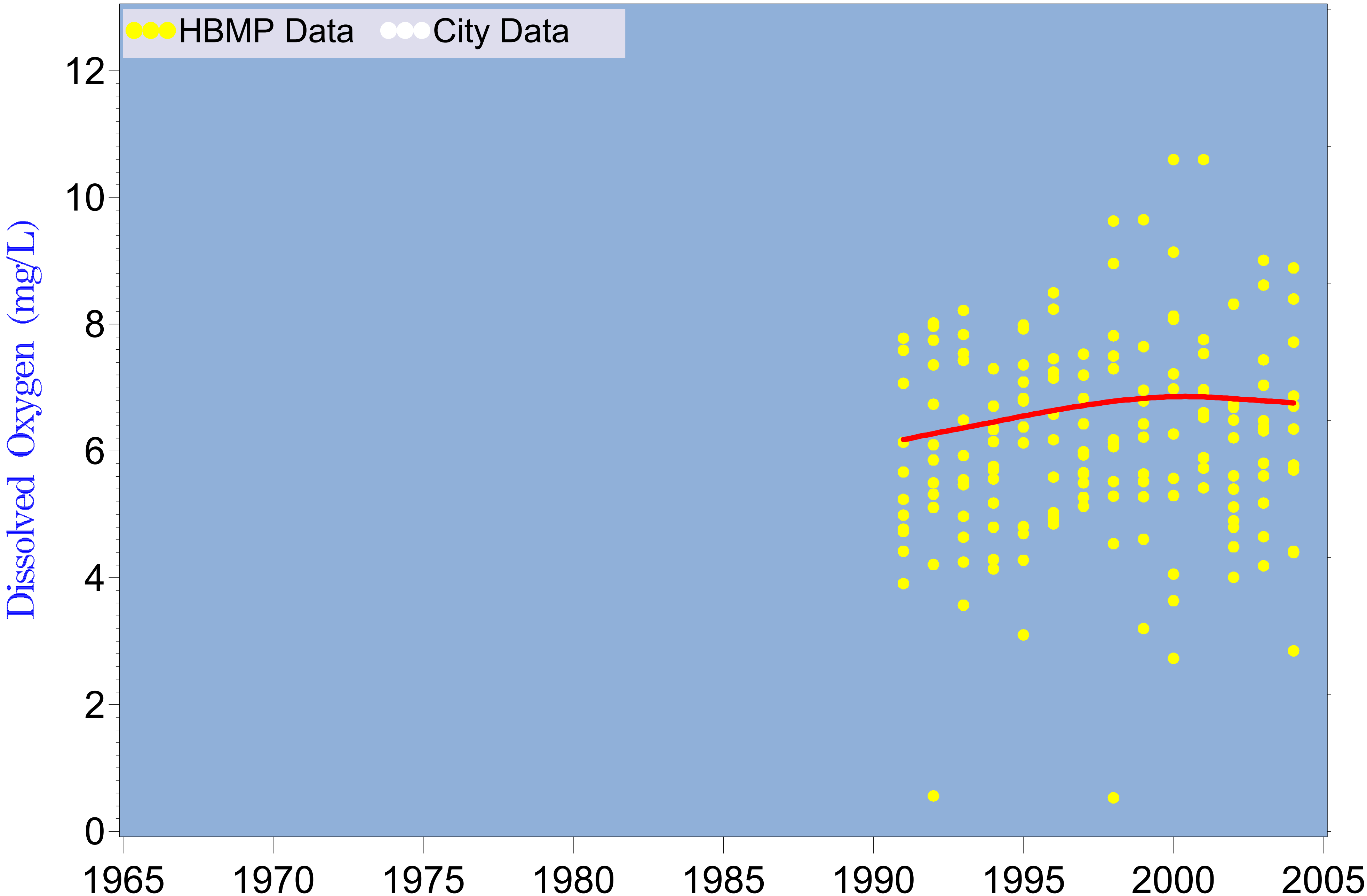


Figure 6.23 Dissolved oxygen at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

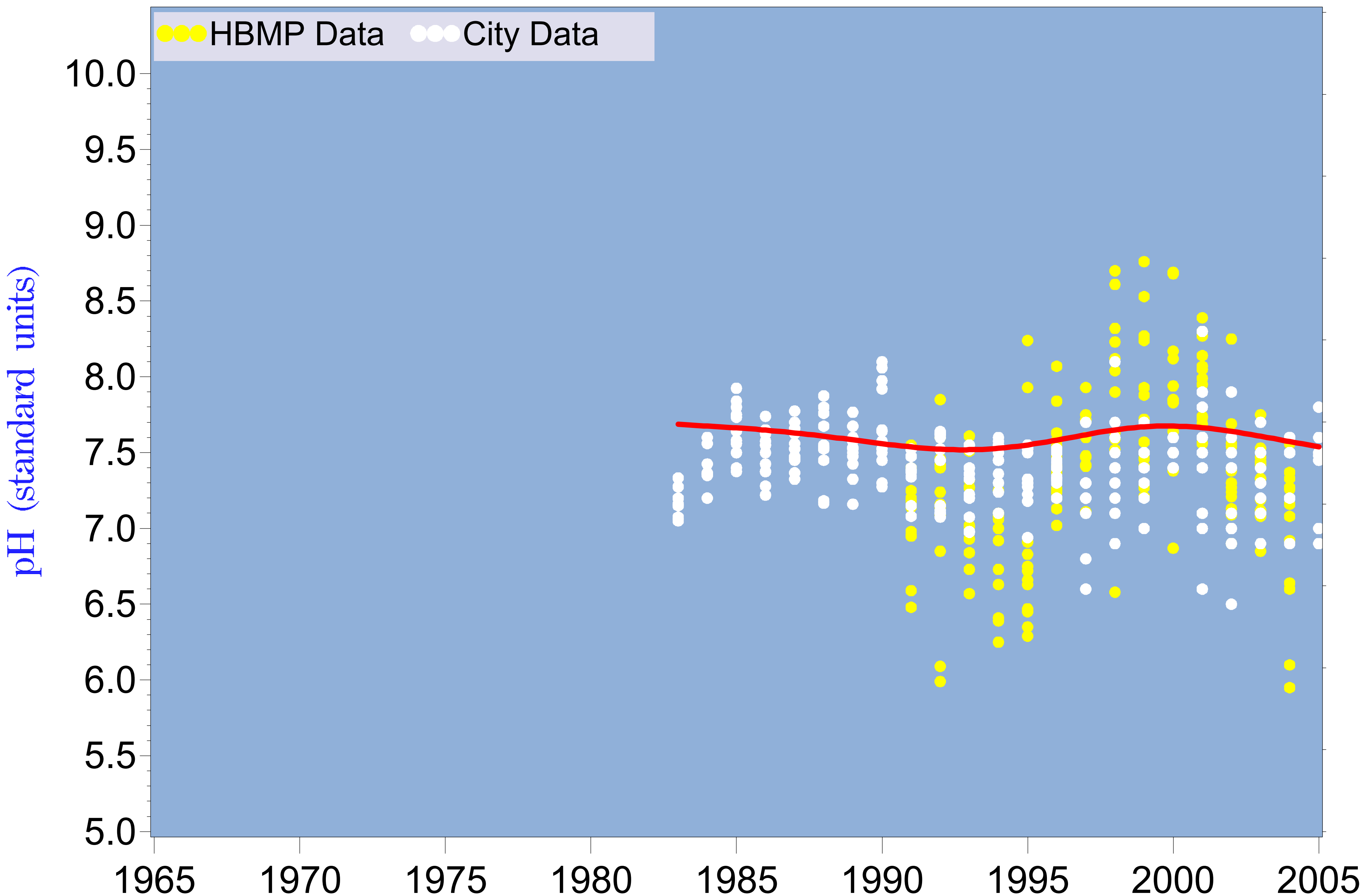


Figure 6.24 pH at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

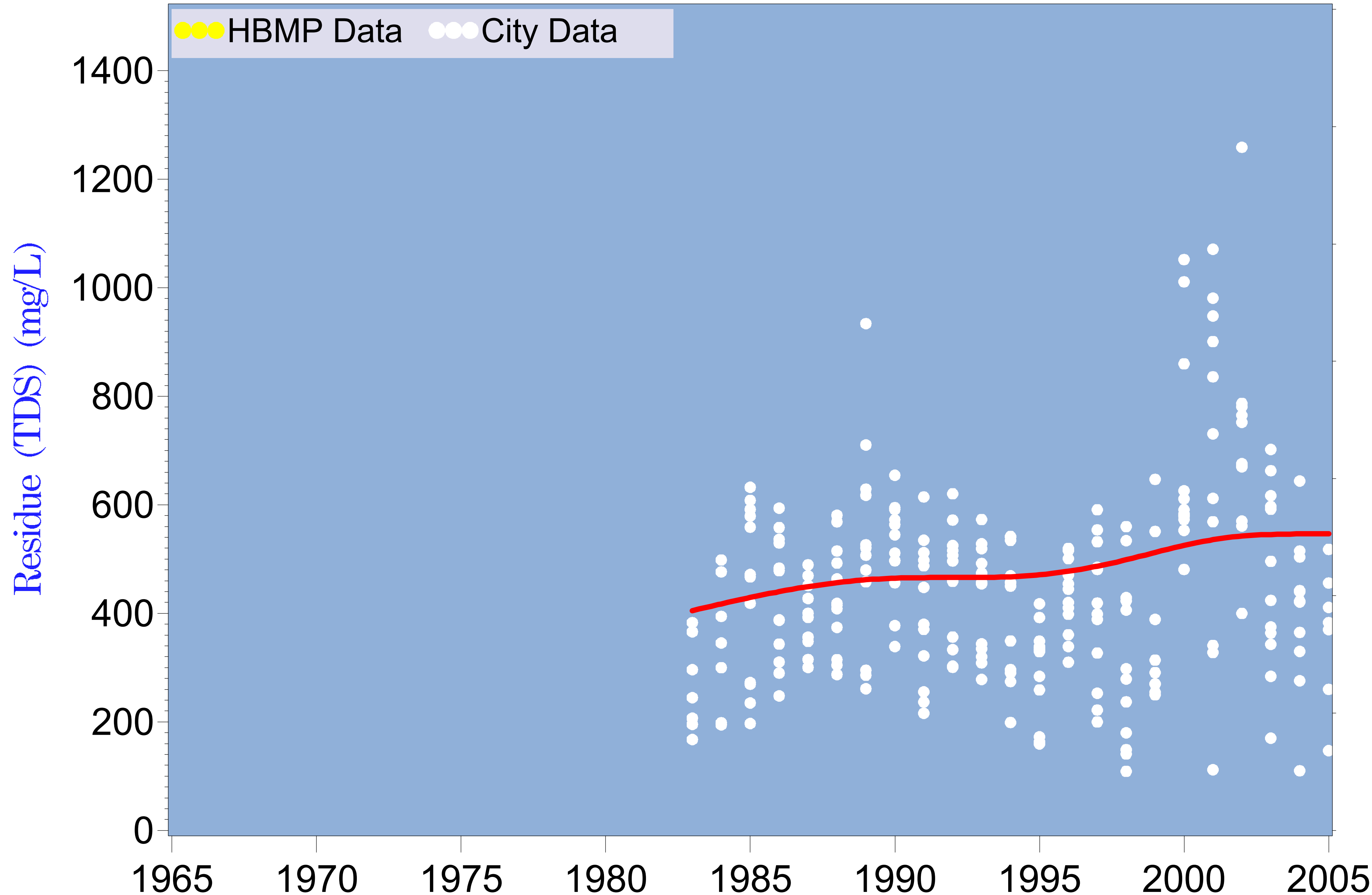


Figure 6.25 TDS Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

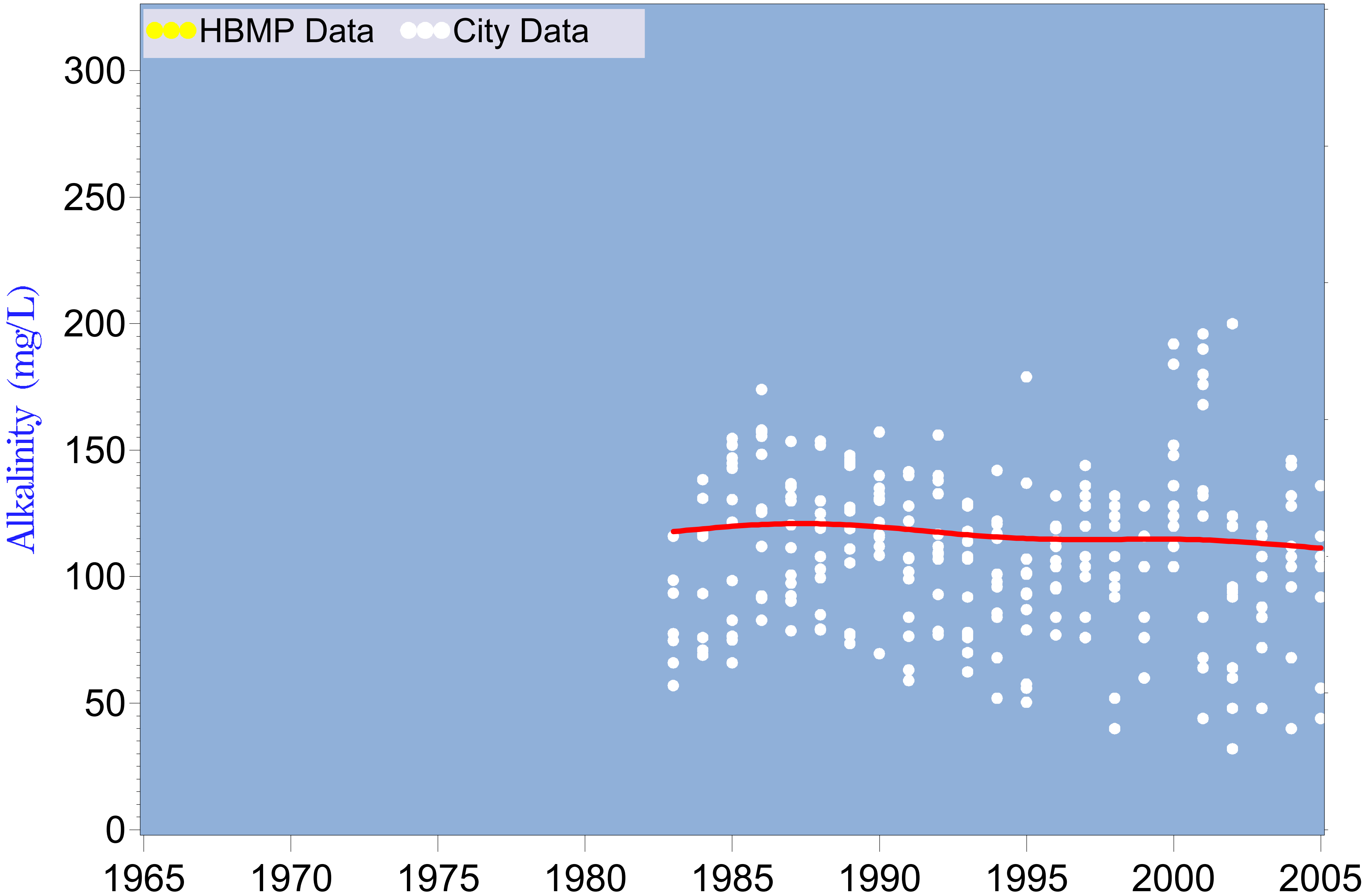


Figure 6.26 Alkalinity at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

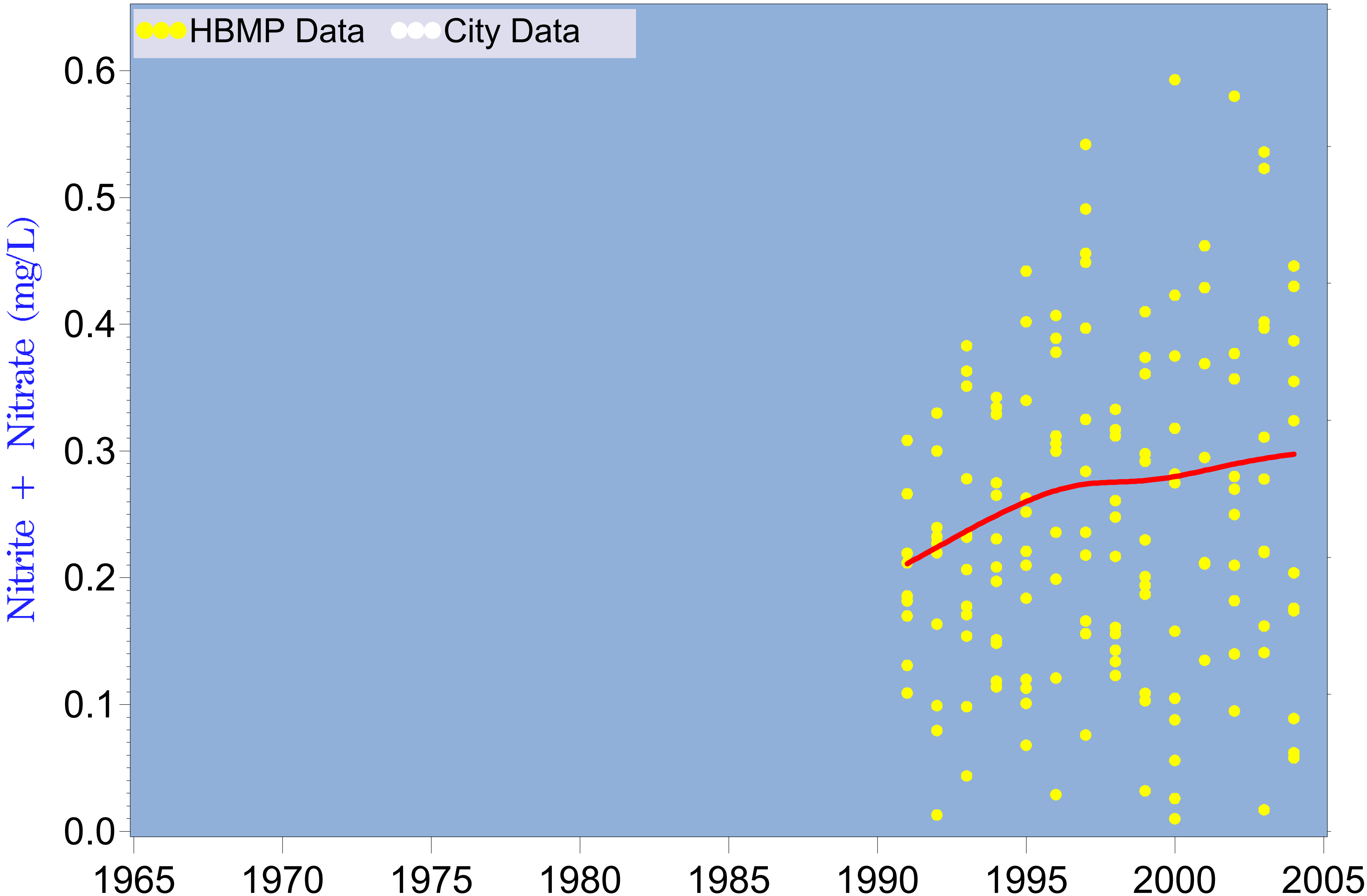


Figure 6.27 Nitrite + nitrate at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

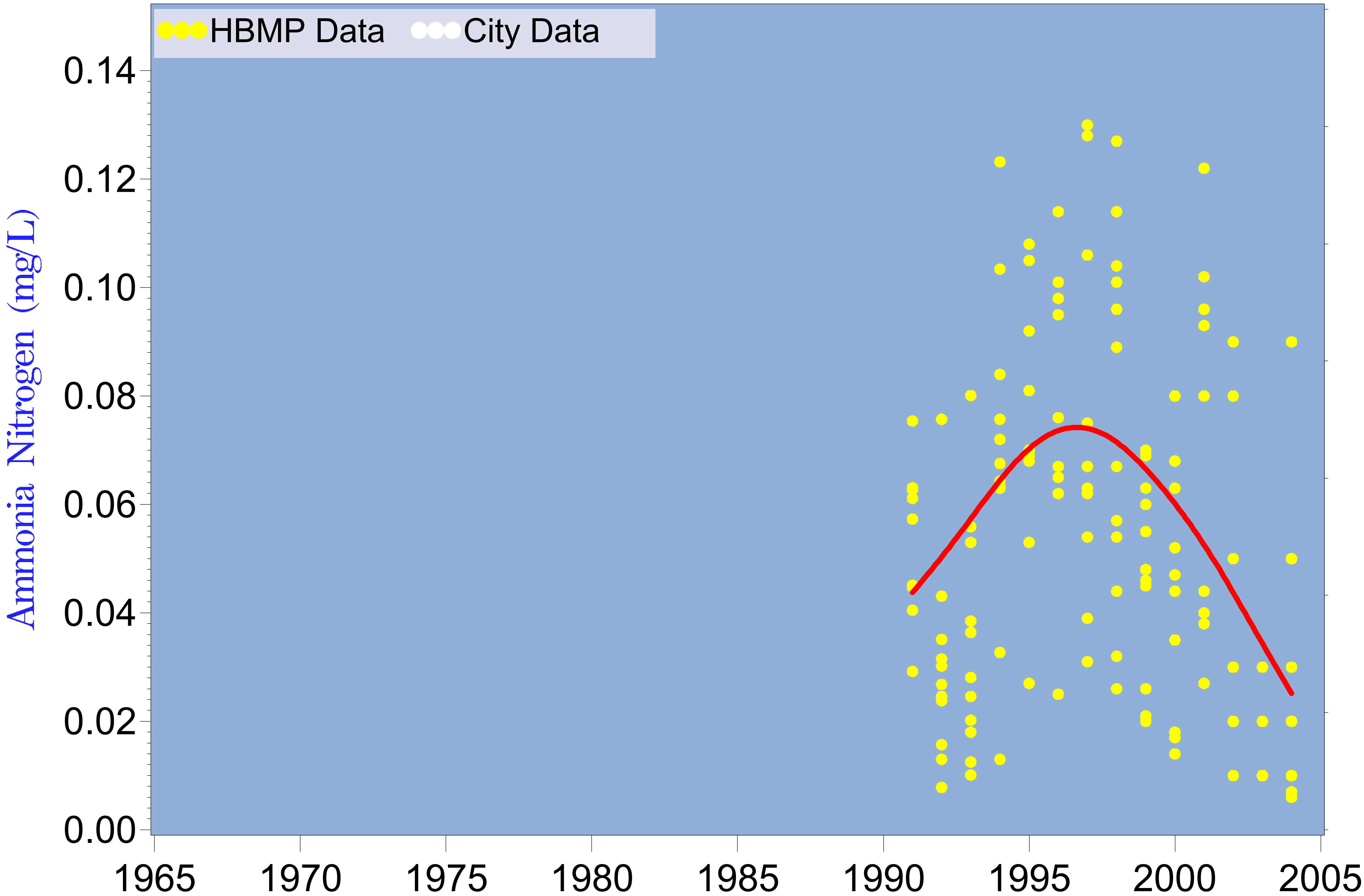


Figure 6.28 Ammonia nitrogen at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

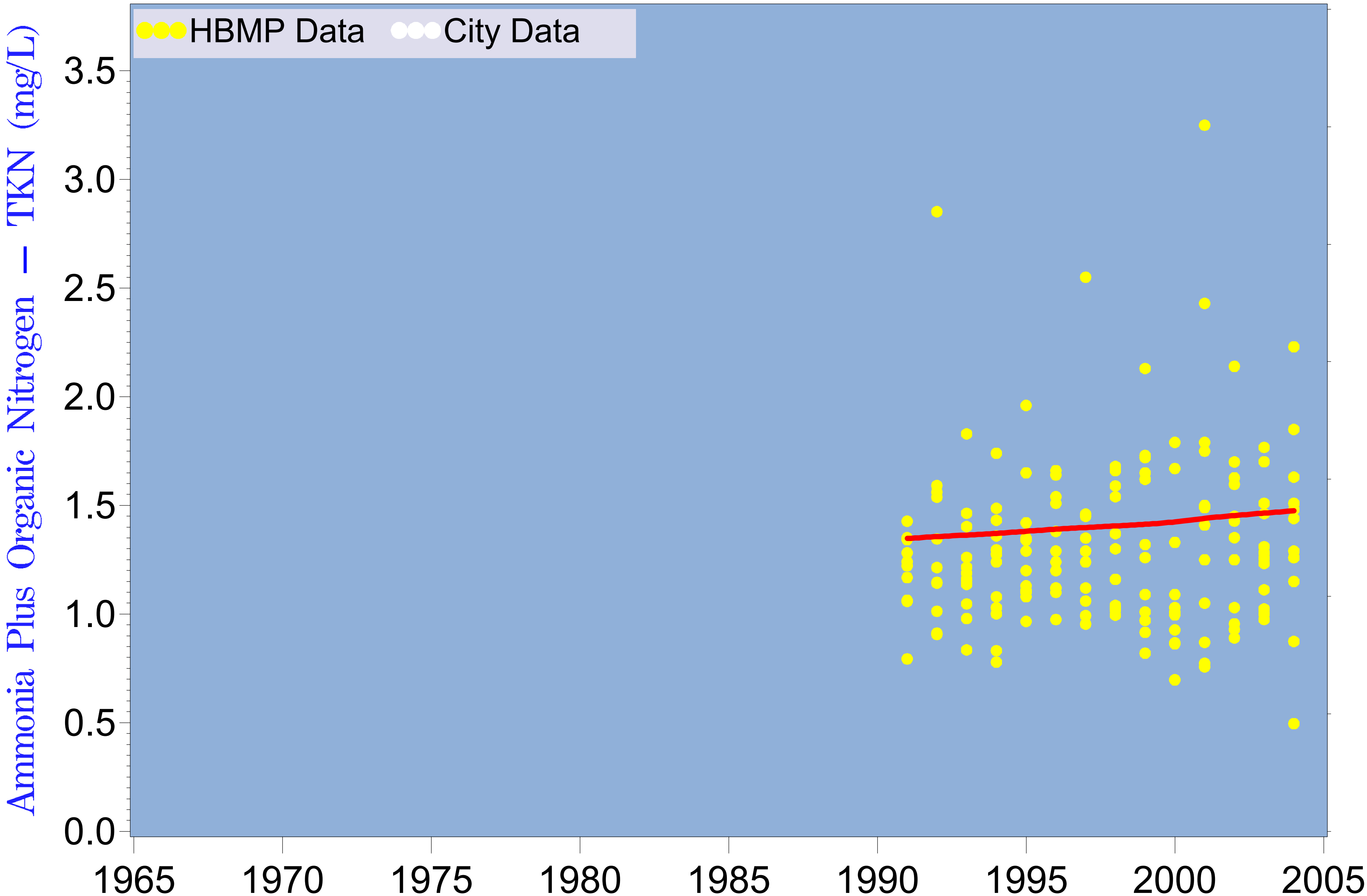


Figure 6.29 Total Kjeldahl nitrogen at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

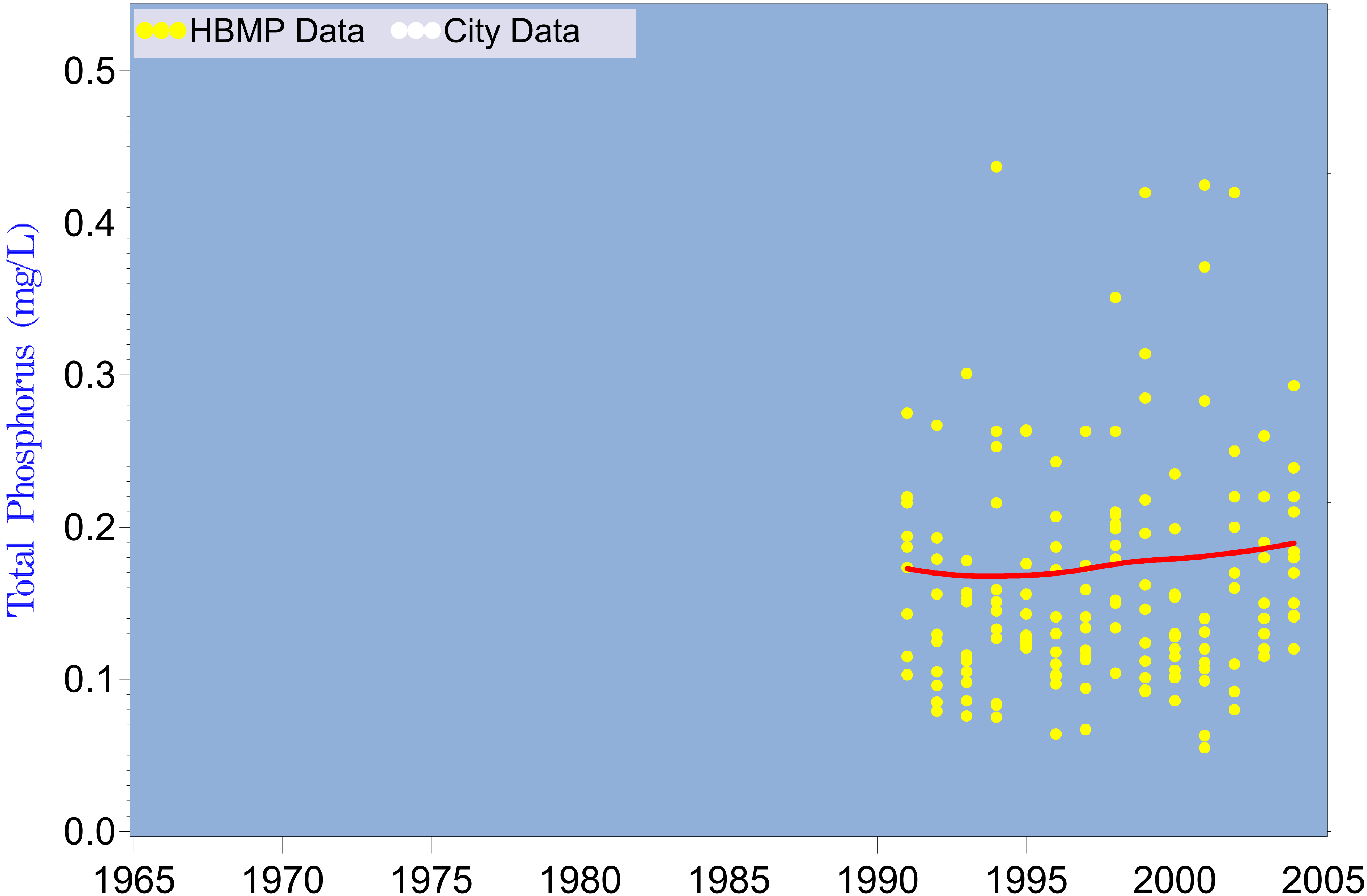


Figure 6.30 Total phosphorus at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

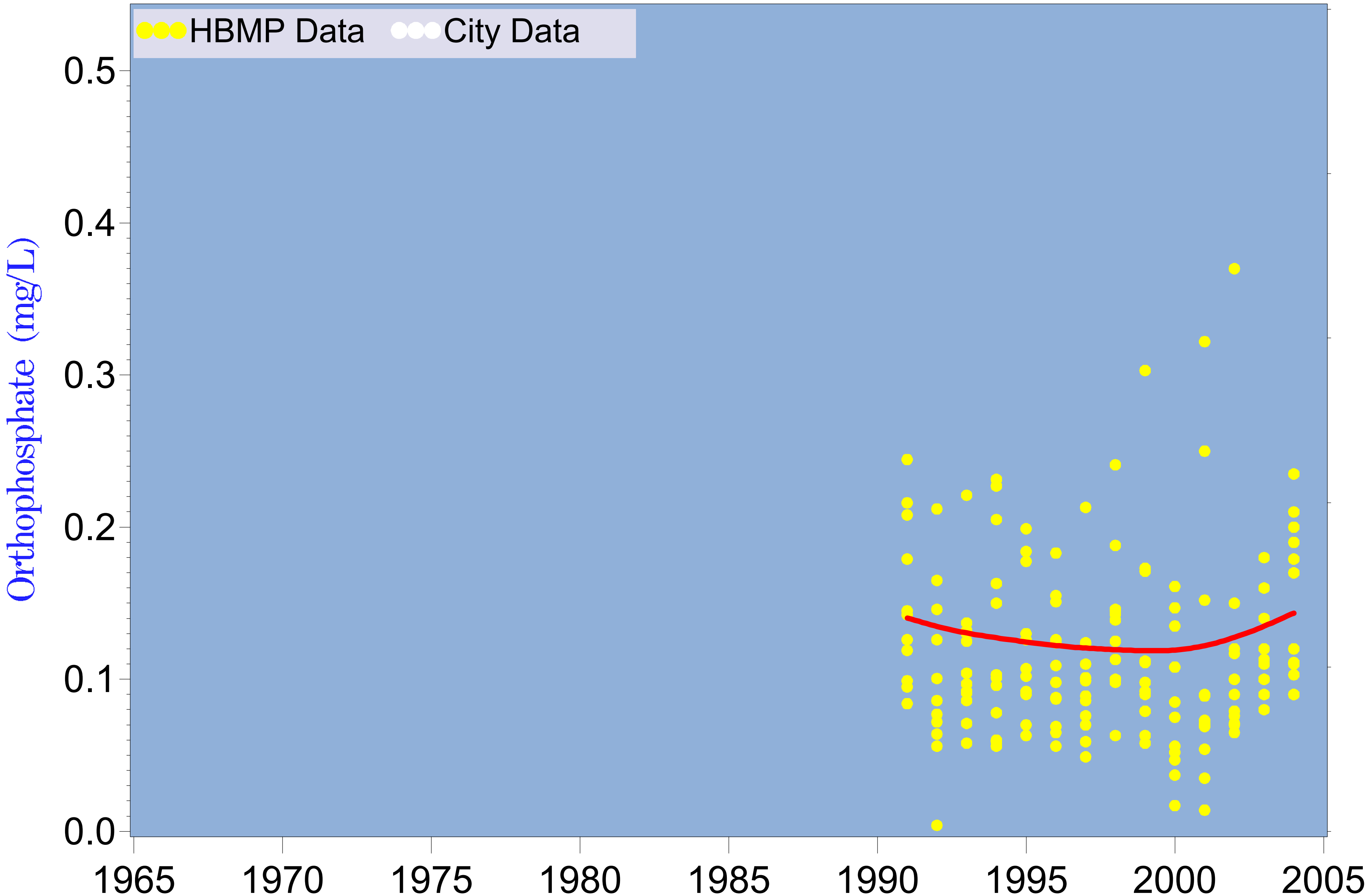


Figure 6.31 Orthophosphate at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

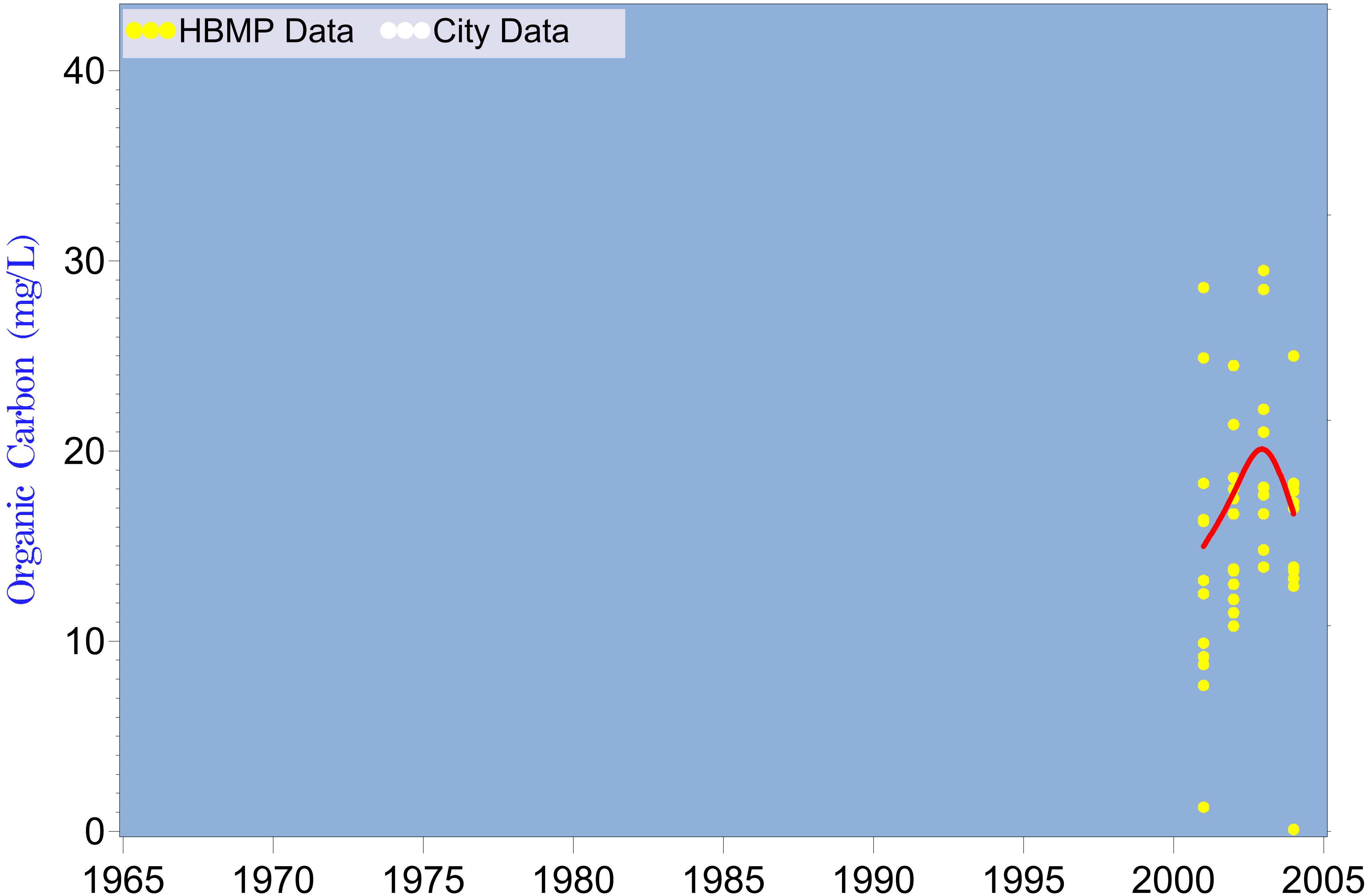


Figure 6.32 Organic carbon at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

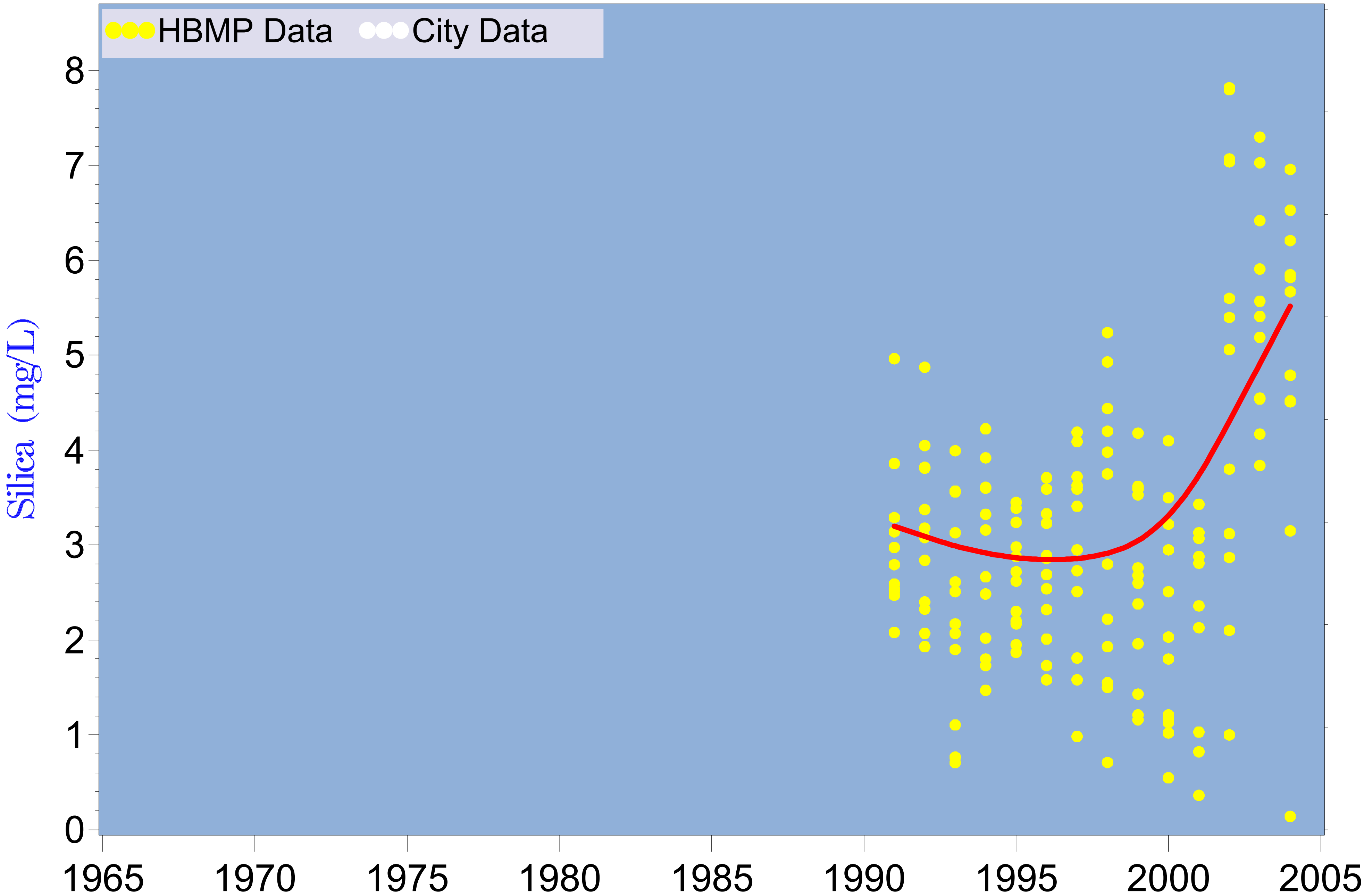


Figure 6.33 Silica at Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

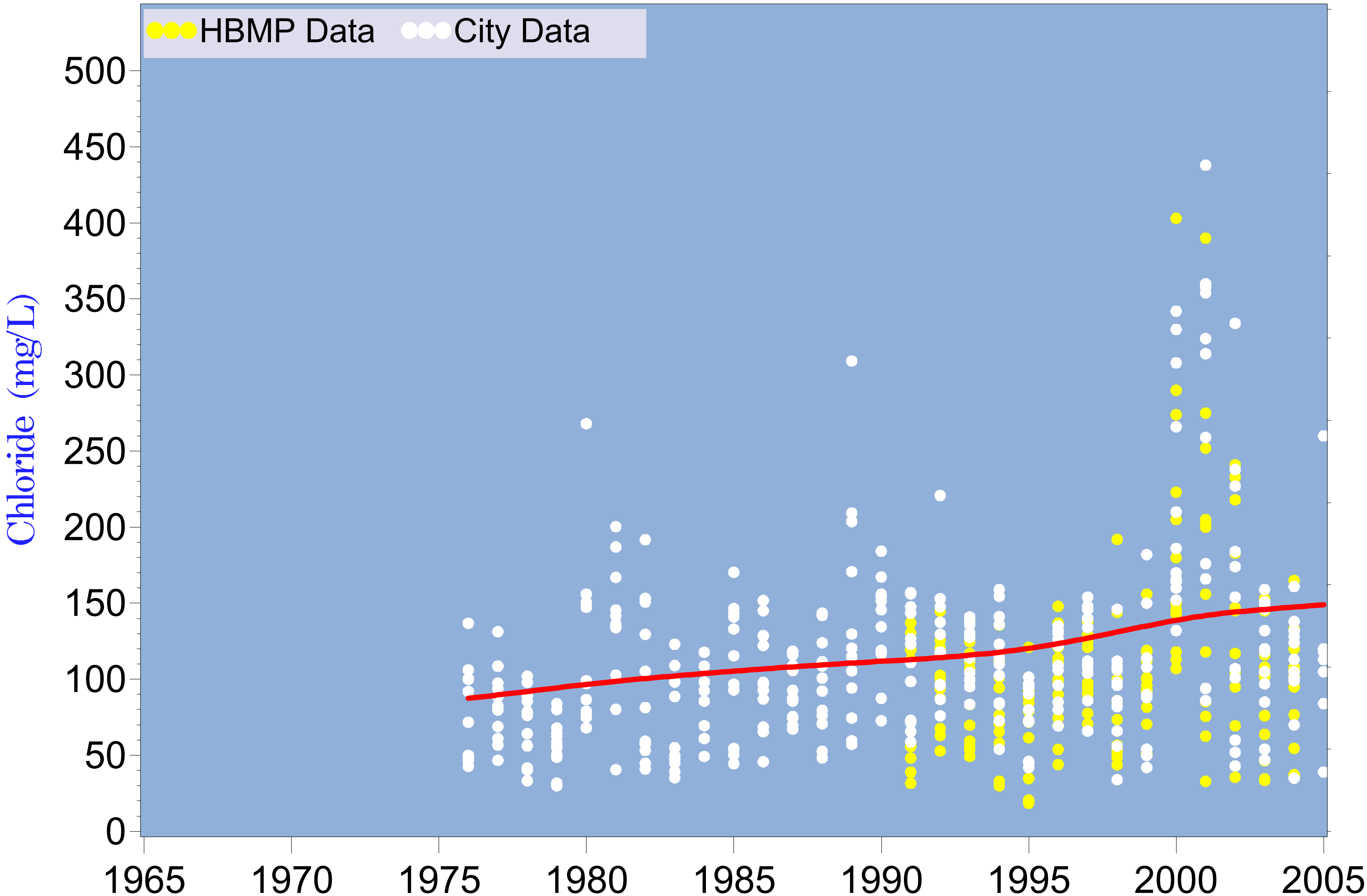


Figure 6.34 Chloride Shell Creek HBMP Site#1
Prairie Creek near Punta Gorda

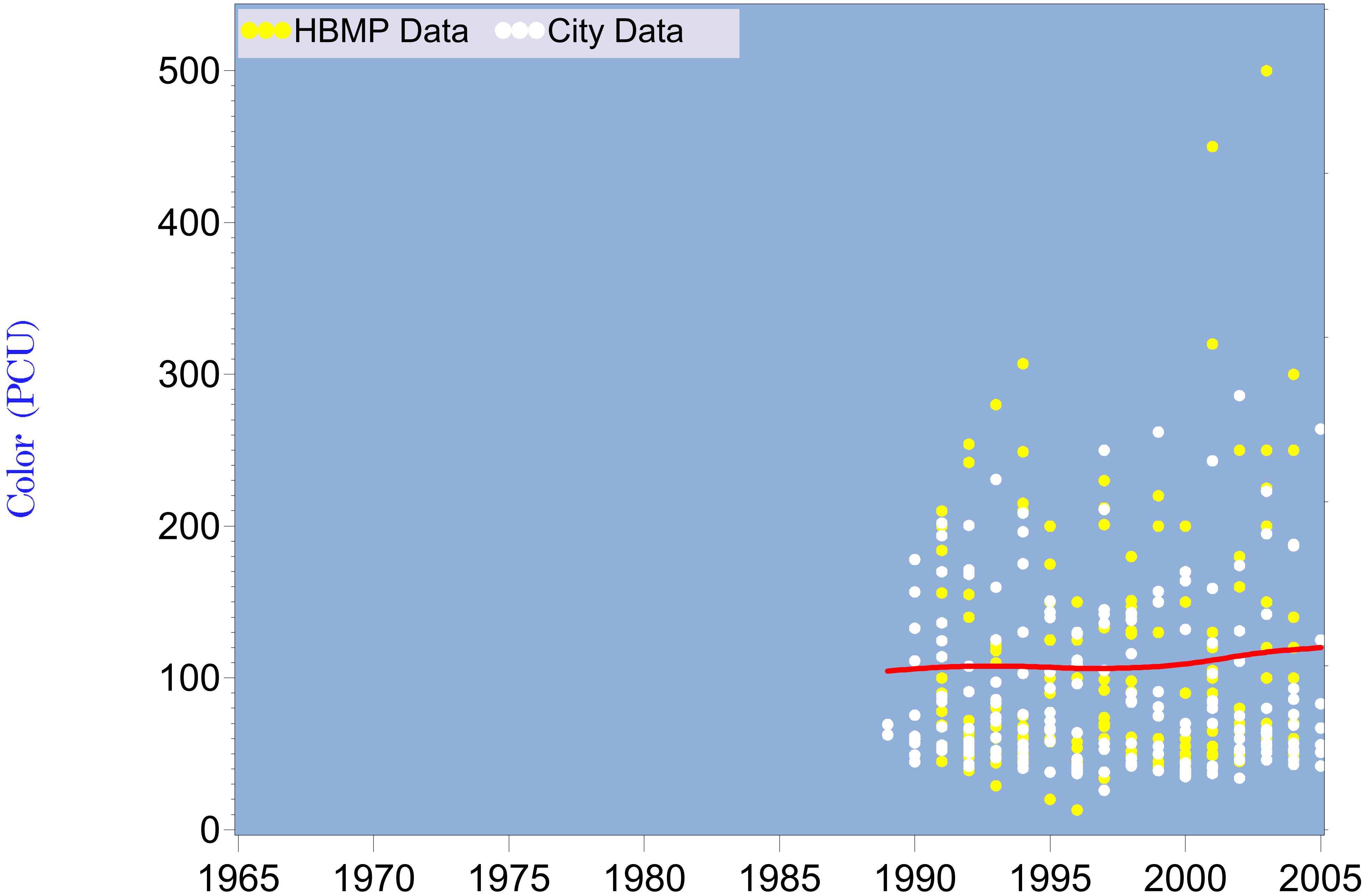


Figure 6.35 Water color at Shell Creek HBMP Site#2
Shell Creek at SR 764

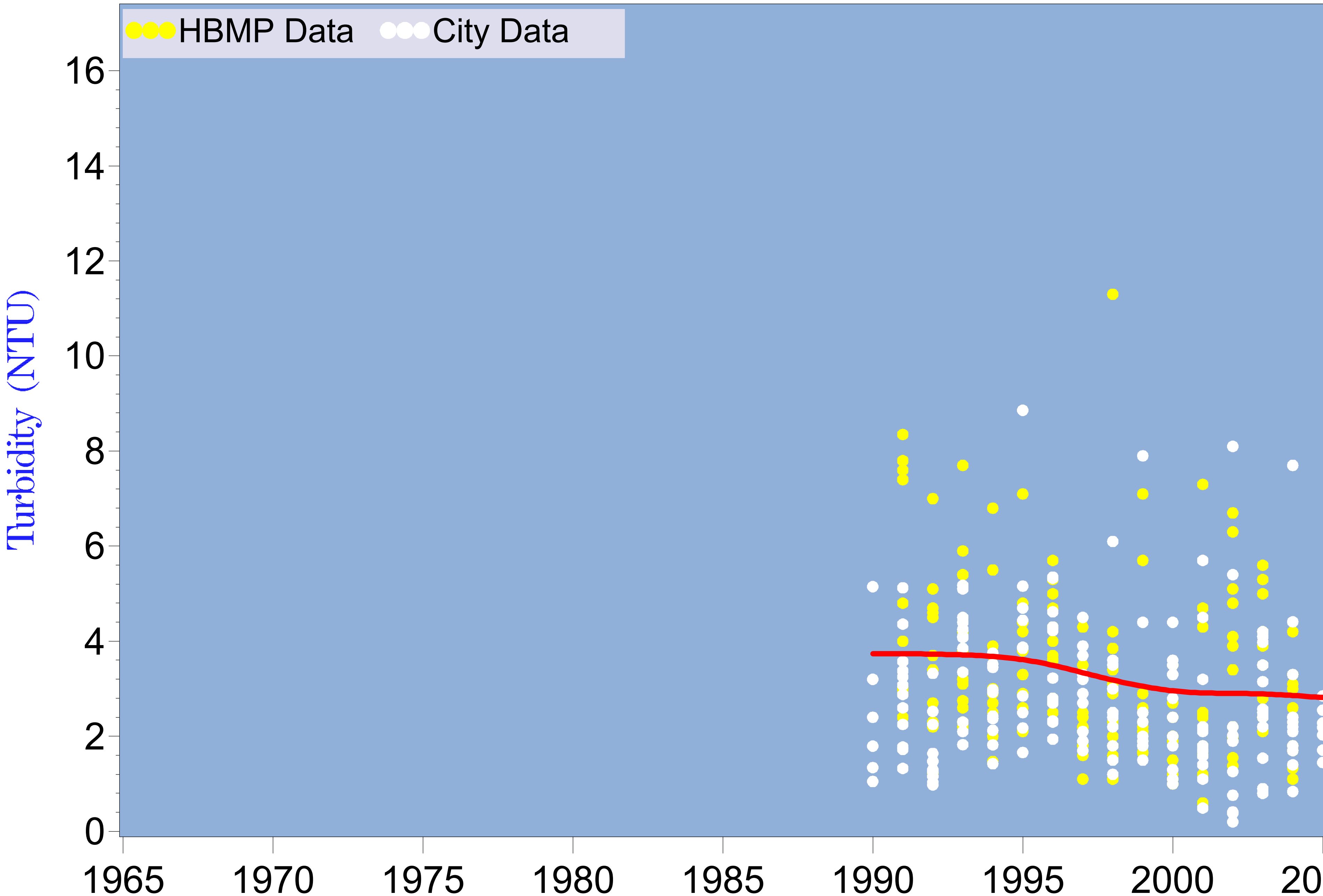


Figure 6.36 Turbidity at Shell Creek HBMP Site#2
Shell Creek at SR 764

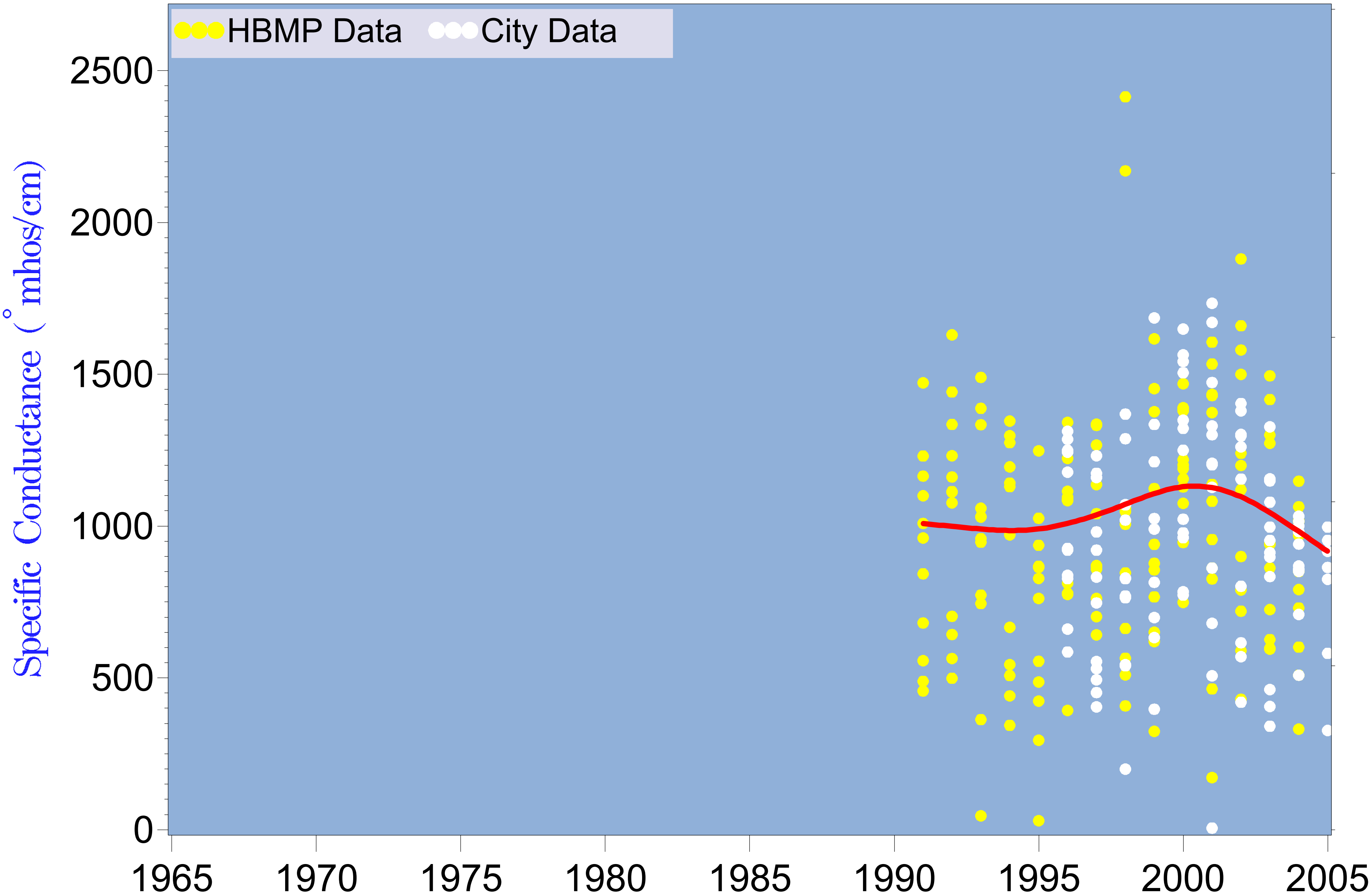


Figure 6.37 Specific conductance Shell Creek HBMP Site#2
Shell Creek at SR 764

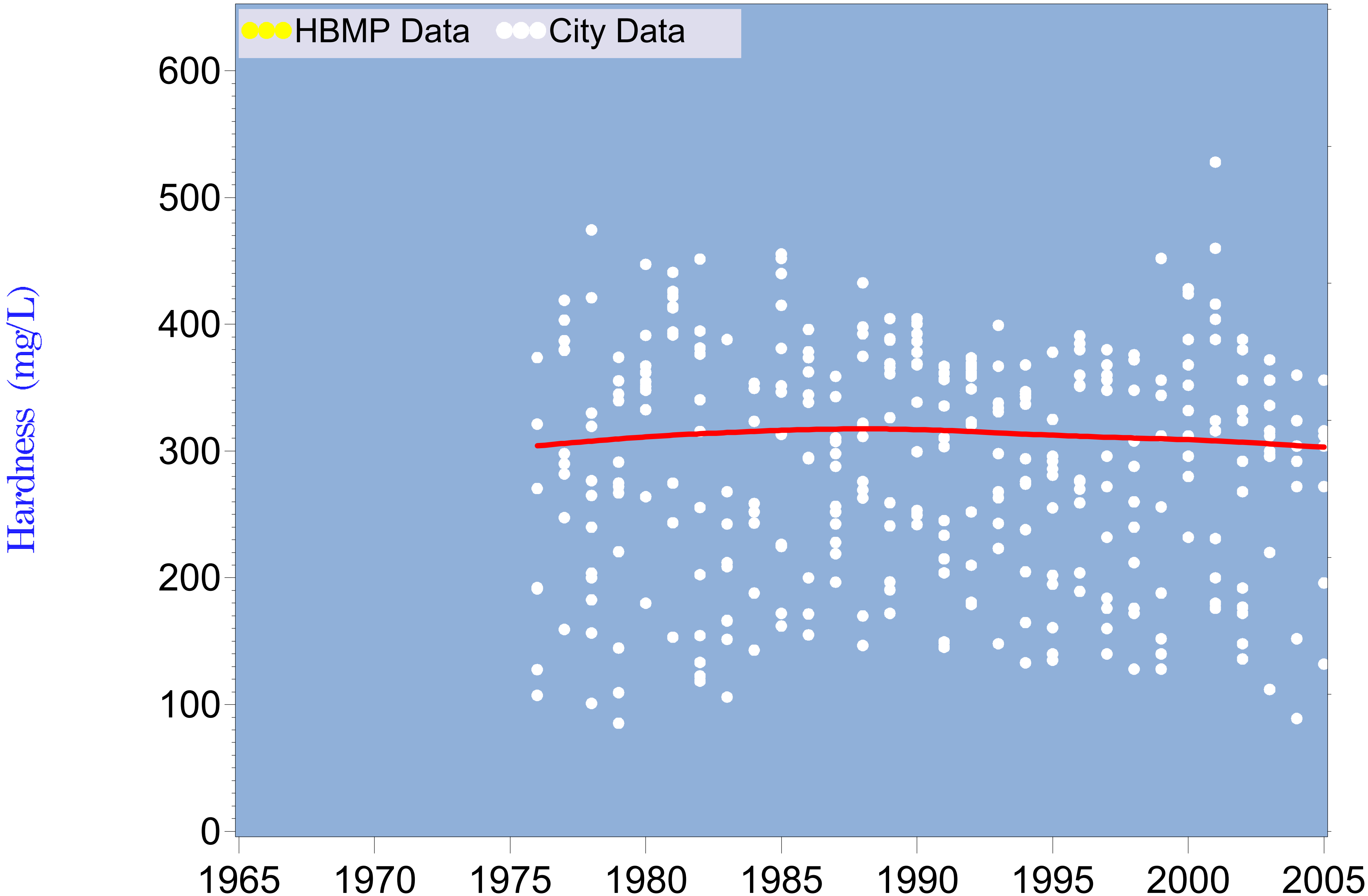


Figure 6.38 Hardness Shell Creek HBMP Site#2
Shell Creek at SR 764

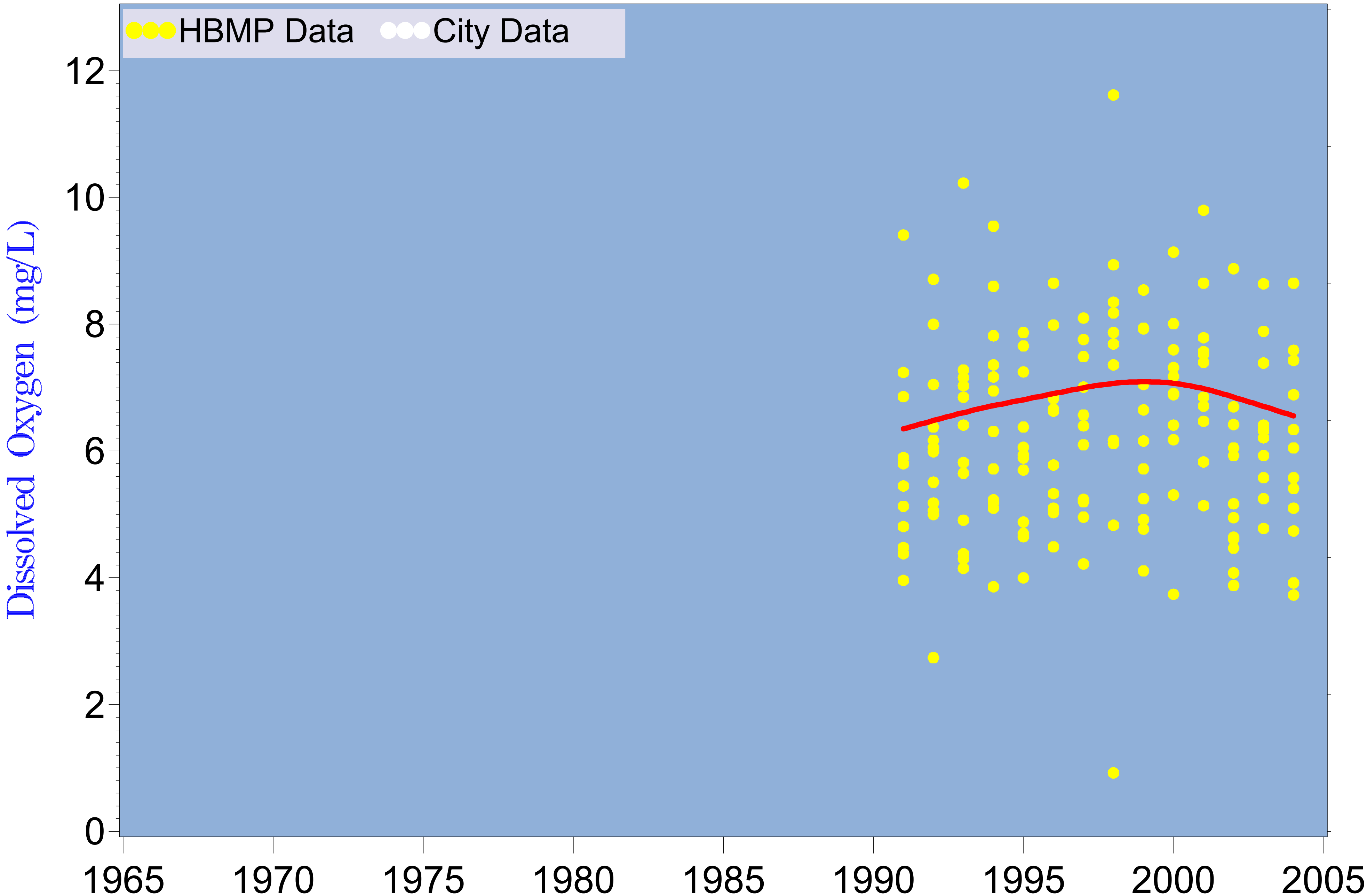


Figure 6.39 Dissolved oxygen at Shell Creek HBMP Site#2
Shell Creek at SR 764

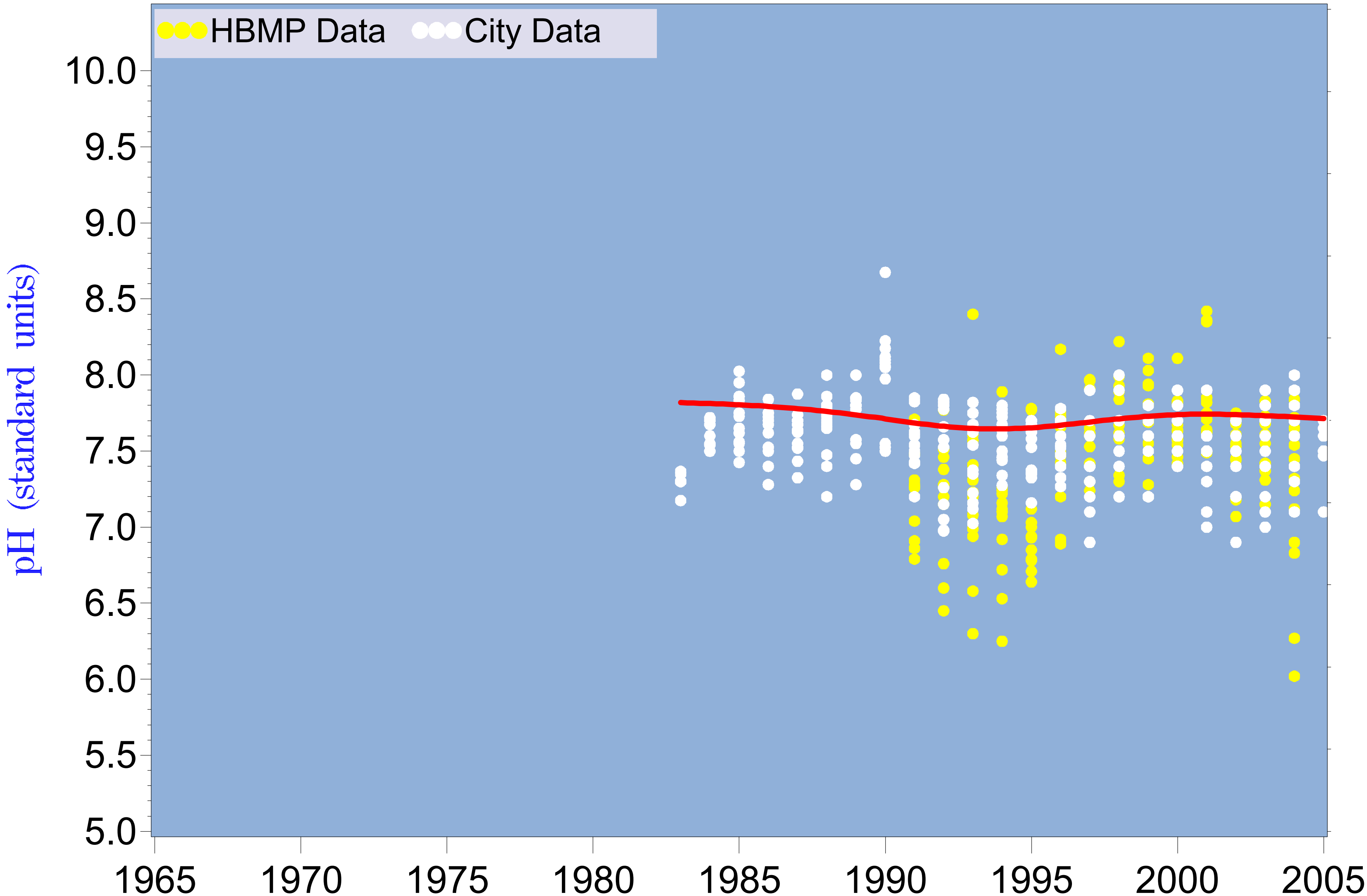


Figure 6.40 pH at Shell Creek HBMP Site#2
Shell Creek at SR 764

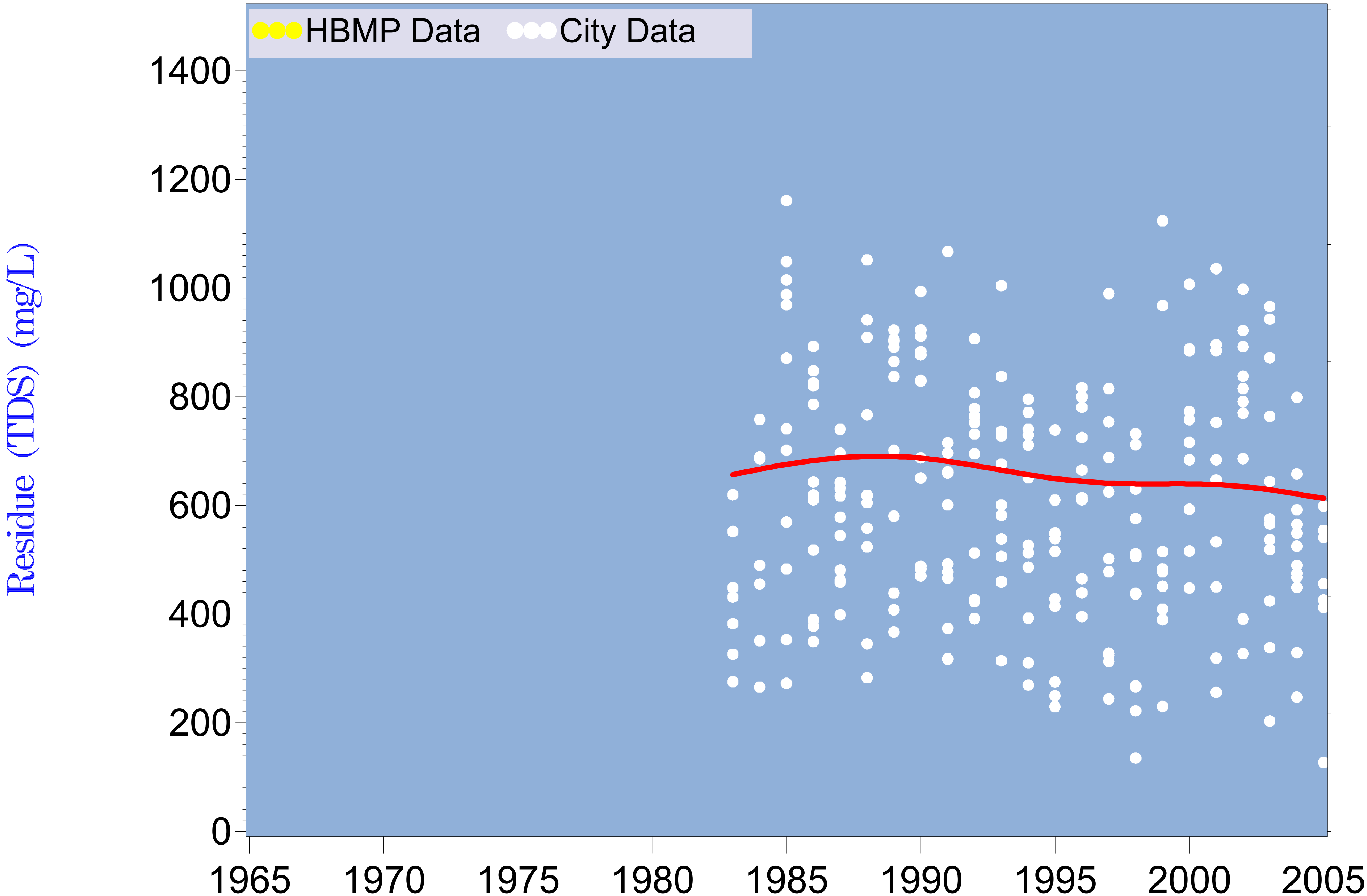


Figure 6.41 TDS Shell Creek HBMP Site#2
Shell Creek at SR 764

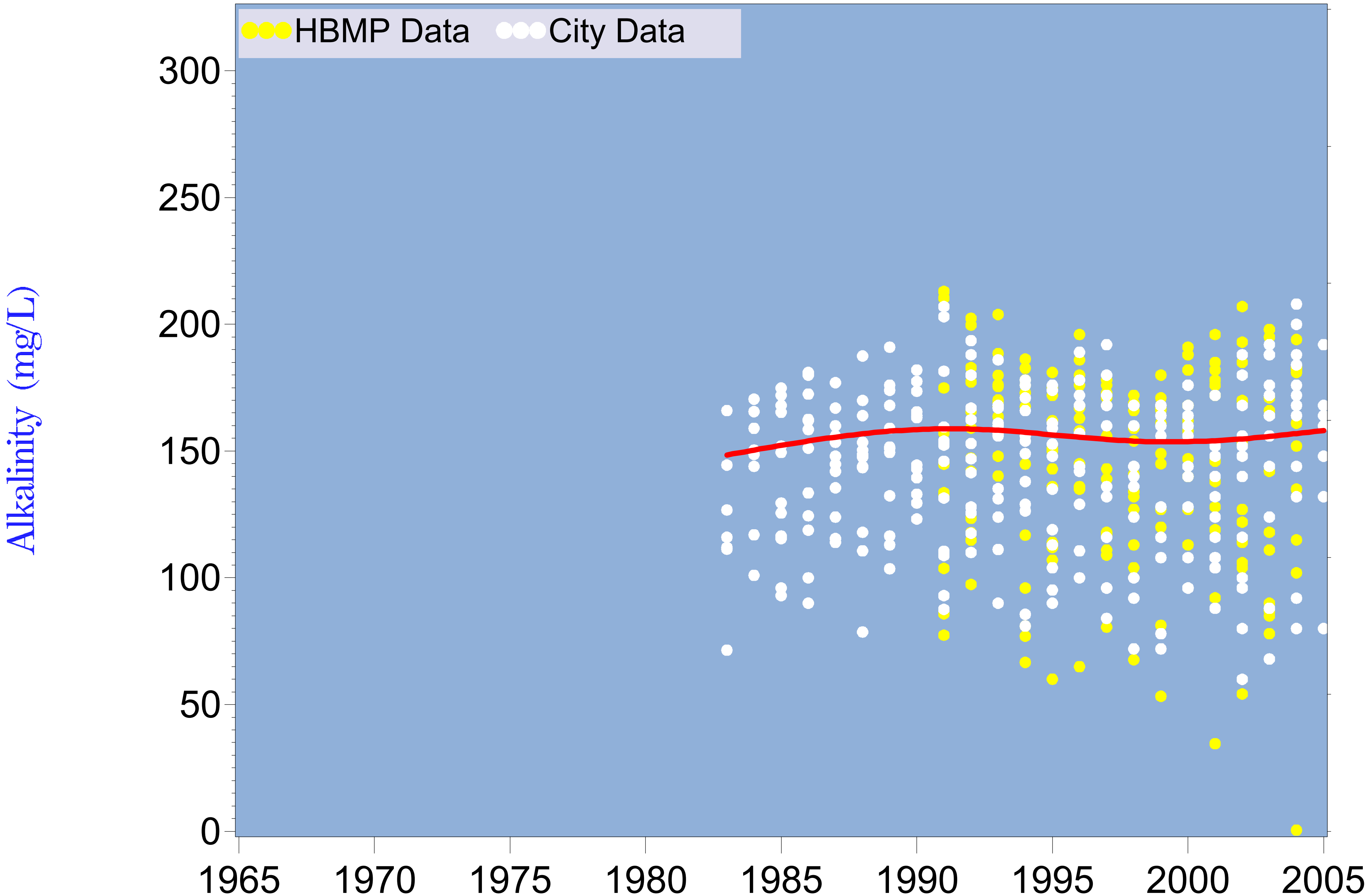


Figure 6.42 Alkalinity at Shell Creek HBMP Site#2
Shell Creek at SR 764

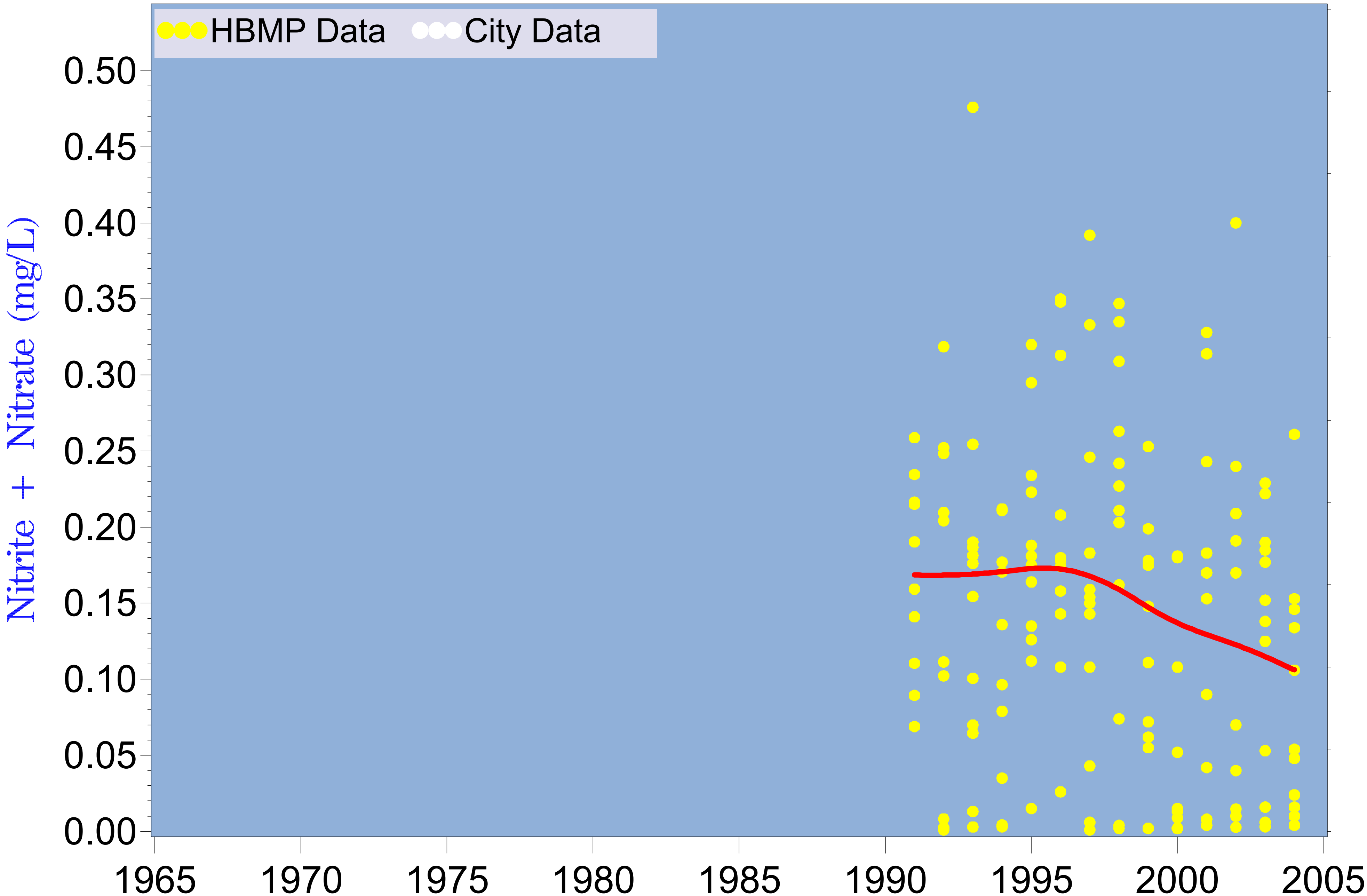


Figure 6.43 Nitrite + nitrate at Shell Creek HBMP Site#2
Shell Creek at SR 764

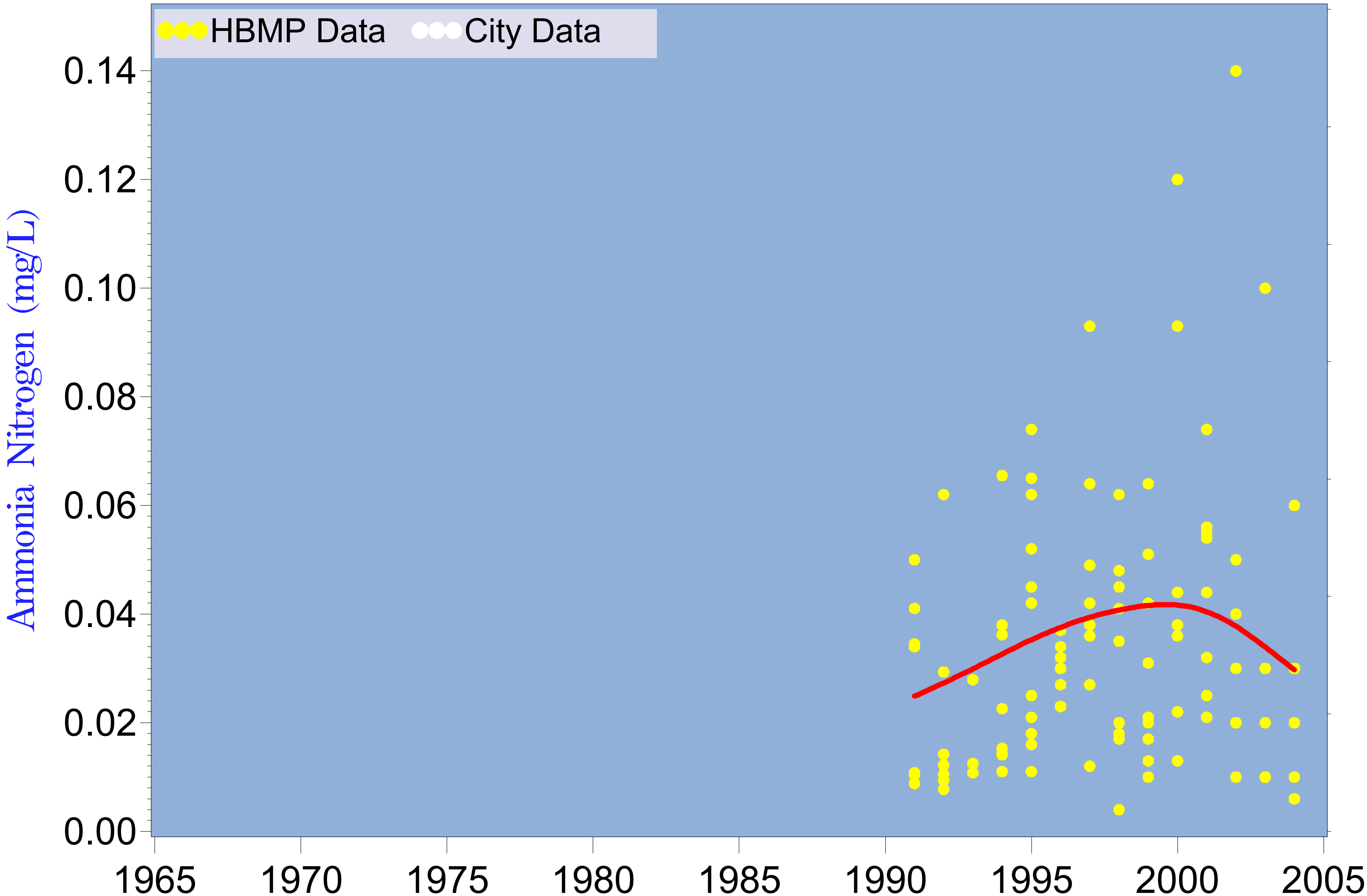


Figure 6.44 Ammonia nitrogen at Shell Creek HBMP Site#2
Shell Creek at SR 764

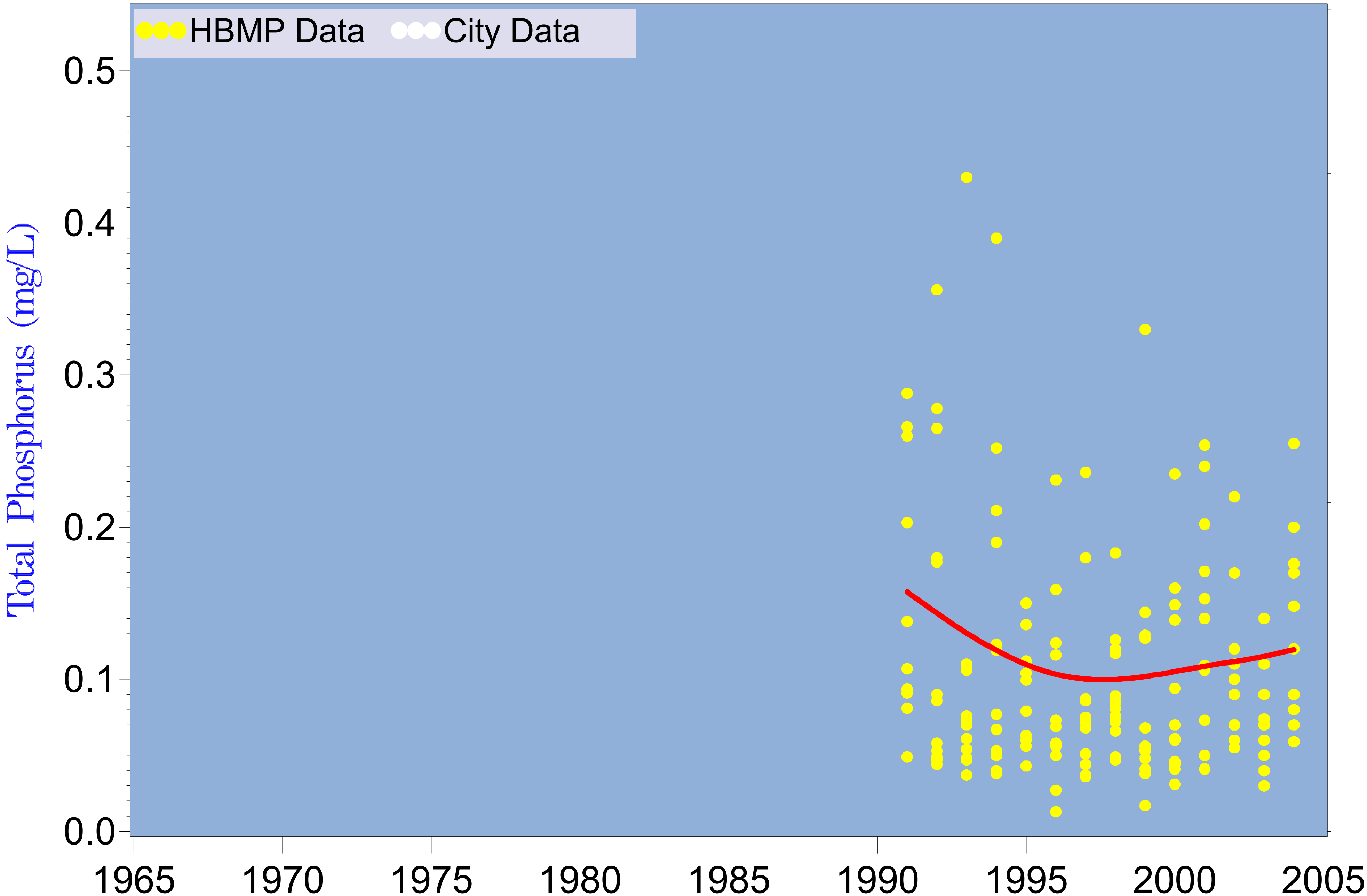


Figure 6.45 Total phosphorus at Shell Creek HBMP Site#2
Shell Creek at SR 764

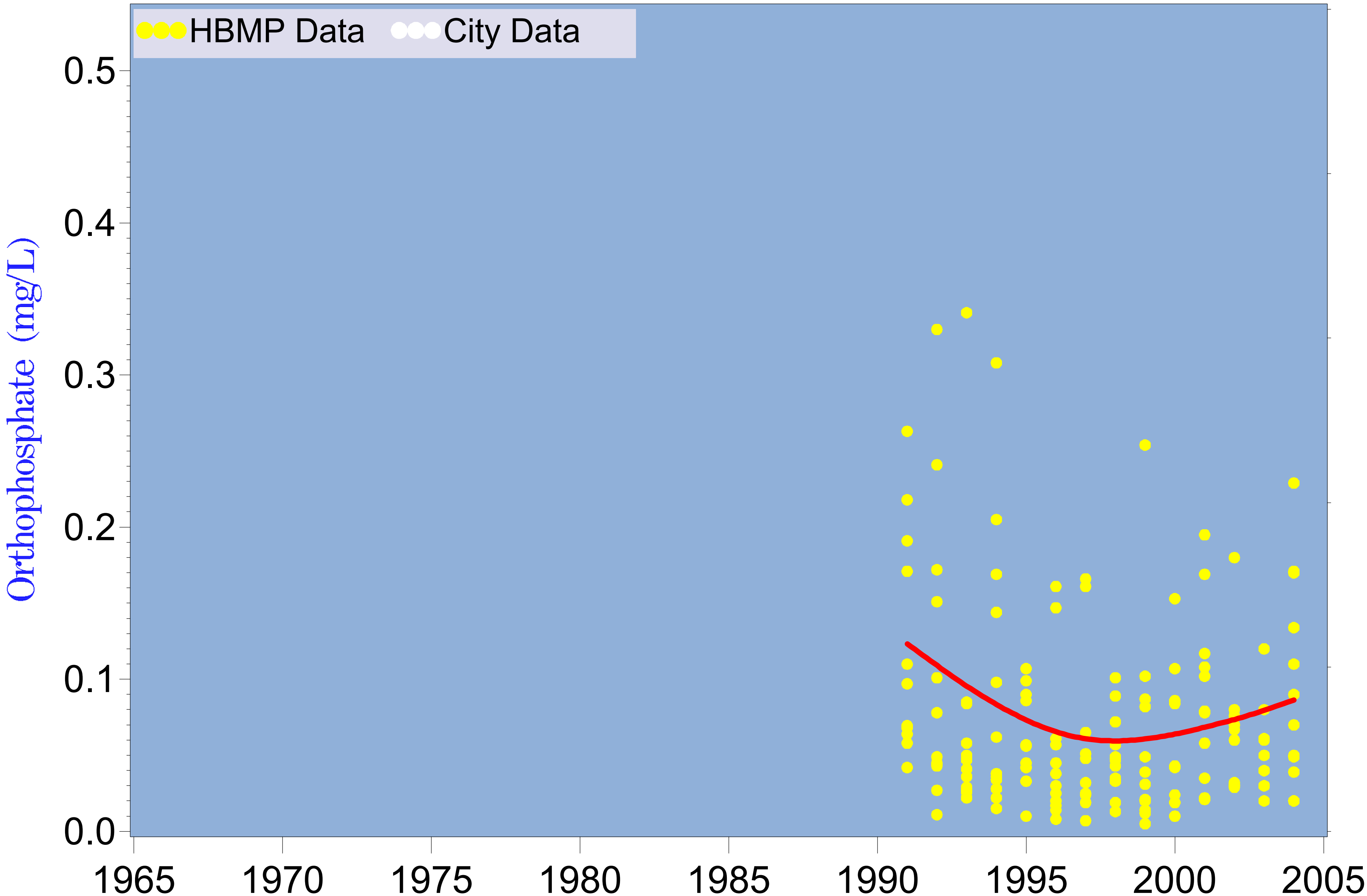


Figure 6.46 Orthophosphate at Shell Creek HBMP Site#2
Shell Creek at SR 764

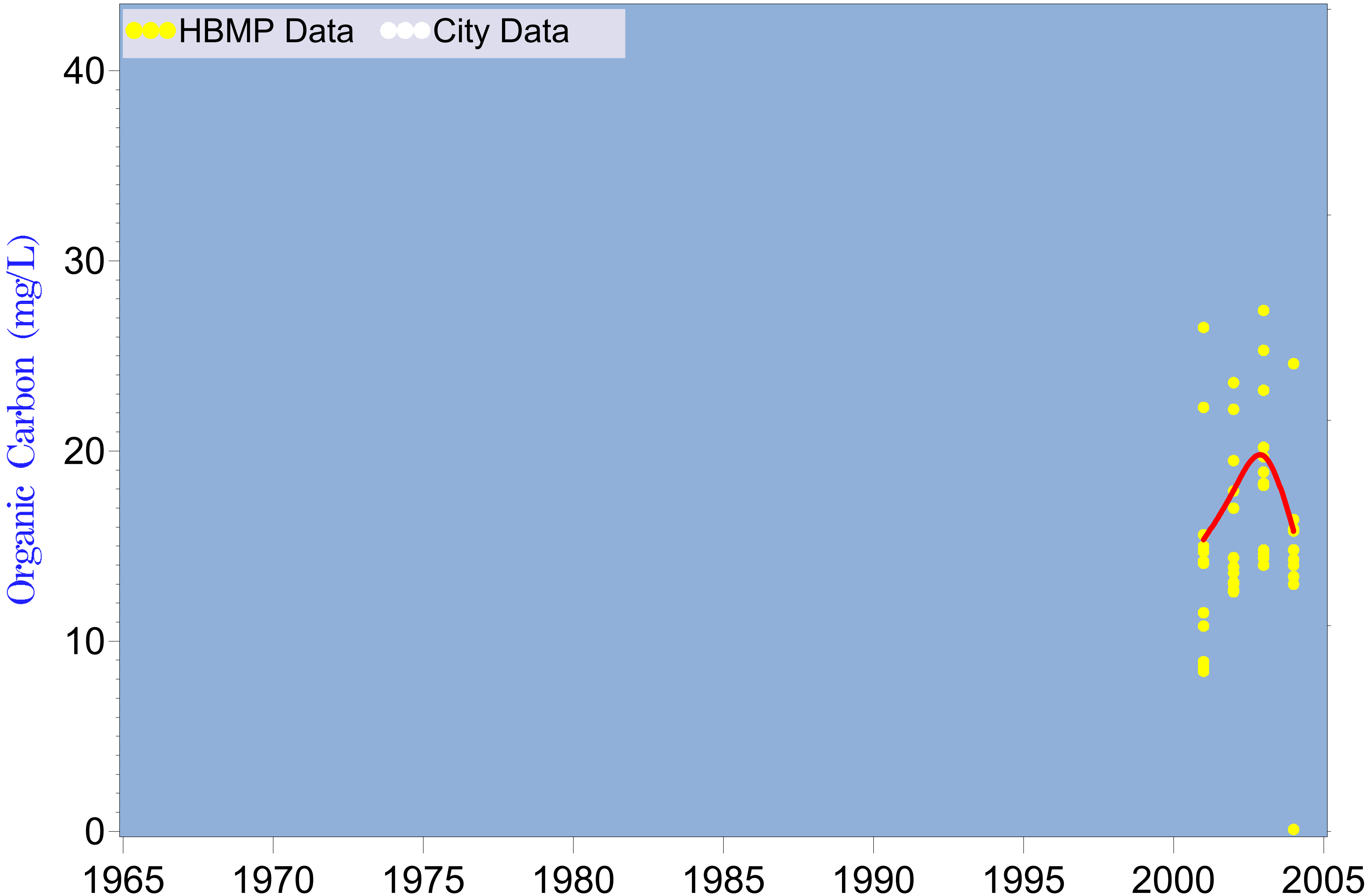


Figure 6.47 Organic carbon at Shell Creek HBMP Site#2
Shell Creek at SR 764

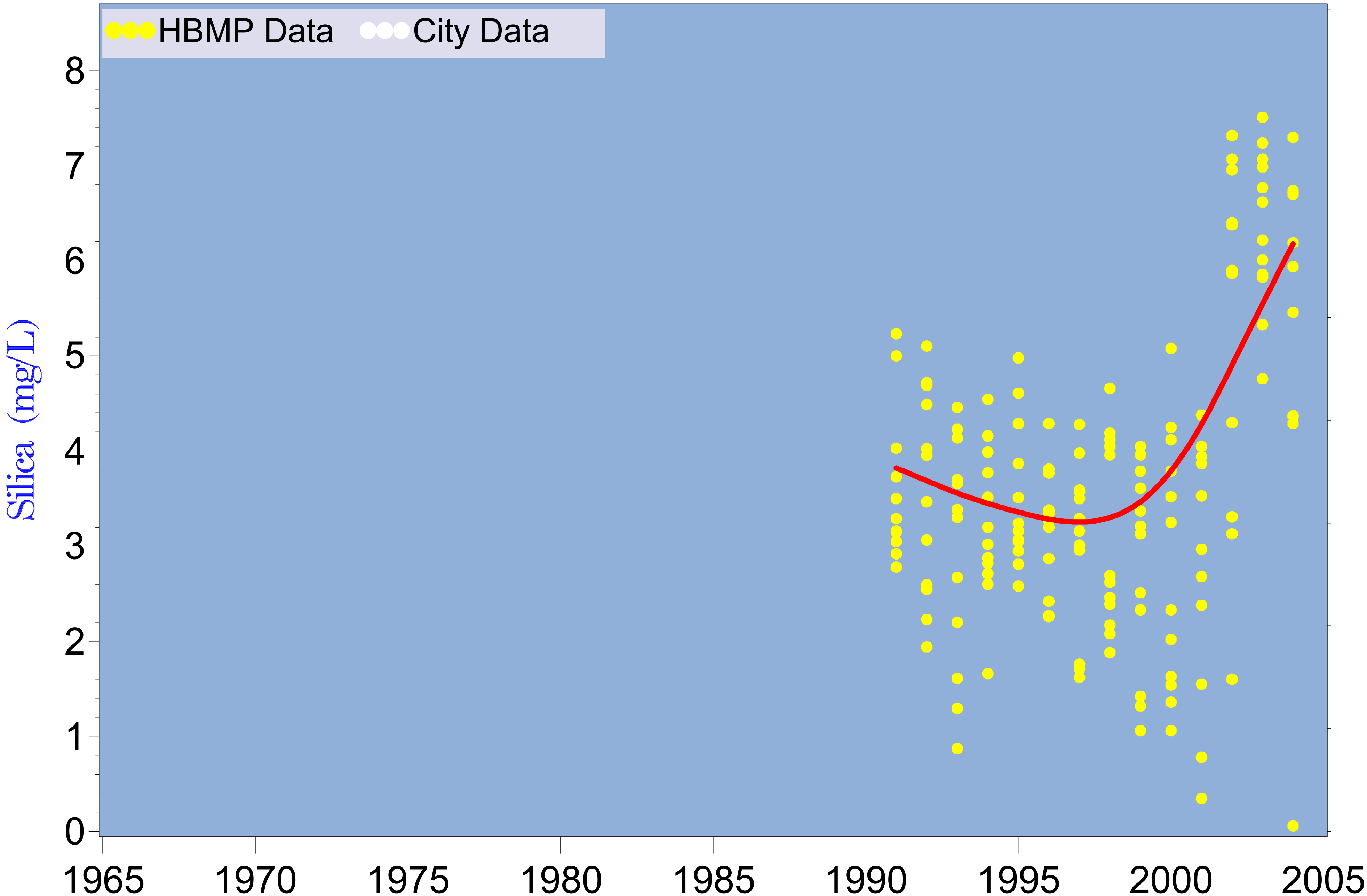


Figure 6.48 Silica at Shell Creek HBMP Site#2
Shell Creek at SR 764

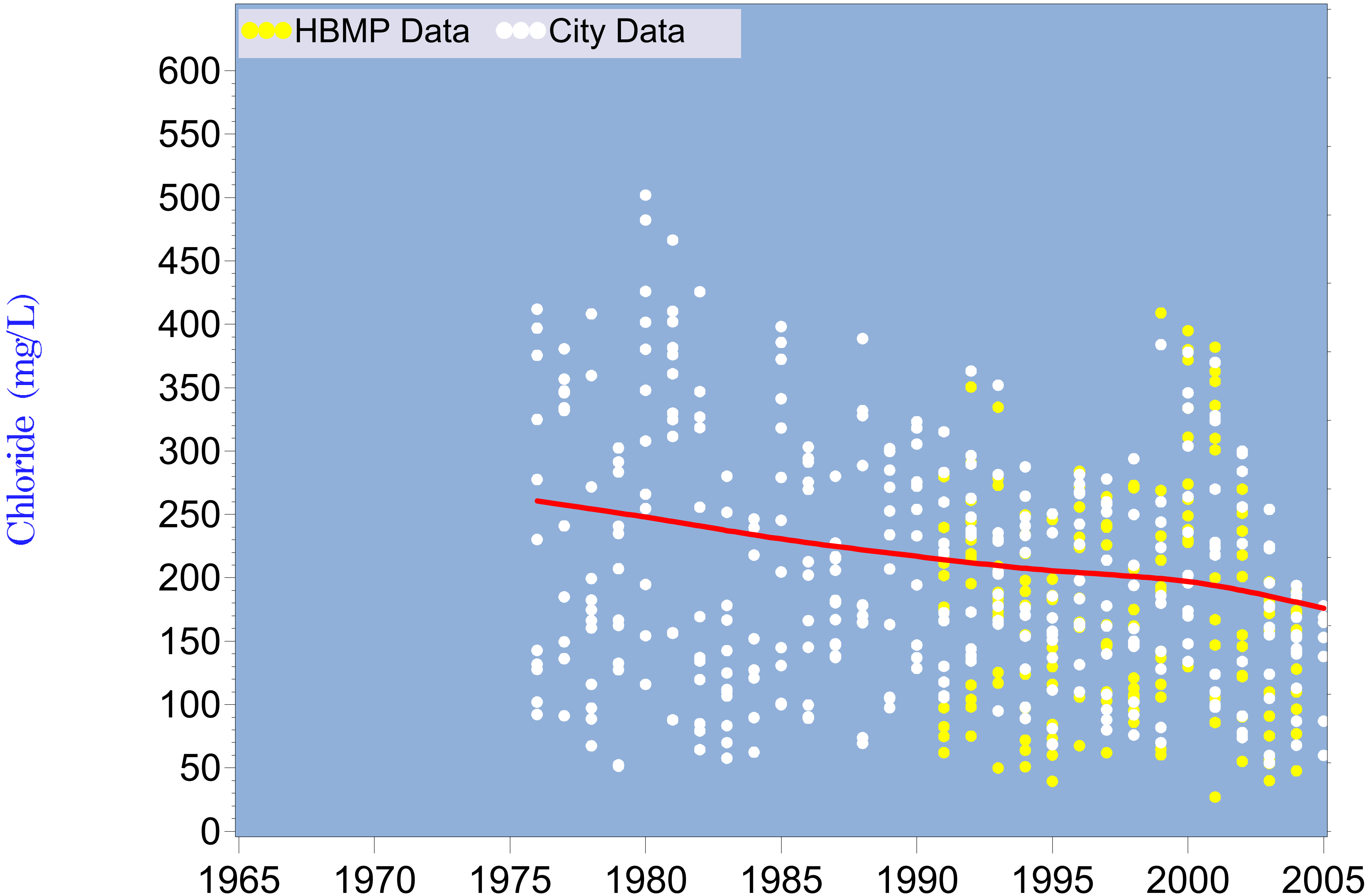


Figure 6.49 Chloride Shell Creek HBMP Site#2
Shell Creek at SR 764

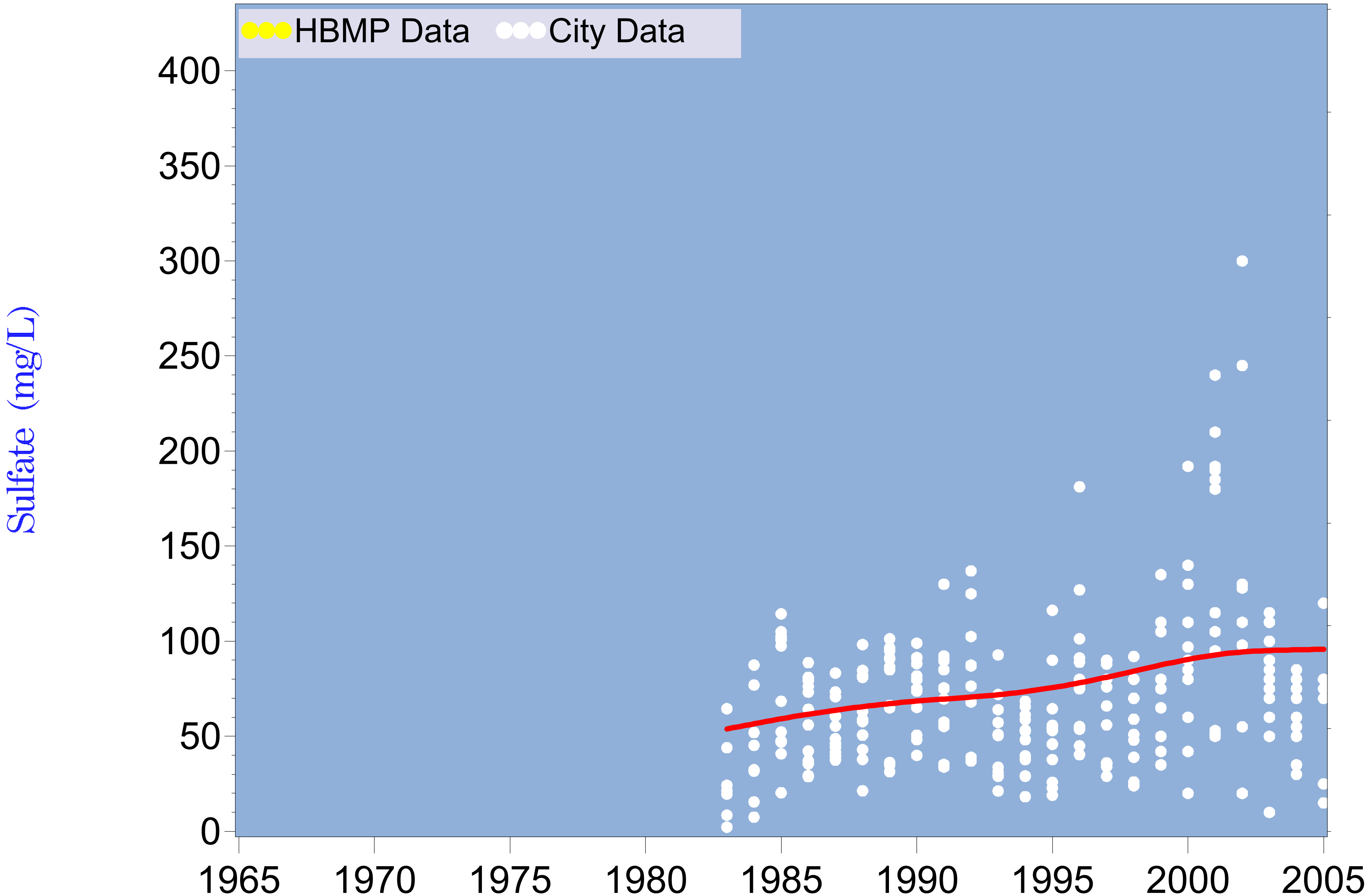


Figure 6.50 Sulfate Shell Creek HBMP Site#2
Shell Creek at SR 764

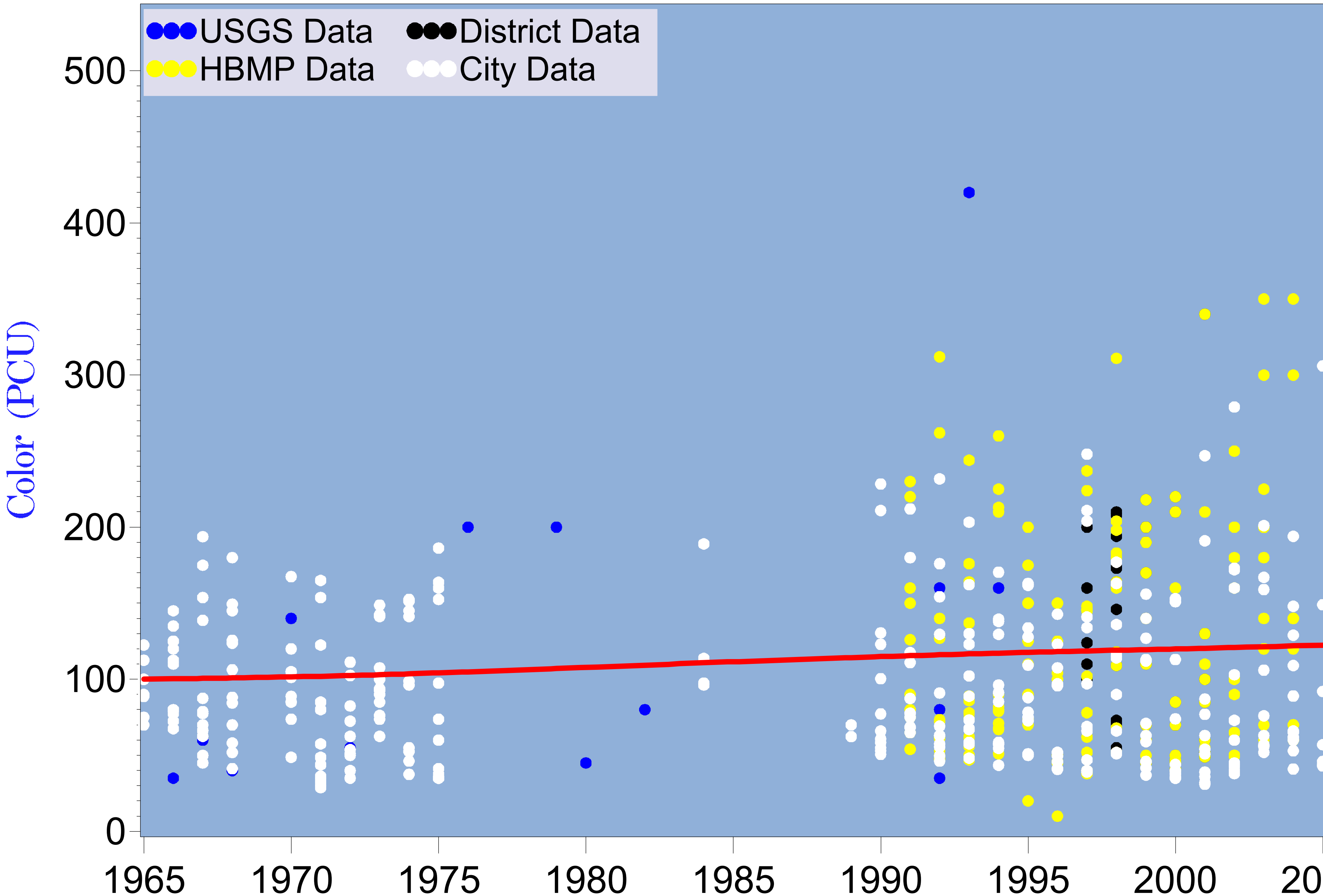


Figure 6.51 Water color at USGS site 2298202
Shell Creek near Punta Gorda

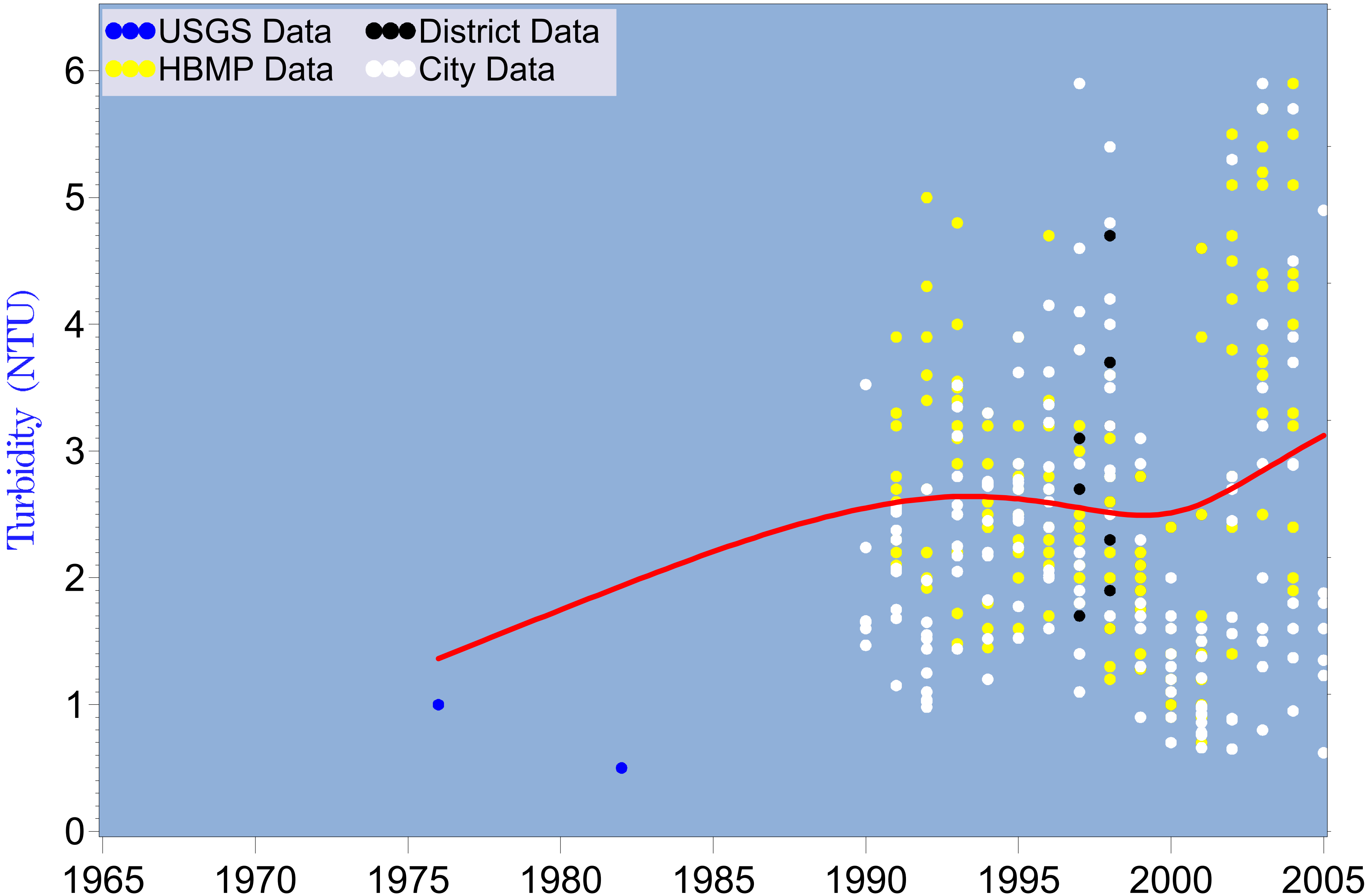


Figure 6.52 Turbidity at USGS site 2298202
Shell Creek near Punta Gorda

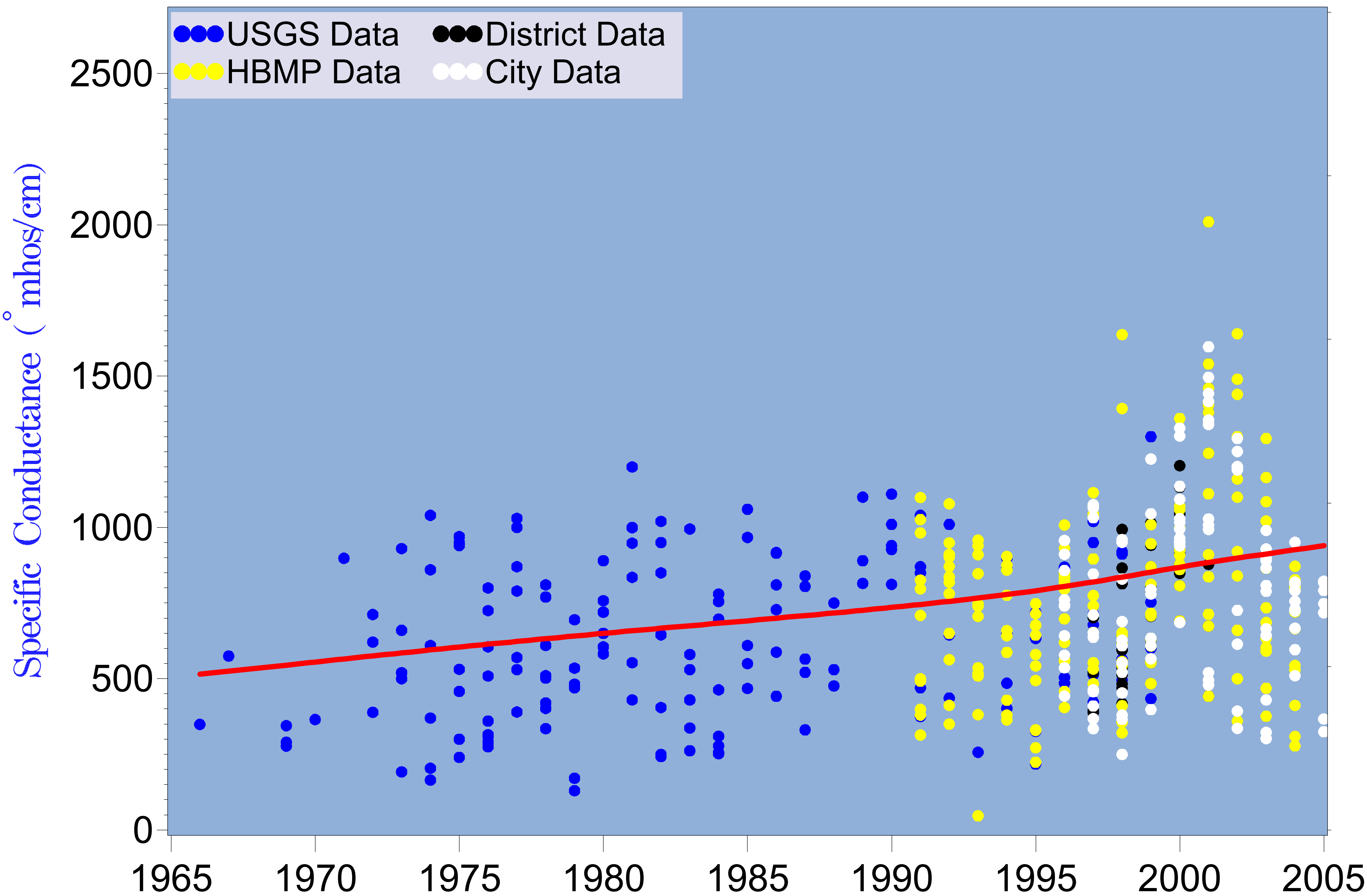


Figure 6.53 Specific conductance USGS site 2298202
Shell Creek near Punta Gorda

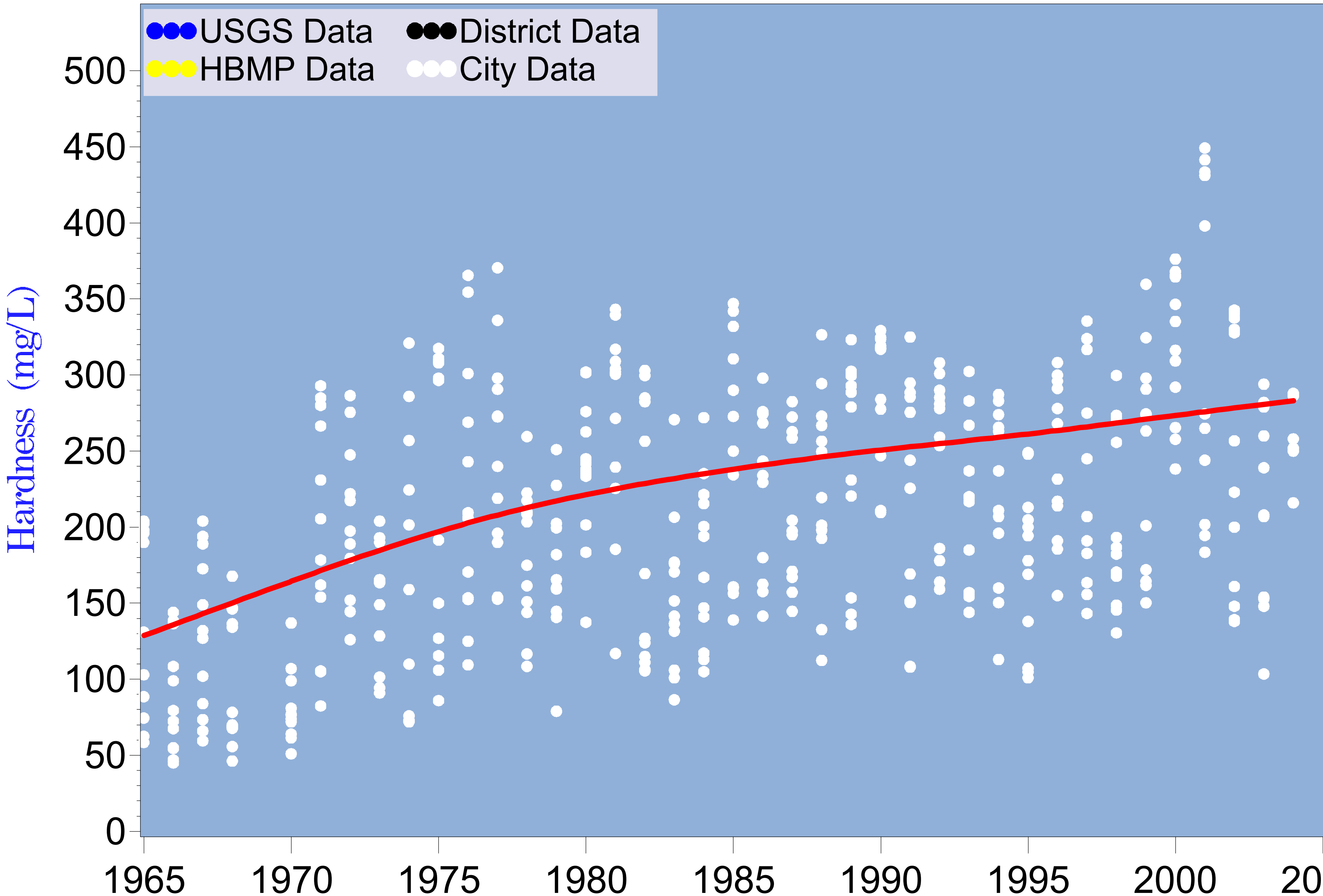


Figure 6.54 Hardness USGS site 2298202
Shell Creek near Punta Gorda

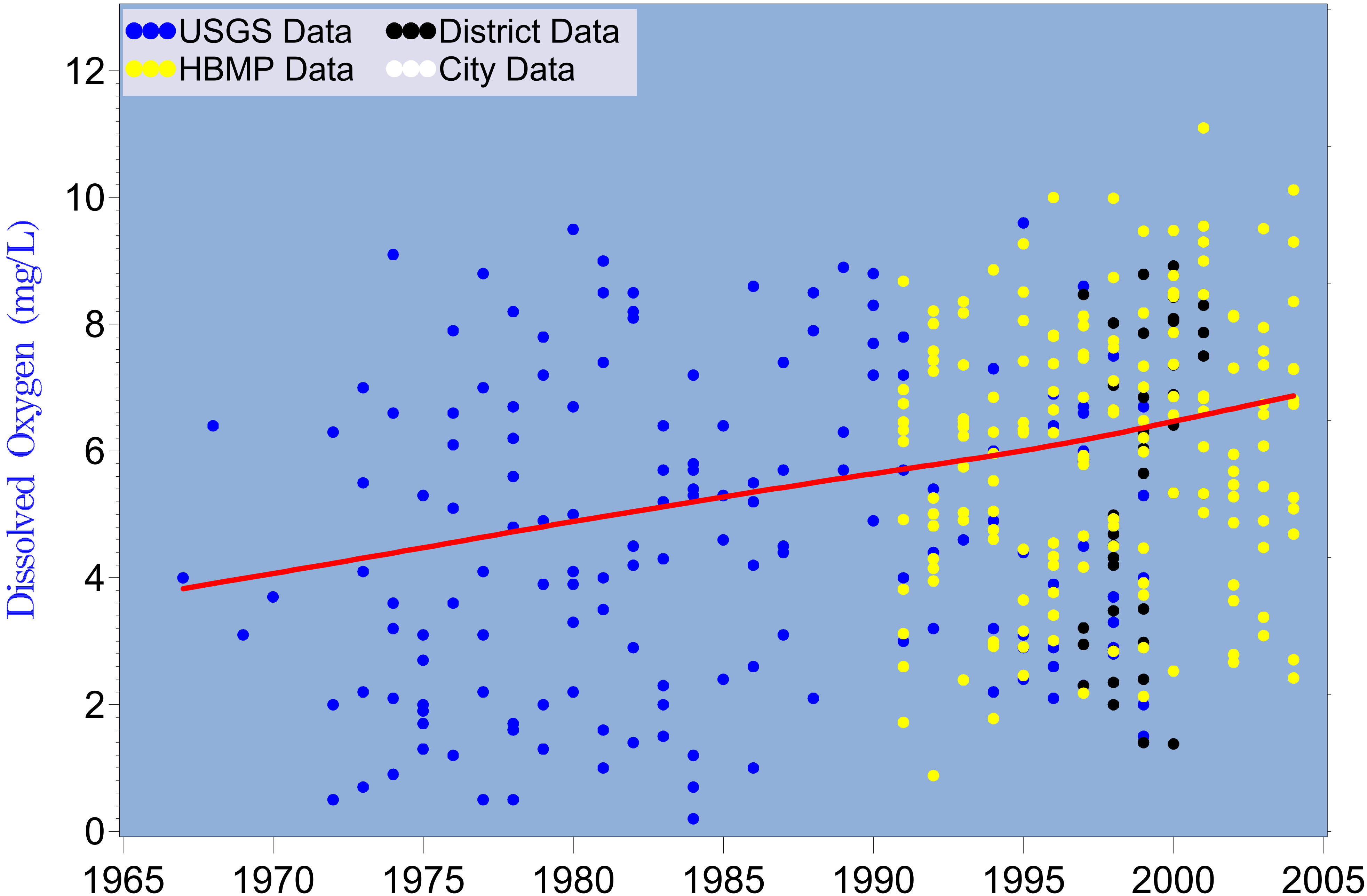


Figure 6.55 Dissolved oxygen at USGS site 2298202
Shell Creek near Punta Gorda

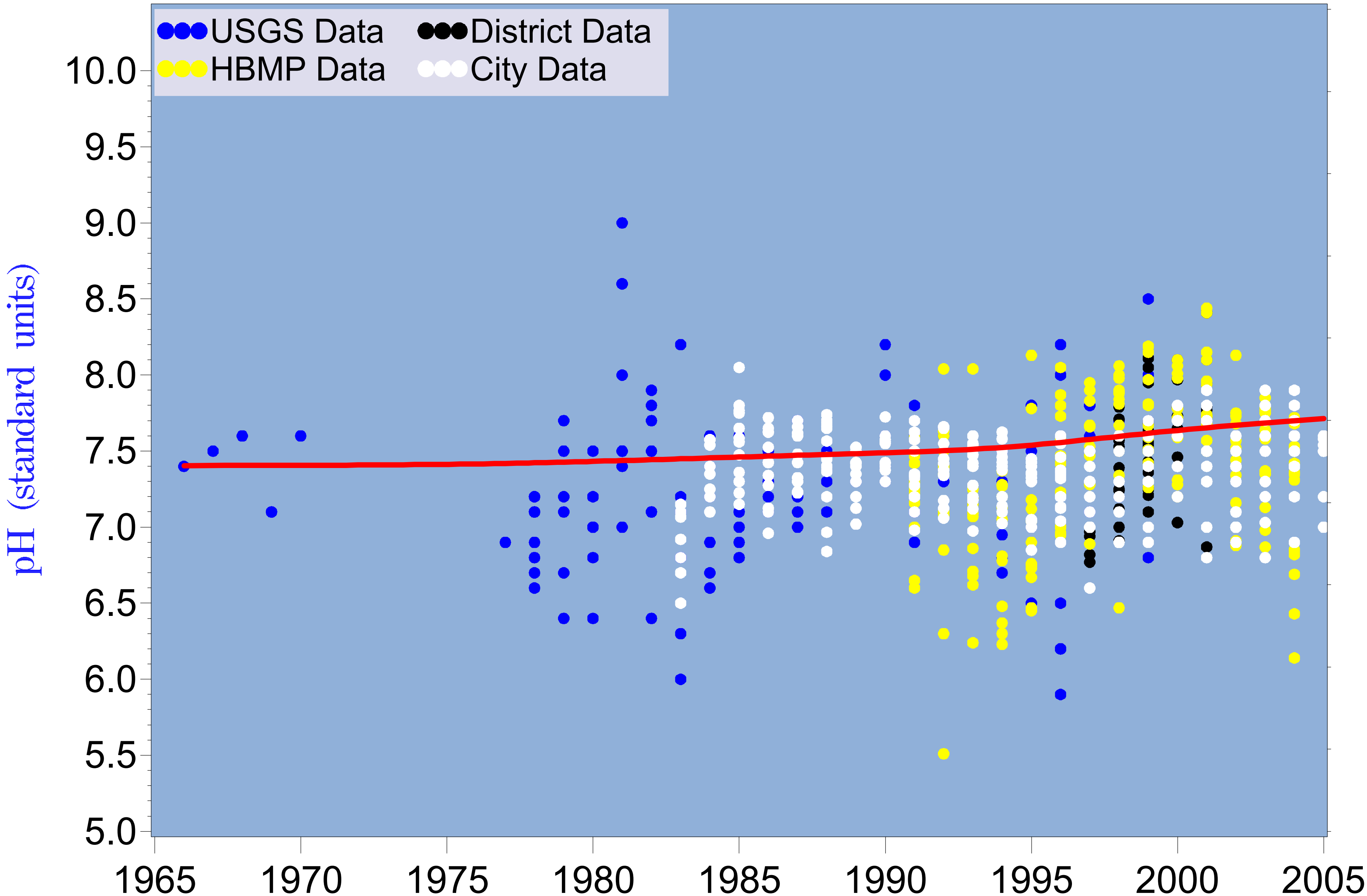


Figure 6.56 pH at USGS site 2298202
Shell Creek near Punta Gorda

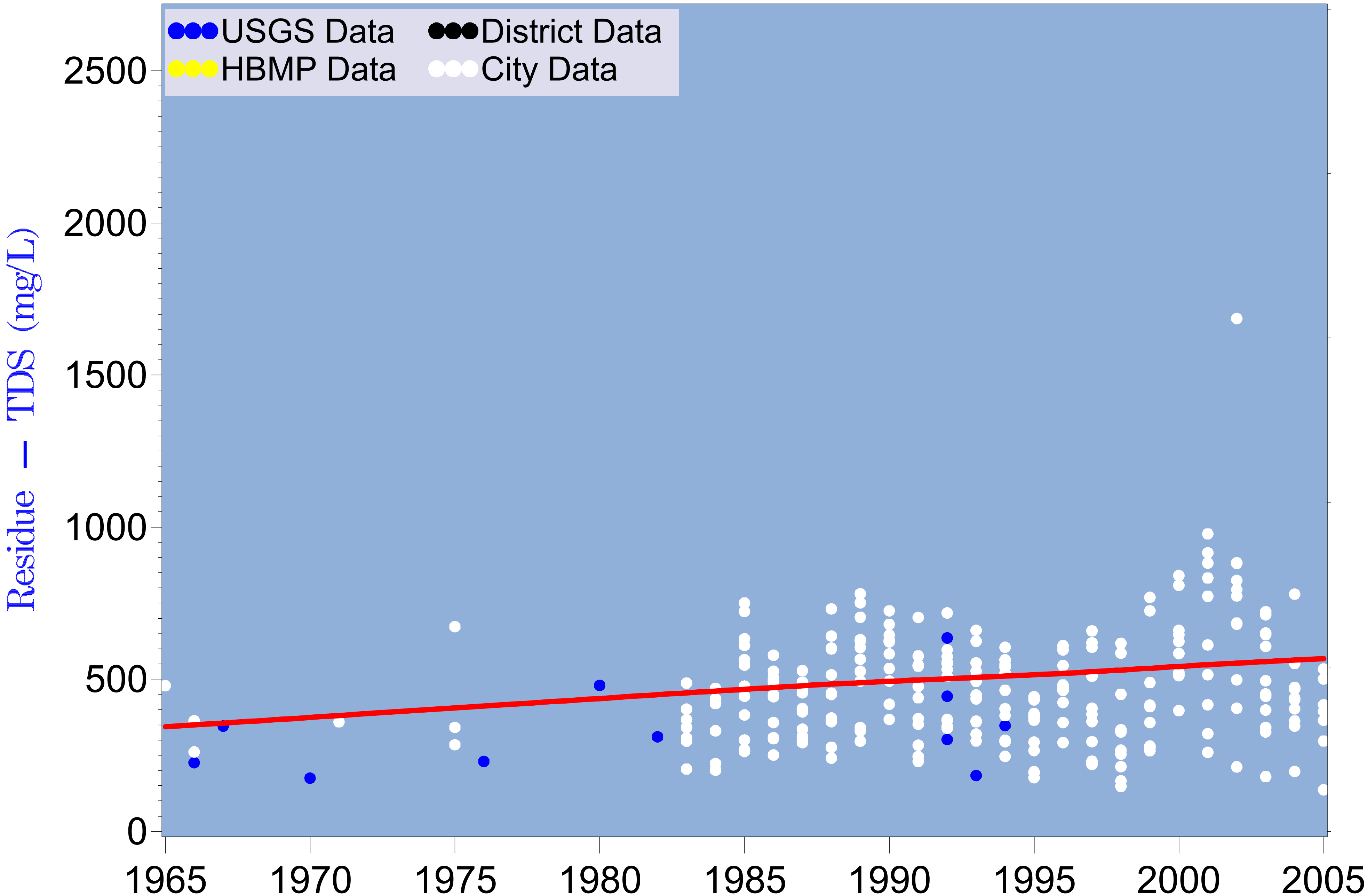


Figure 6.57 TDS at USGS site 2298202
Shell Creek near Punta Gorda

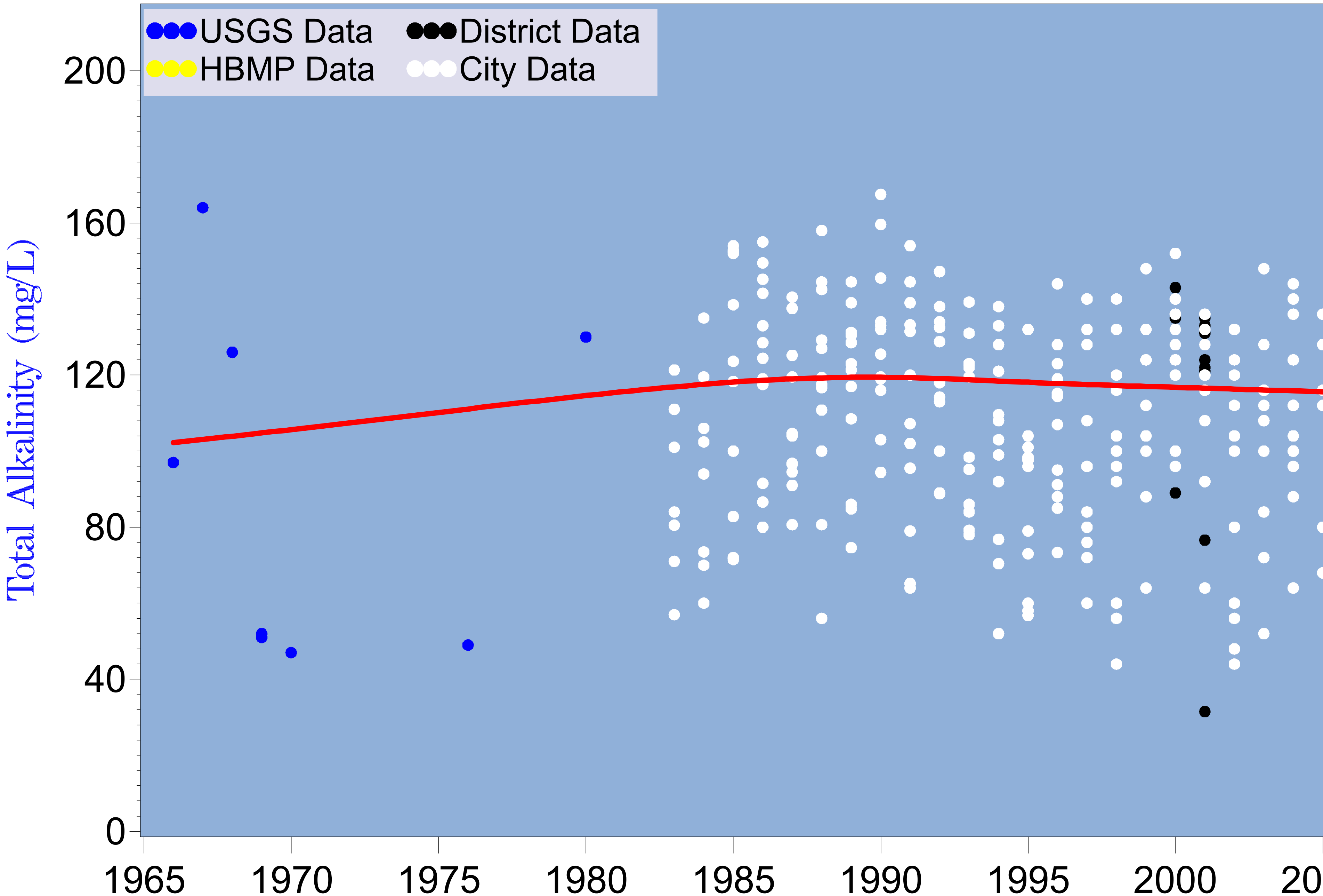


Figure 6.58 Alkalinity at USGS site 2298202
Shell Creek near Punta Gorda

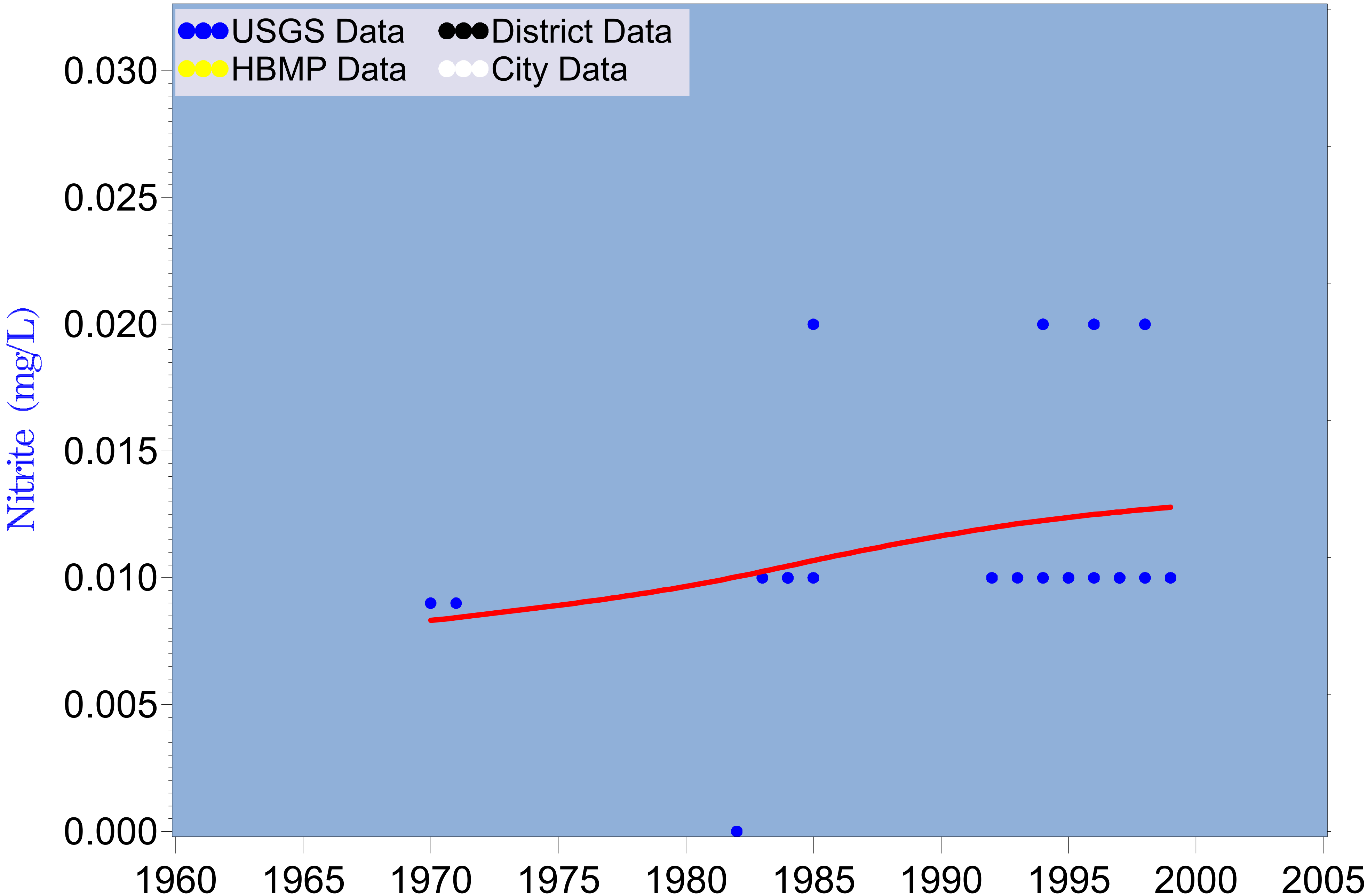


Figure 6.59 Nitrite at USGS site 2298202
Shell Creek near Punta Gorda

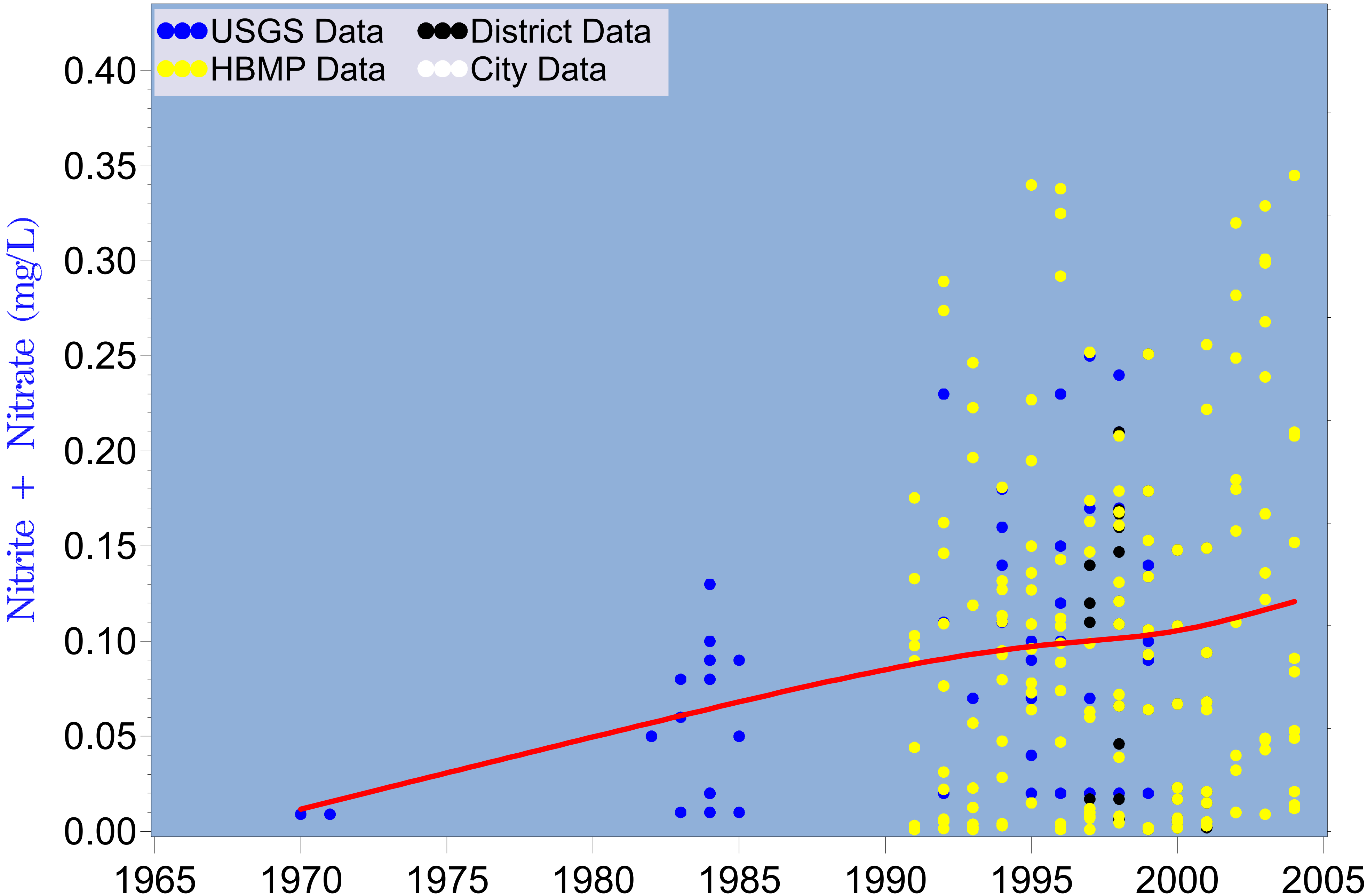


Figure 6.60 Nitrite + nitrate at USGS site 2298202
Shell Creek near Punta Gorda

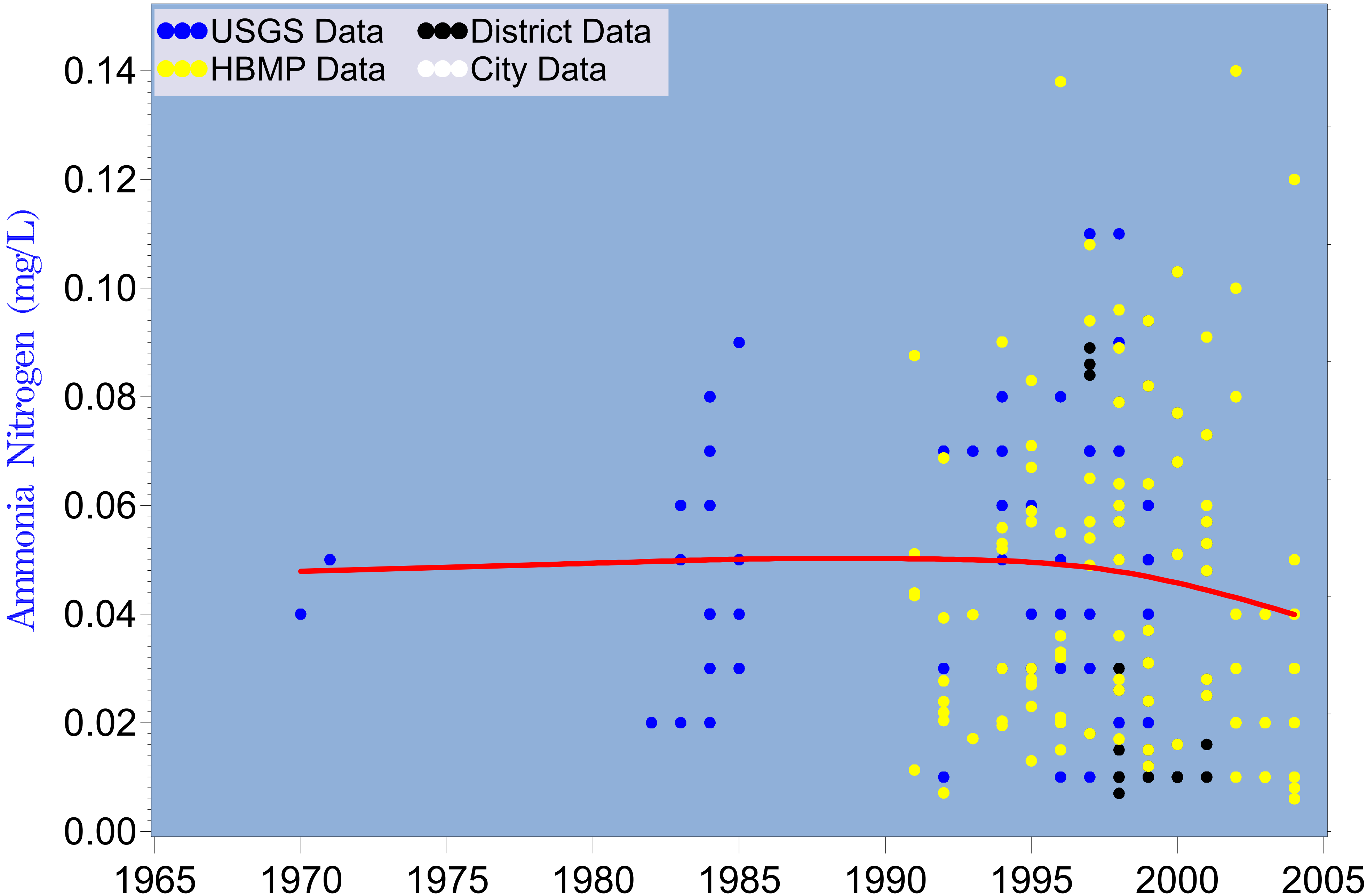


Figure 6.61 Ammonia nitrogen at USGS site 2298202
Shell Creek near Punta Gorda

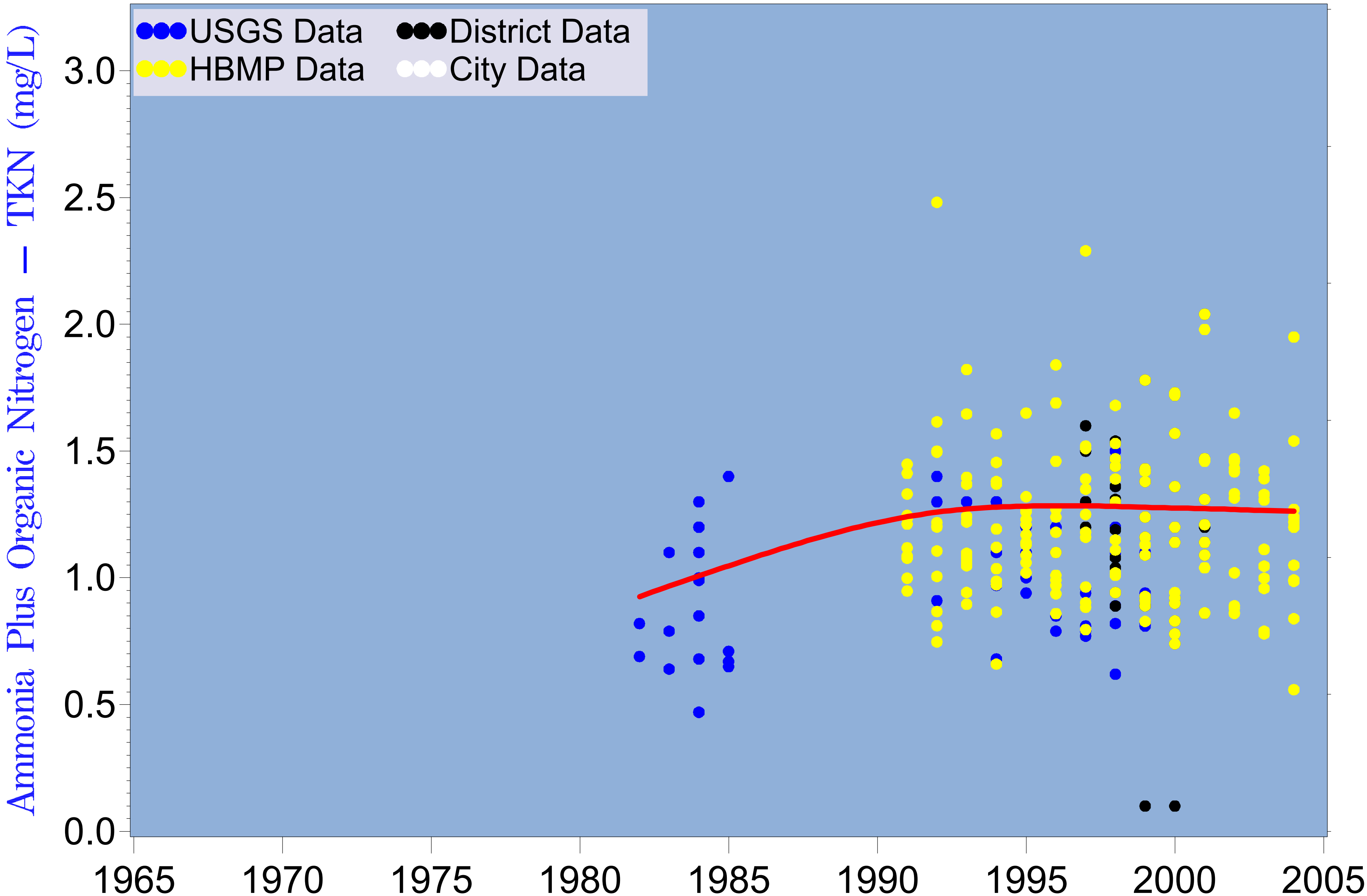


Figure 6.62 Total Kjeldahl nitrogen at USGS site 2298202
Shell Creek near Punta Gorda

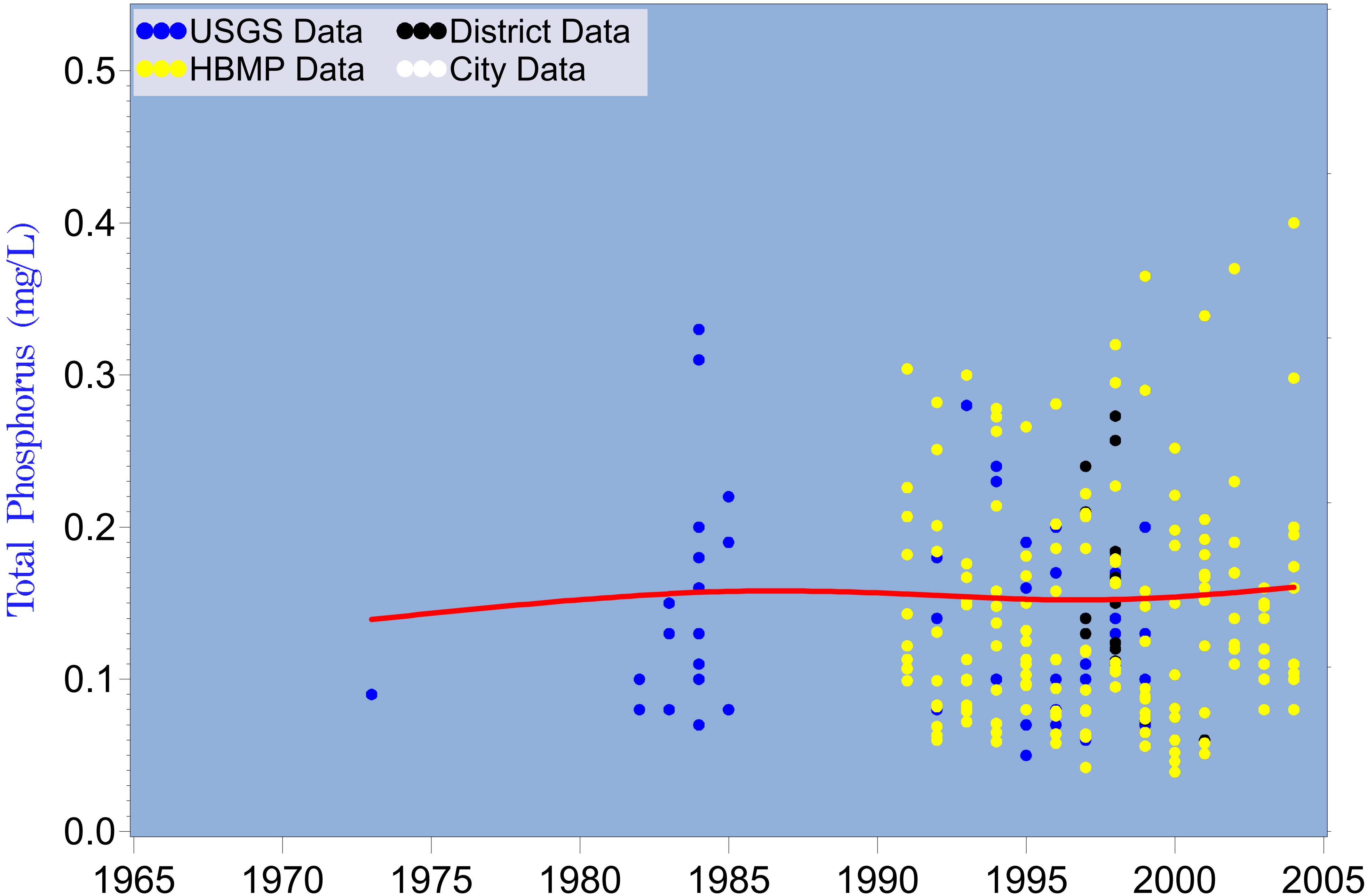


Figure 6.63 Total phosphorus at USGS site 2298202
Shell Creek near Punta Gorda

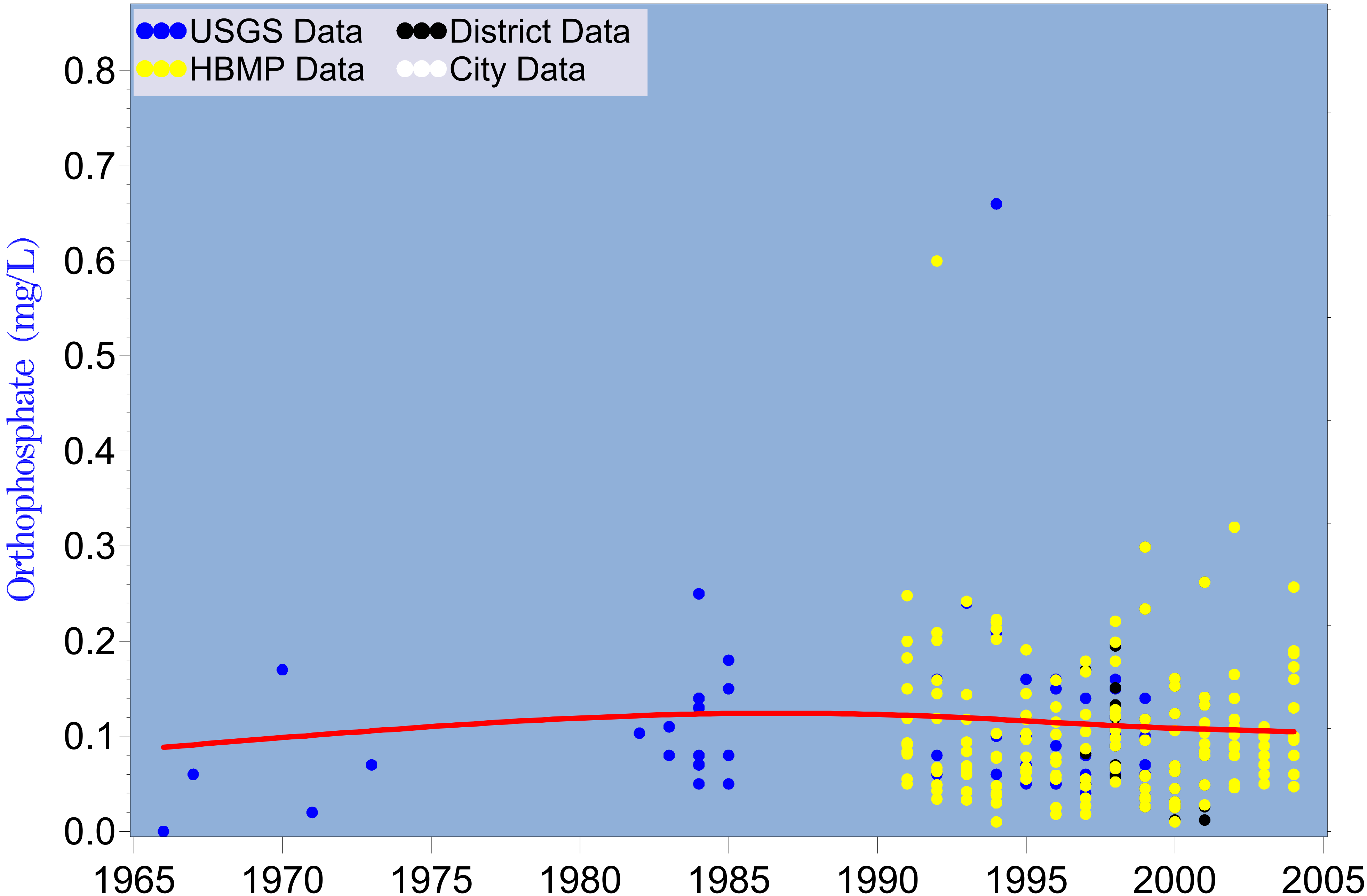


Figure 6.64 Orthophosphate at USGS site 2298202
Shell Creek near Punta Gorda

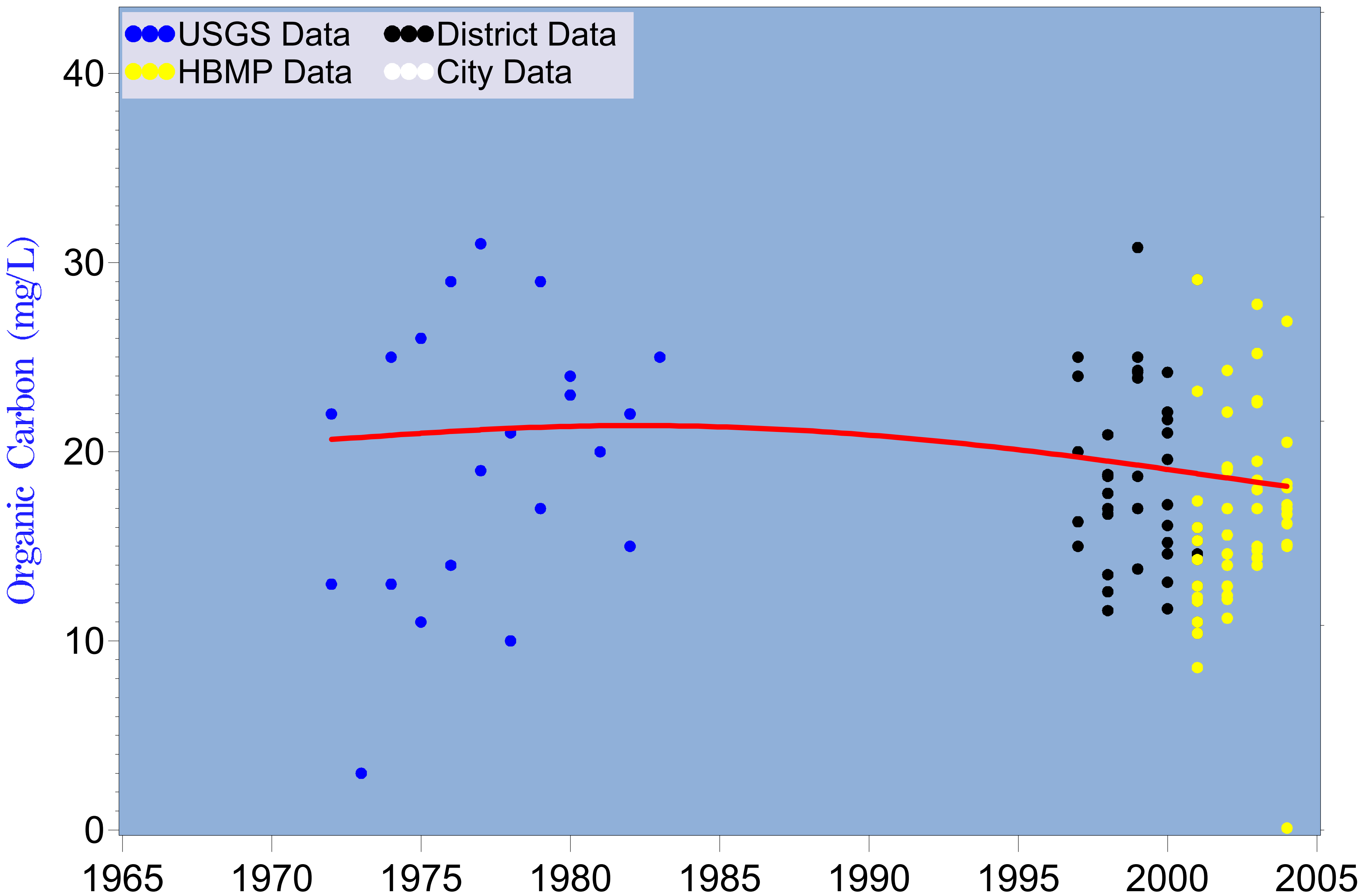


Figure 6.65 Organic carbon at USGS site 2298202
Shell Creek near Punta Gorda

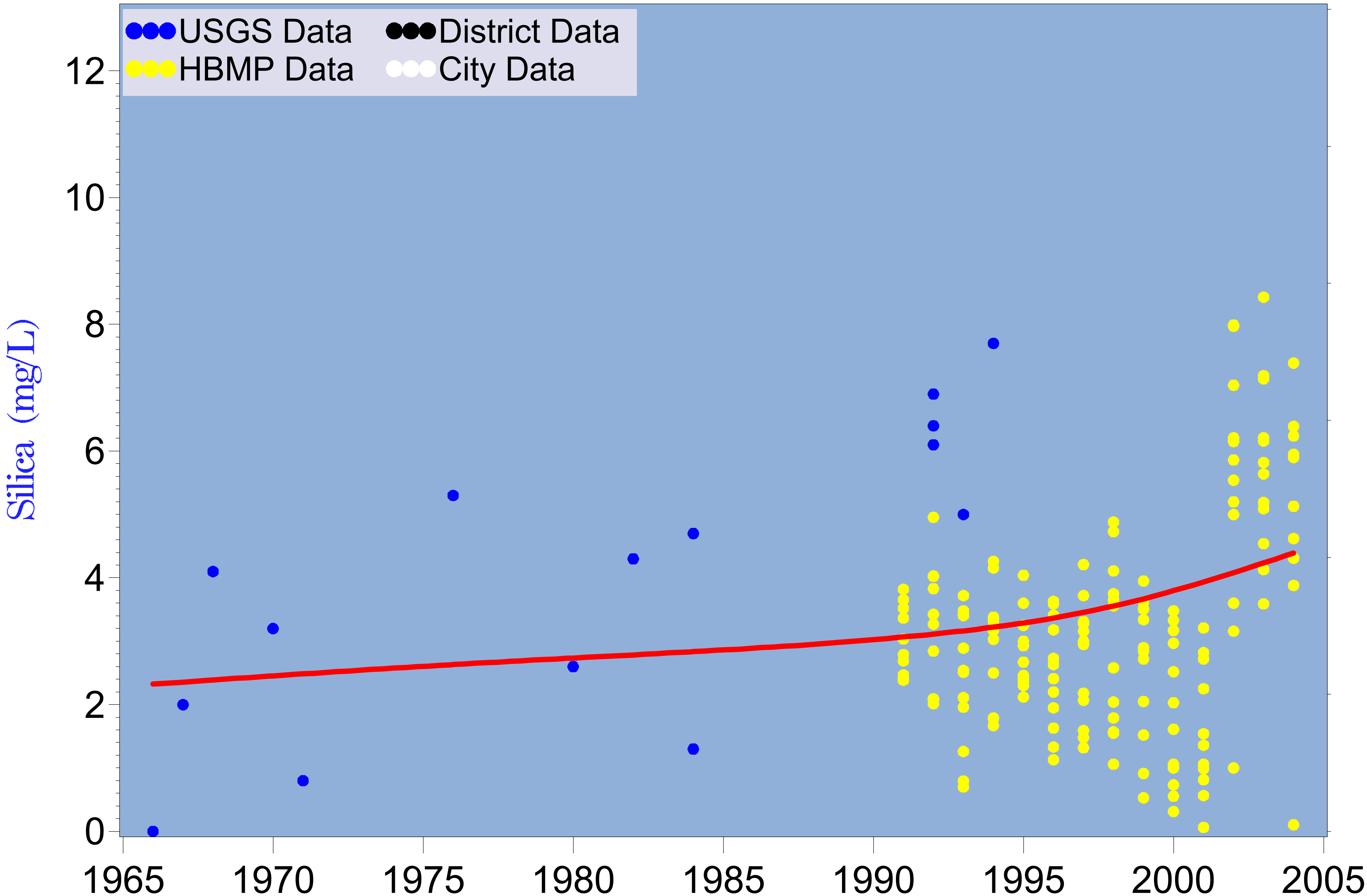


Figure 6.66 Silica at USGS site 2298202
Shell Creek near Punta Gorda

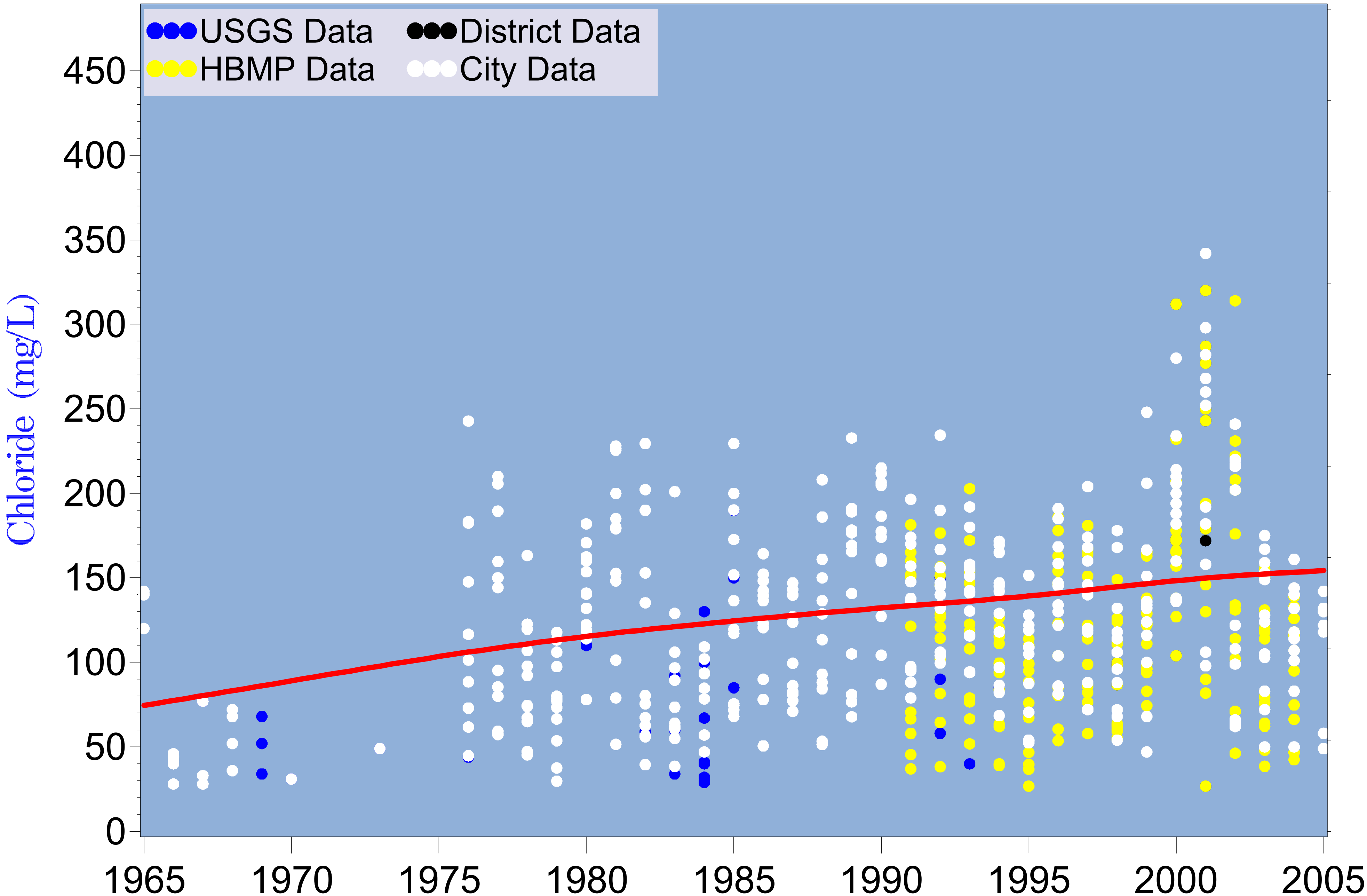


Figure 6.67 Chloride USGS site 2298202
Shell Creek near Punta Gorda

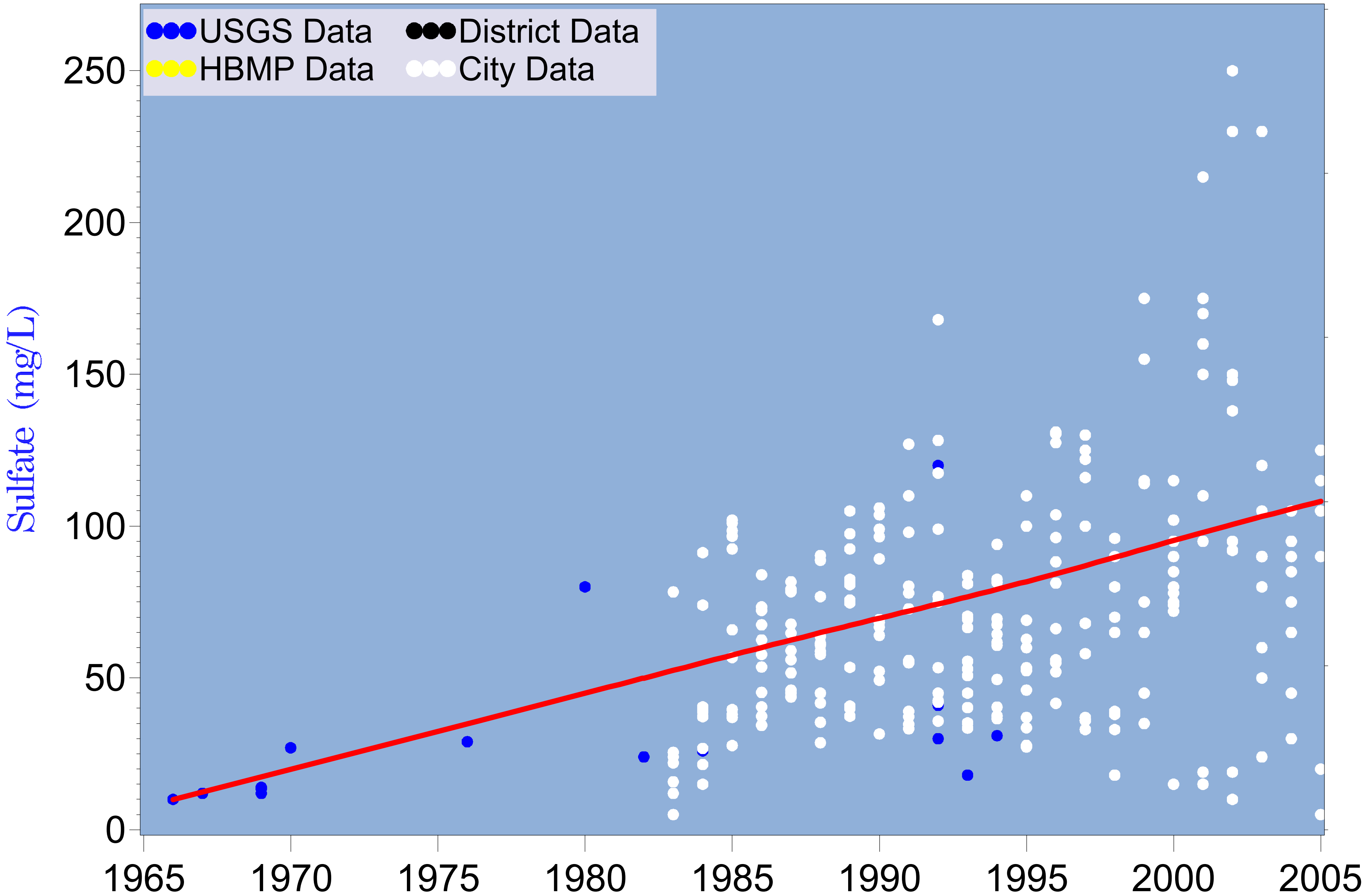


Figure 6.68 Sulfate USGS site 2298202
Shell Creek near Punta Gorda

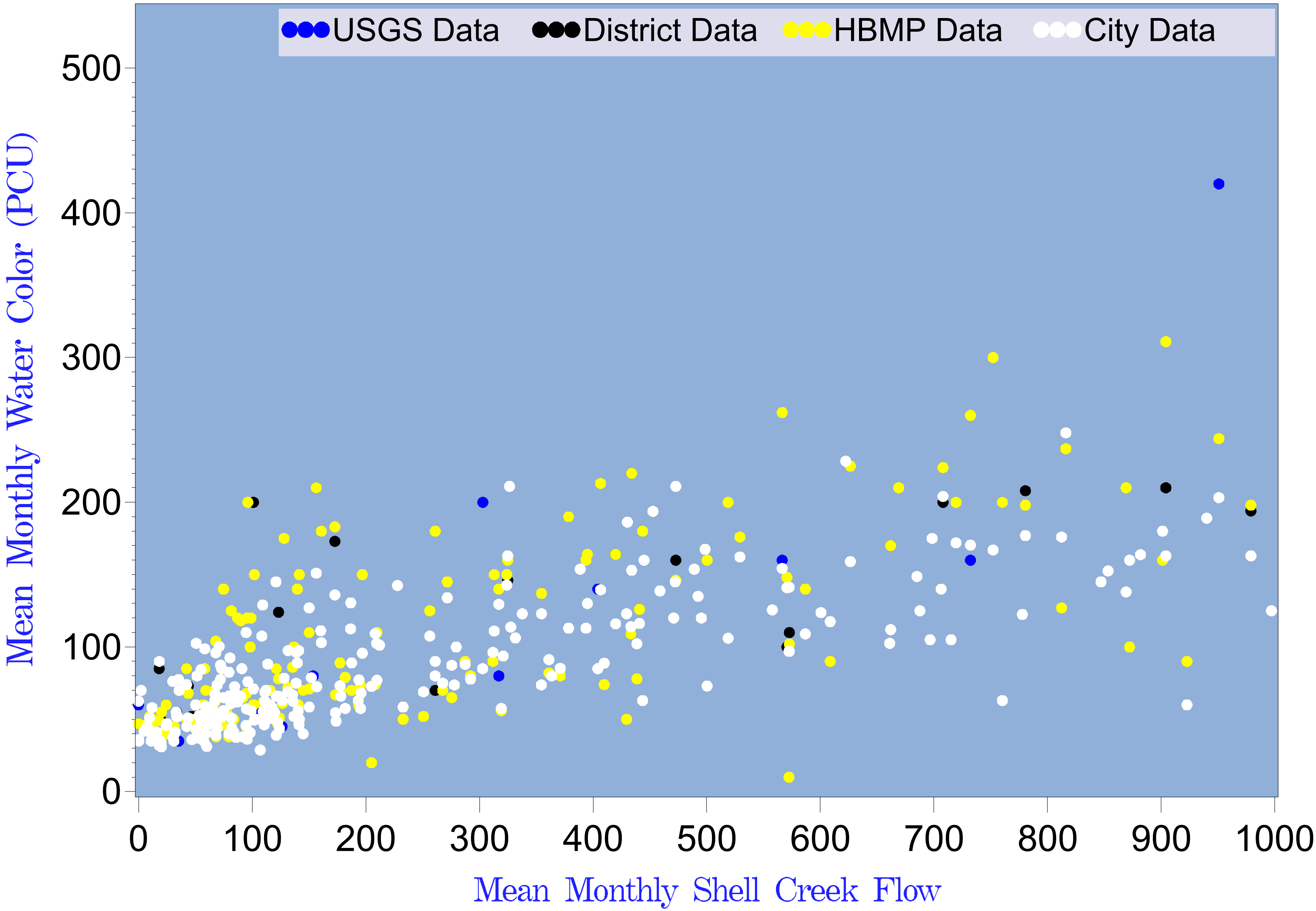


Figure 6.69 Water color versus Shell Creek flow at USGS site 2298202

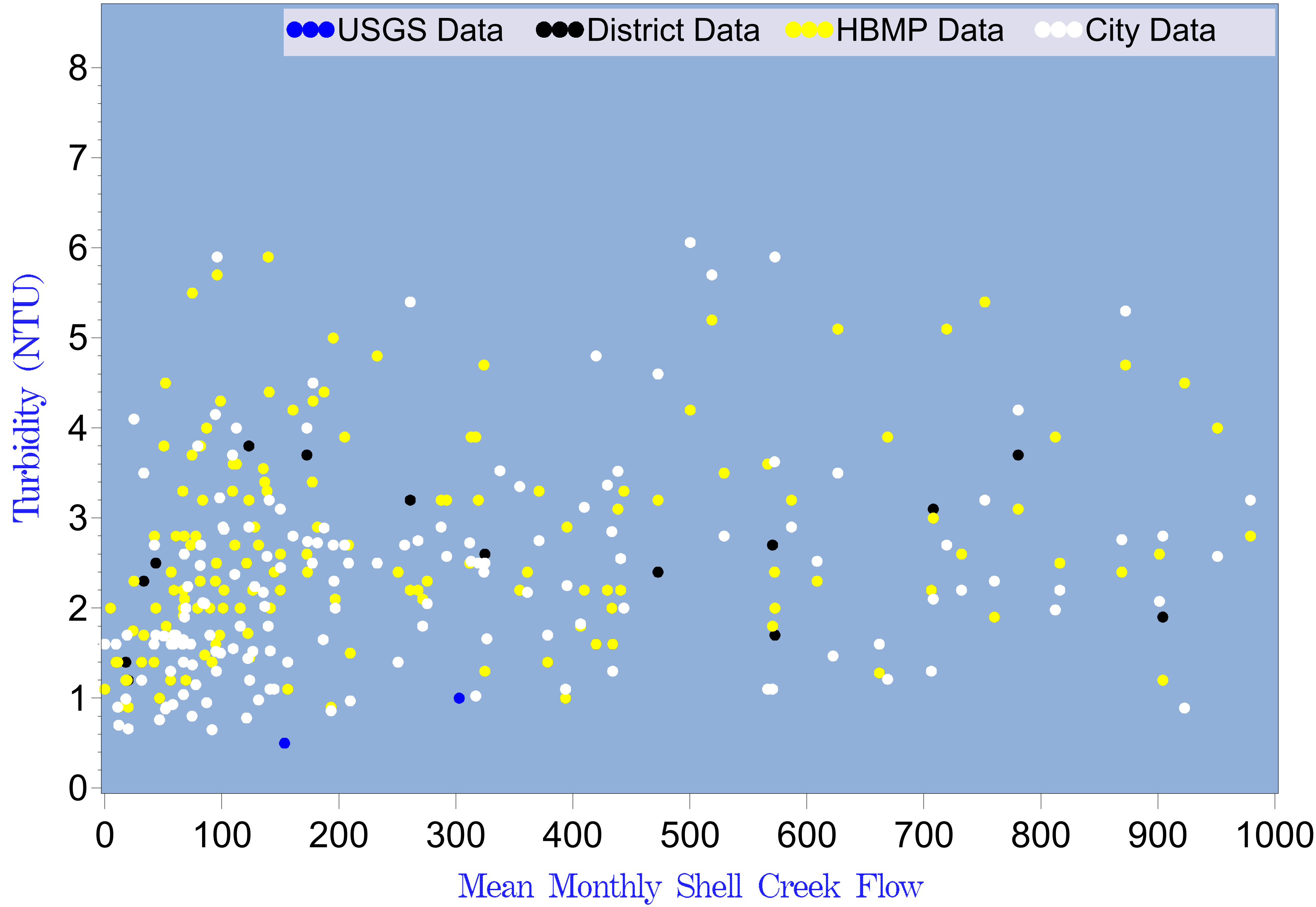


Figure 6.70 Turbidity versus Shell Creek flow at USGS site 2298202

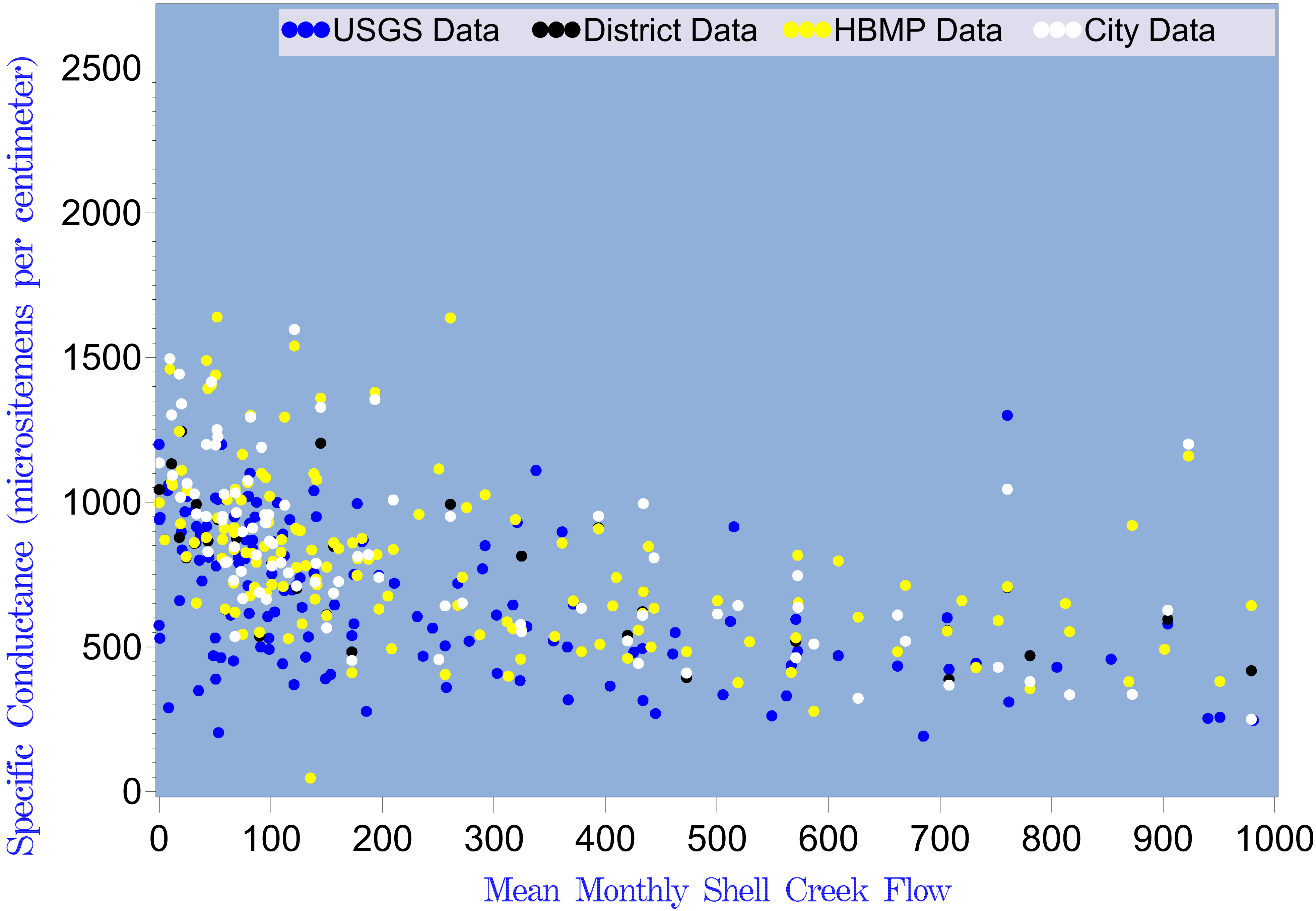


Figure 6.71 Specific conductance versus Shell Creek flow USGS site 2298202

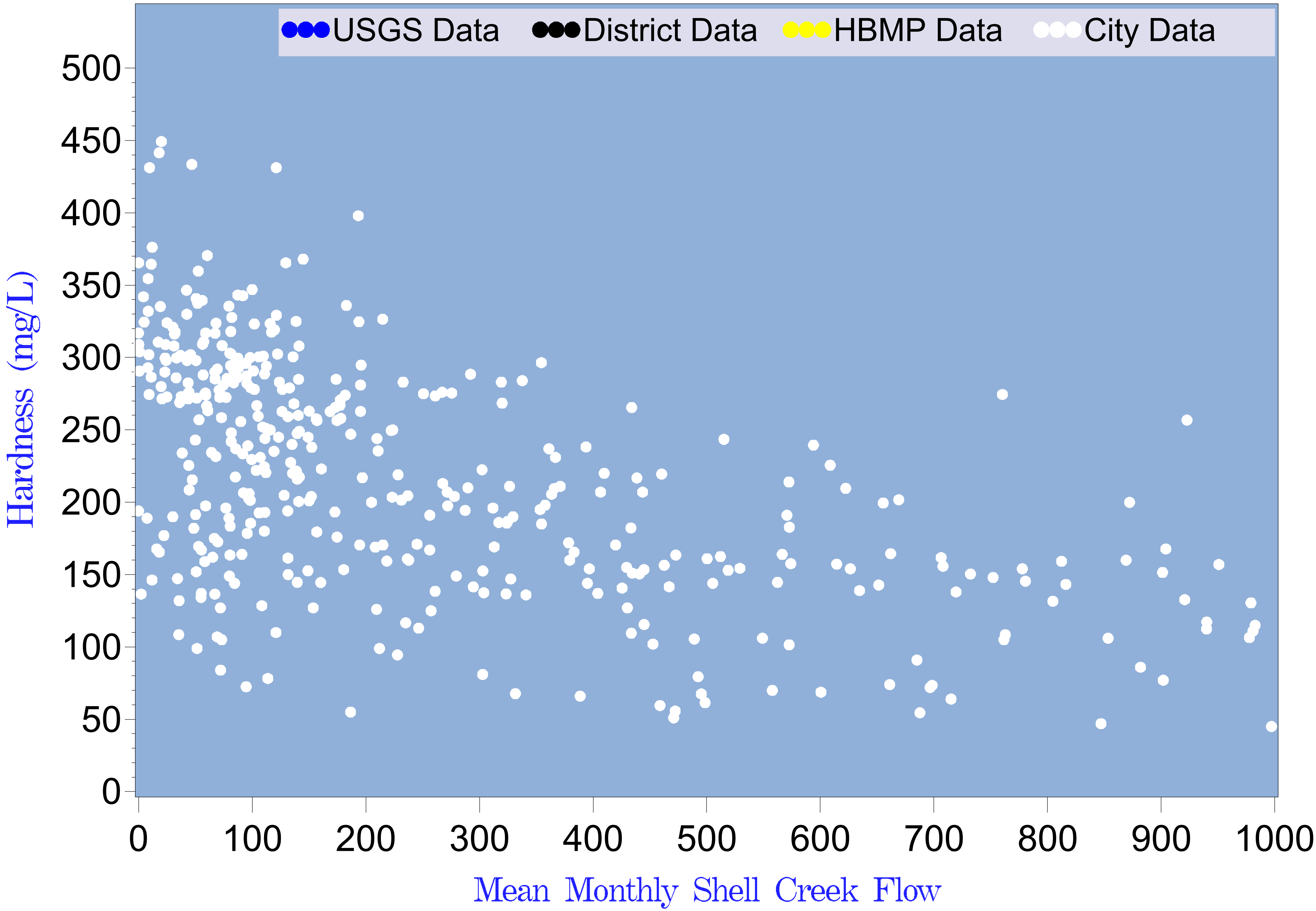


Figure 6.72 Hardness versus Shell Creek flow USGS site 2298202

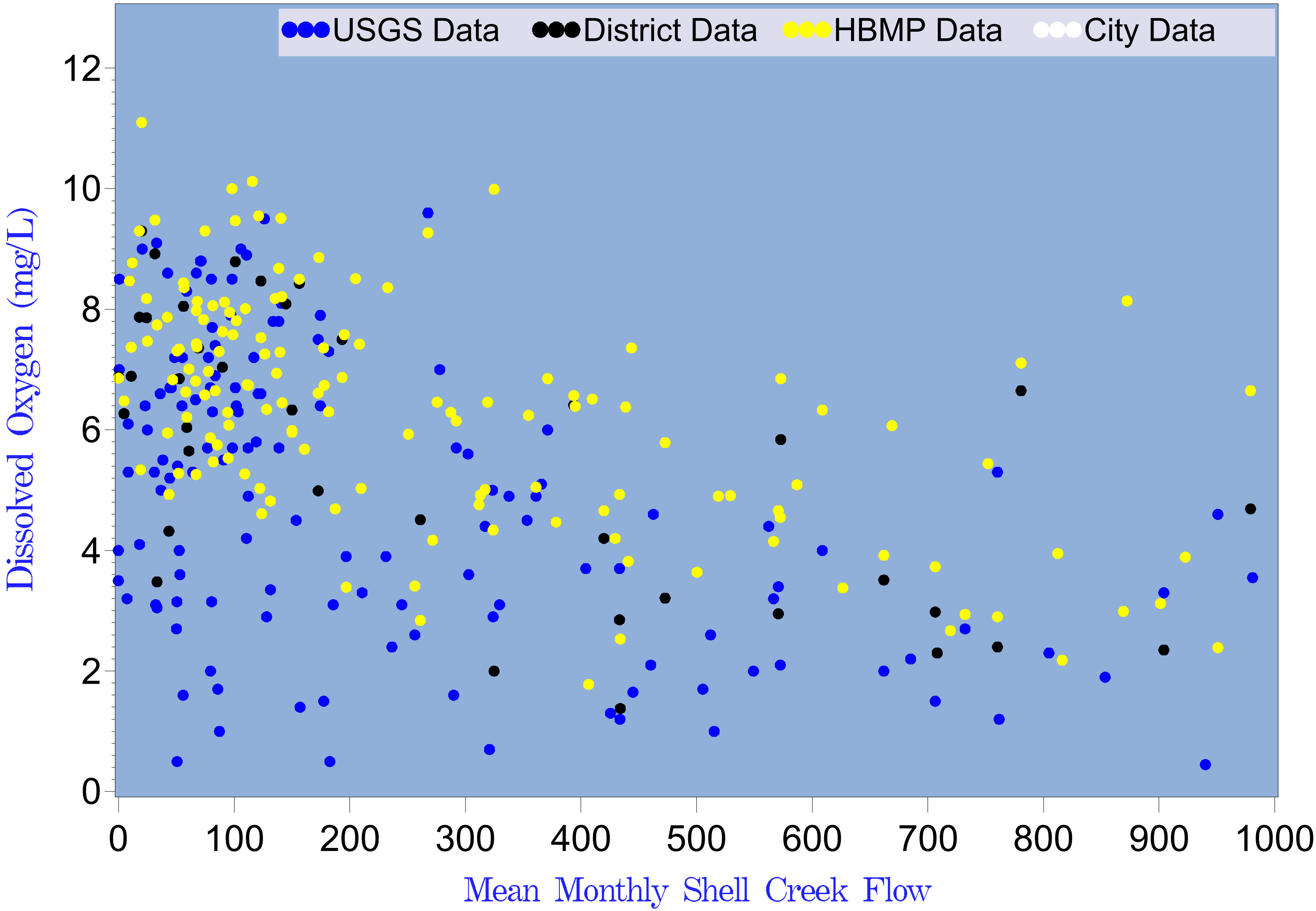


Figure 6.73 Dissolved oxygen versus Shell Creek flow at USGS site 2298202

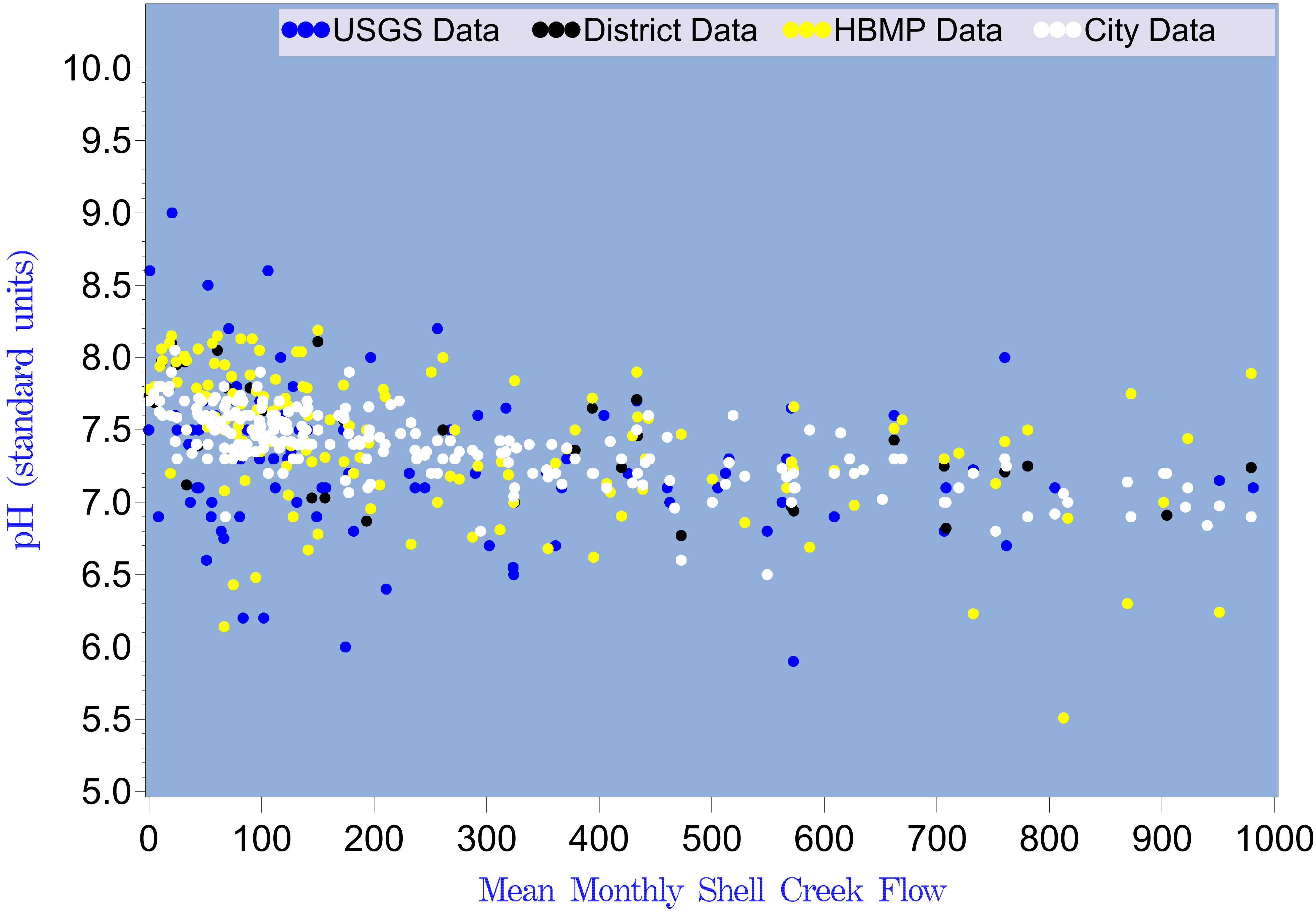


Figure 6.74 pH versus Shell Creek flowat USGS site 2298202

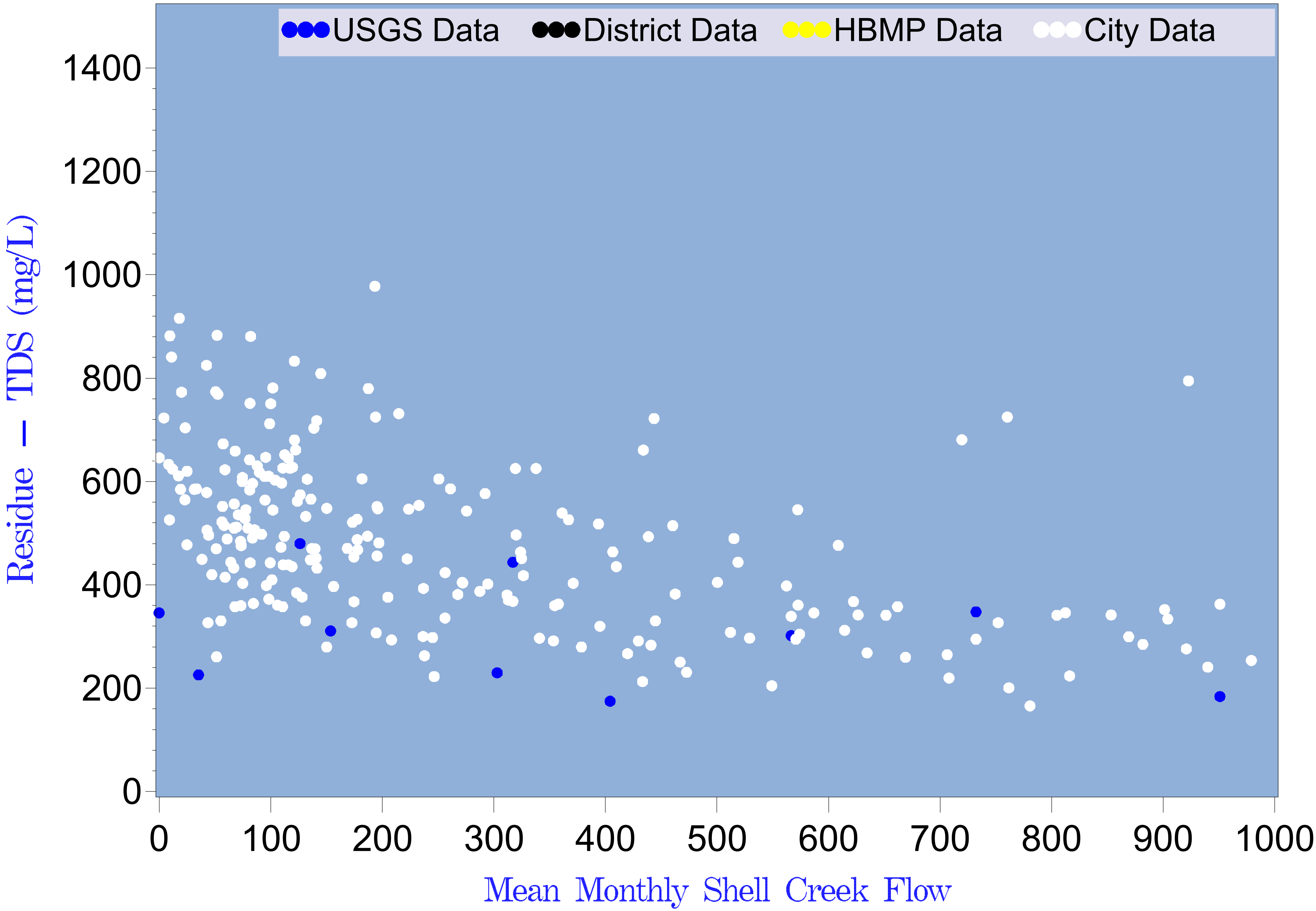


Figure 6.75 TDS versus Shell Creek flowat USGS site 2298202

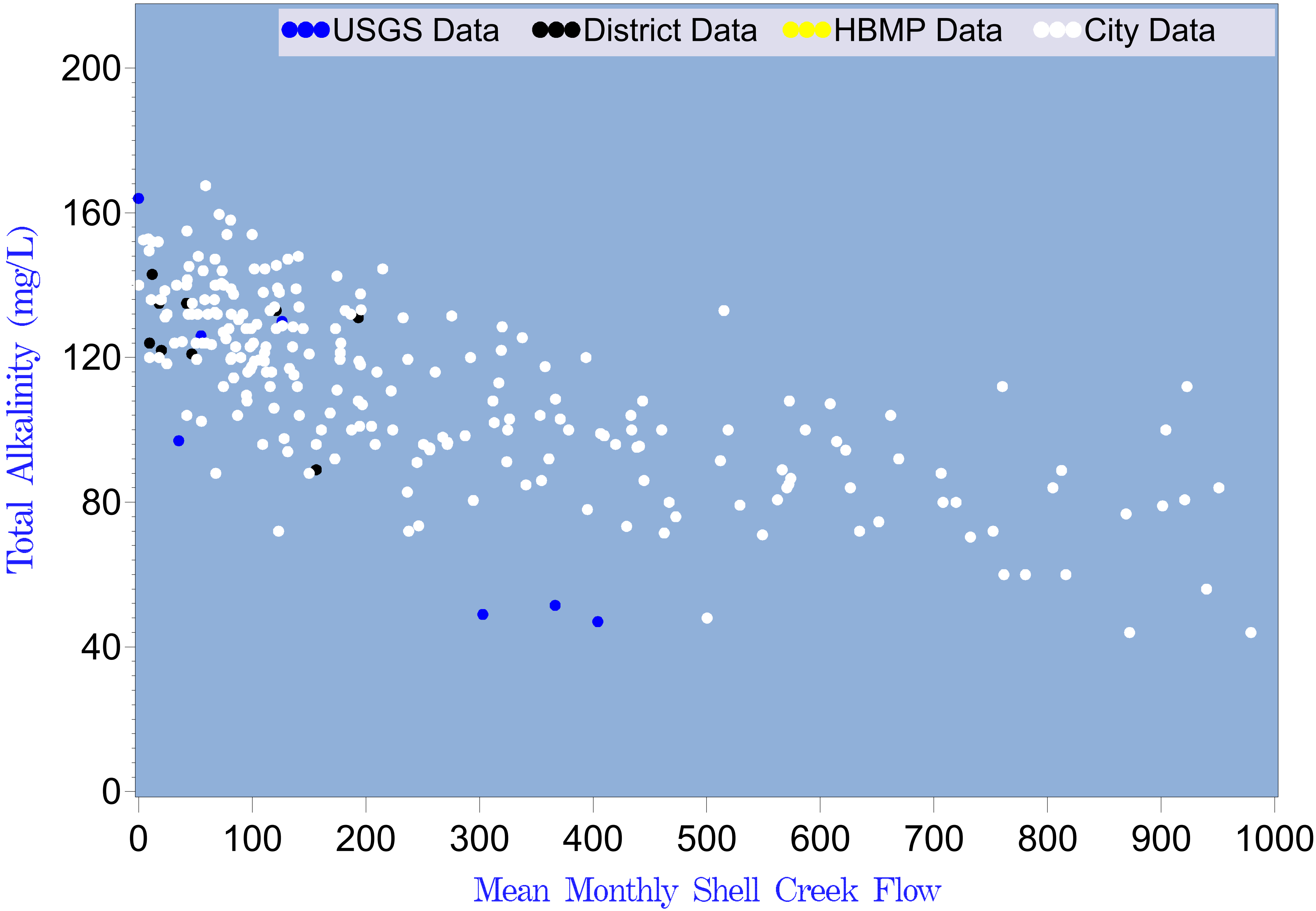


Figure 6.76 Alkalinity versus Shell Creek flow at USGS site 2298202

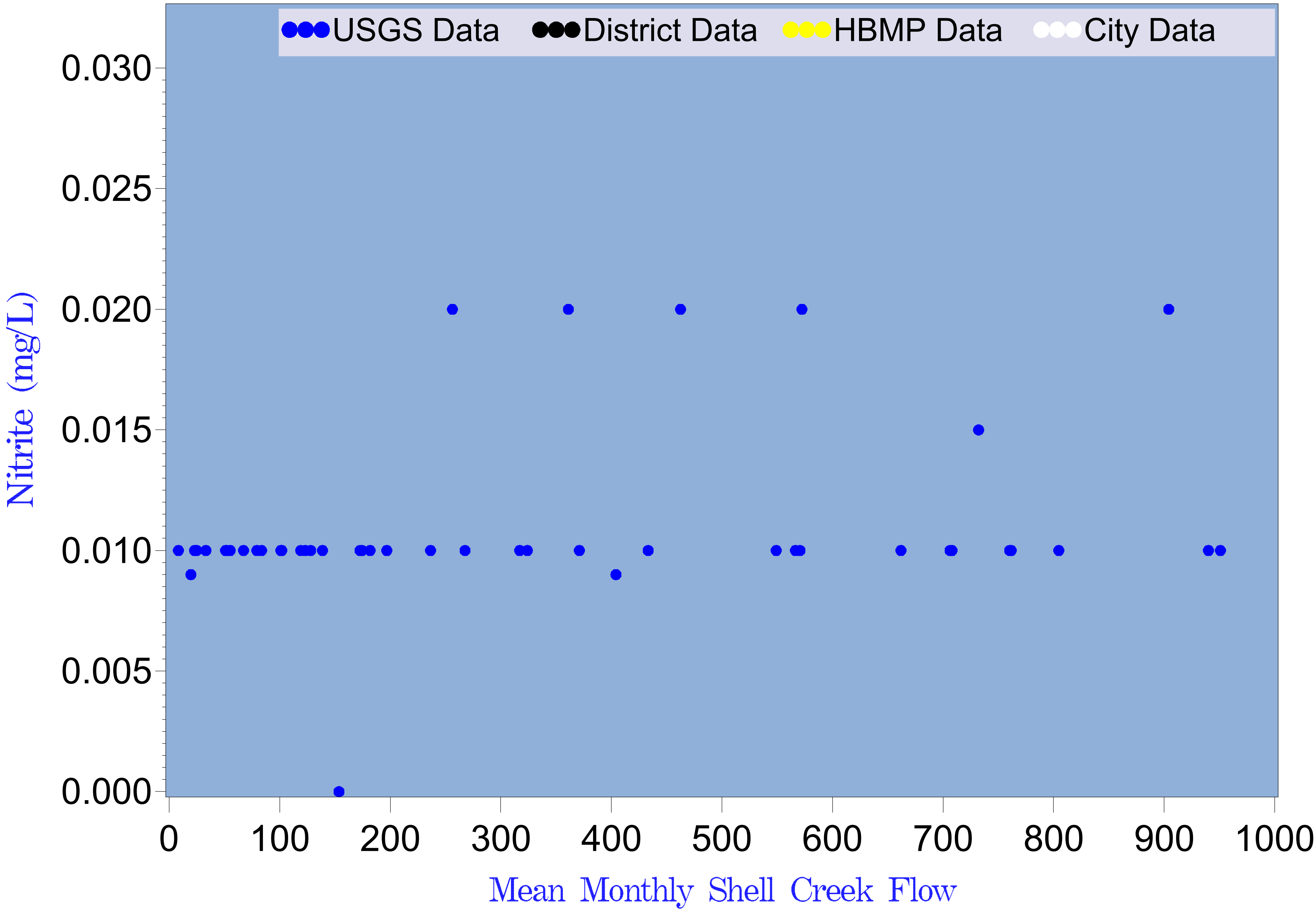


Figure 6.77 Nitrite versus Shell Creek flow at USGS site 2298202

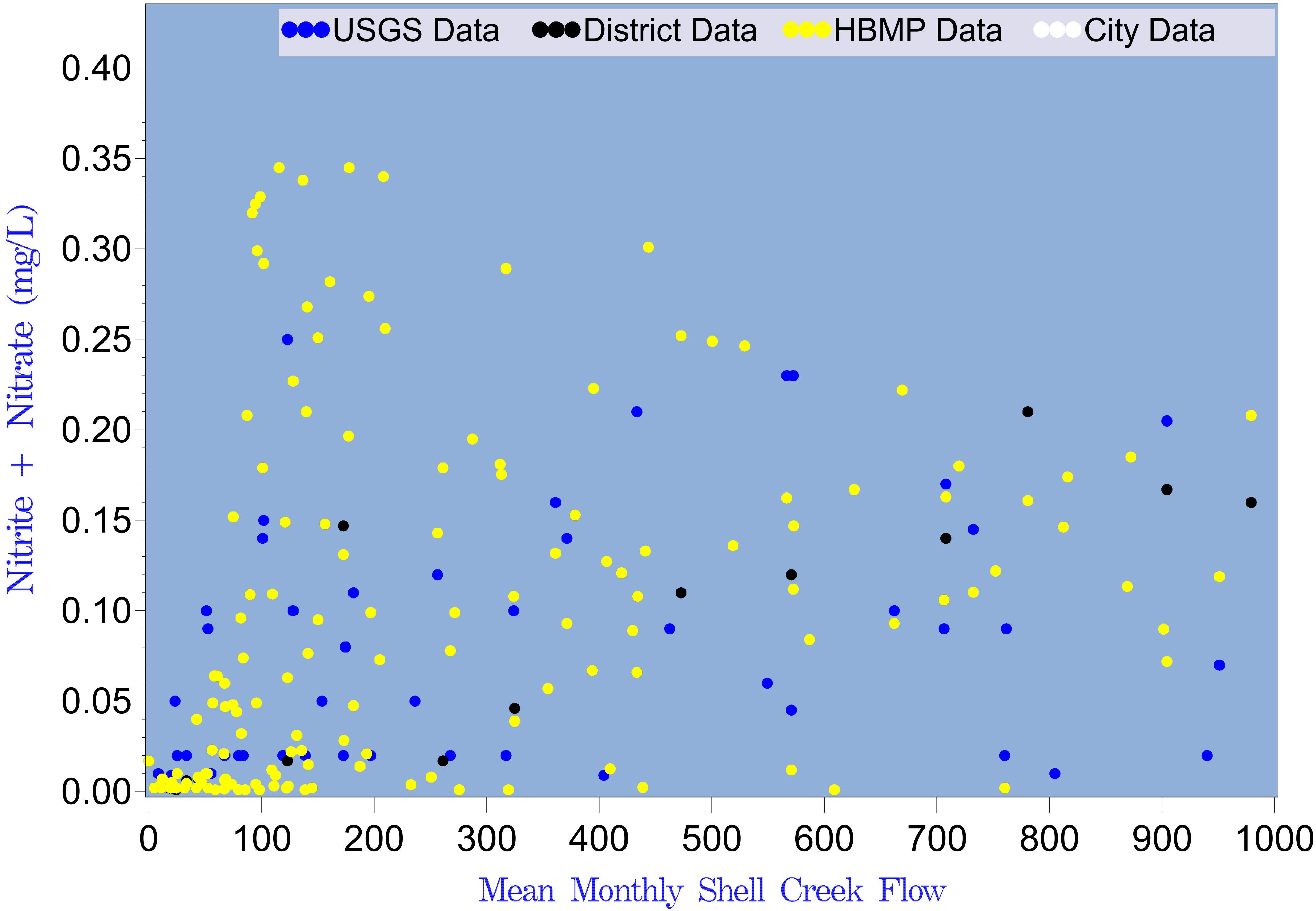


Figure 6.78 Nitrite + nitrate versus Shell Creek flow at USGS site 2298202

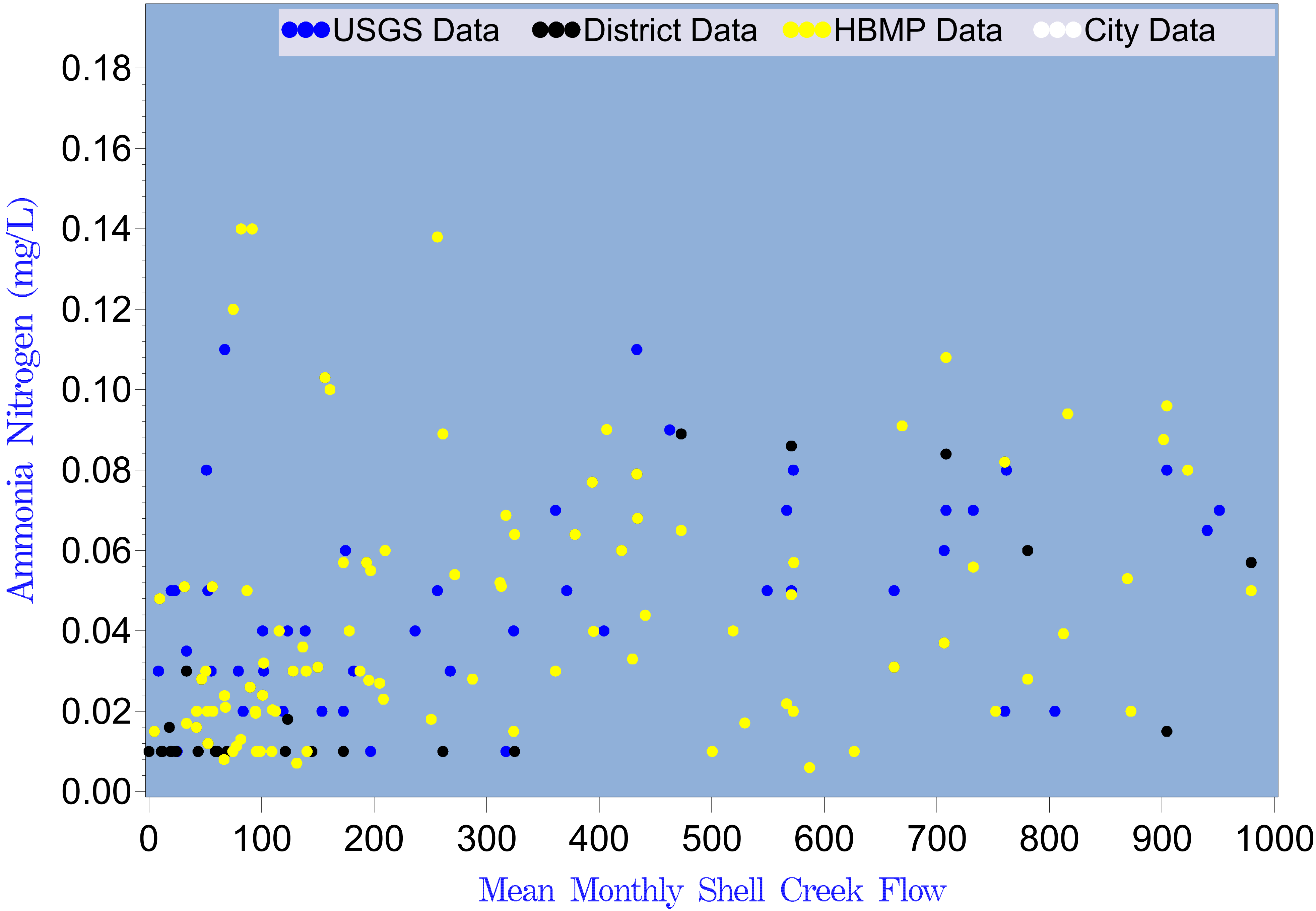


Figure 6.79 Ammonia nitrogen versus Shell Creek flow at USGS site 2298202

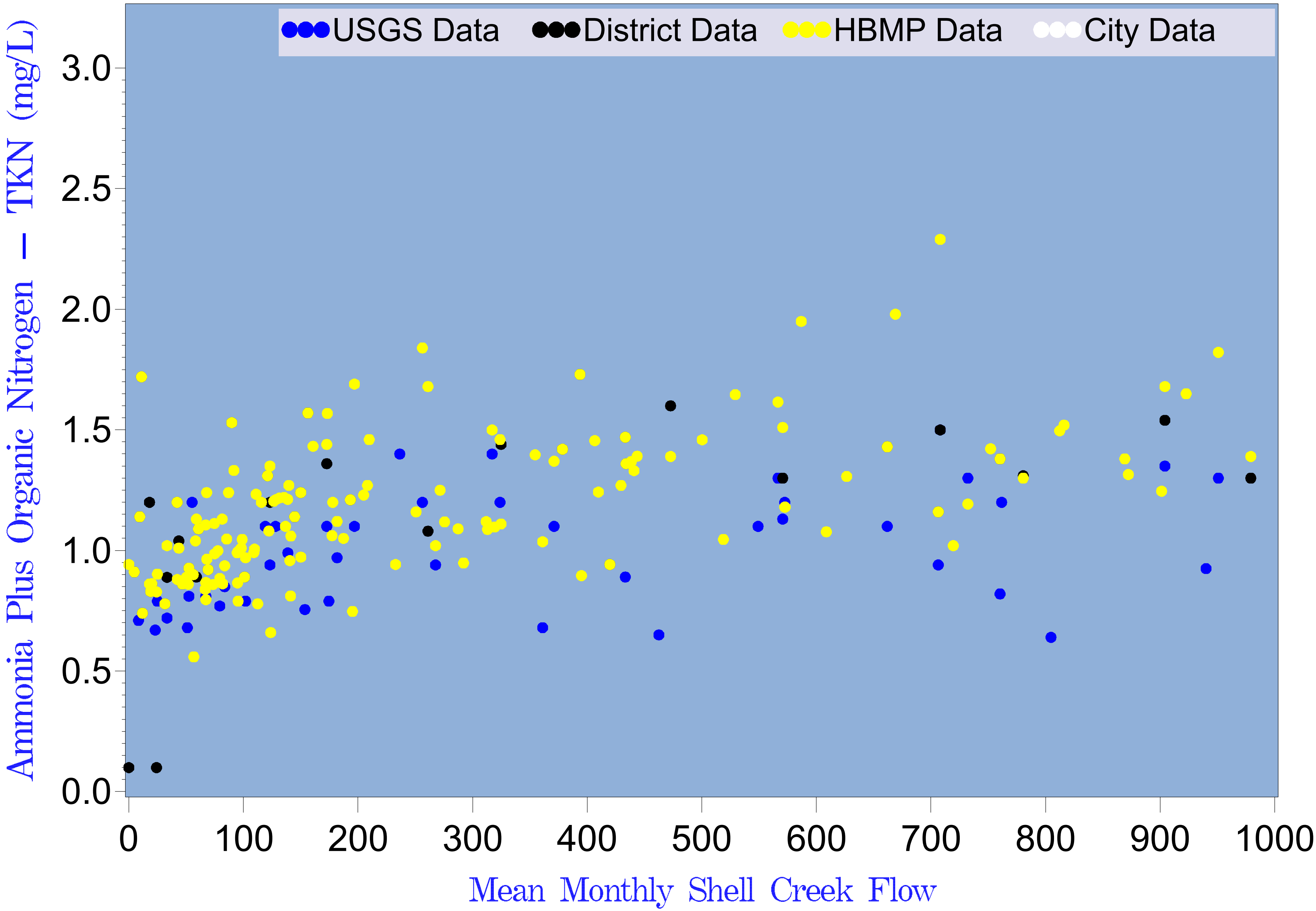


Figure 6.80 TKN (ammonia plus organic nitrogen) vs. Shell Creek flow at USGS site 2298202

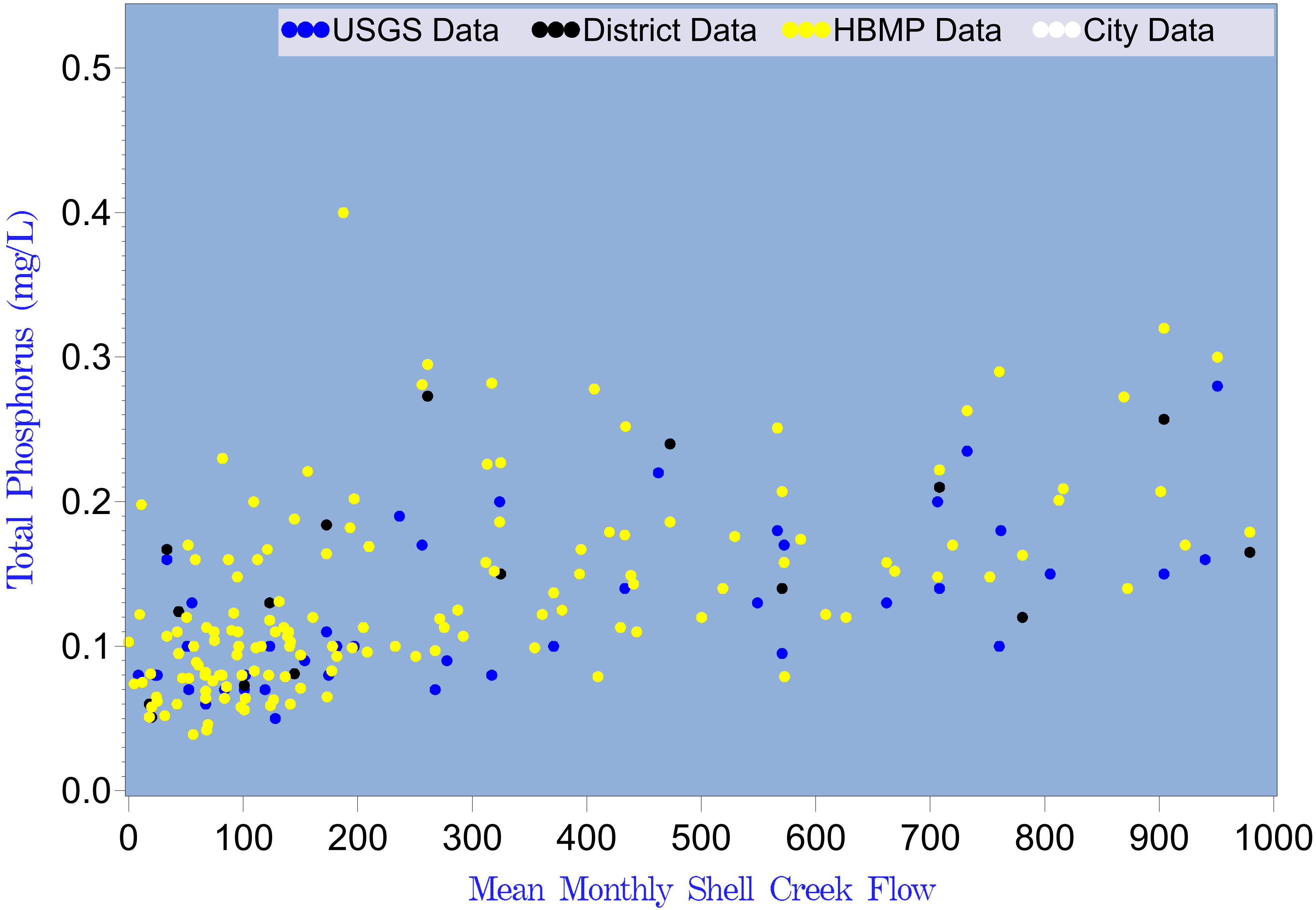


Figure 6.81 Total phosphorus versus Shell Creek flow at USGS site 2298202

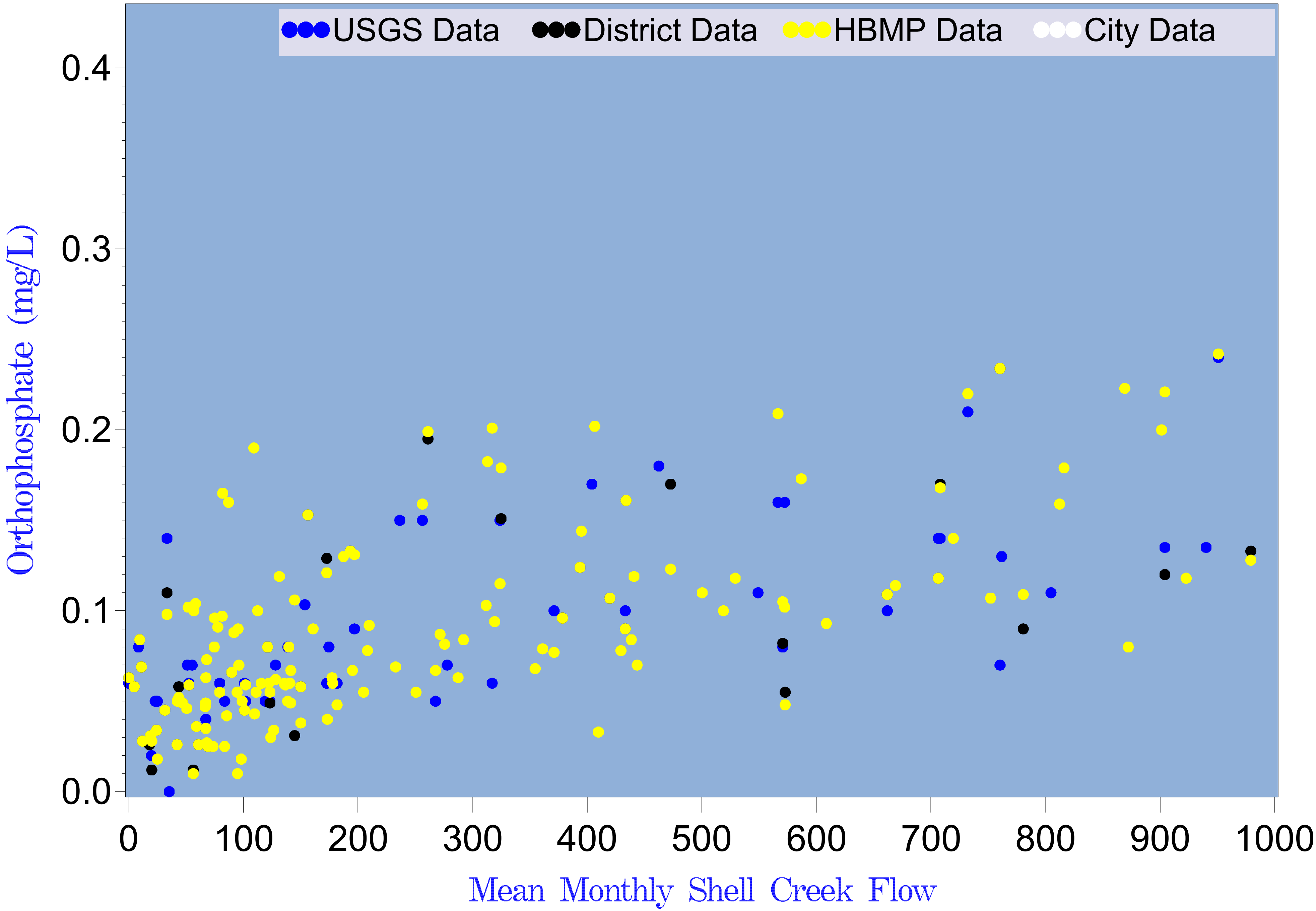


Figure 6.82 Orthophosphate versus Shell Creek flow at USGS site 2298202

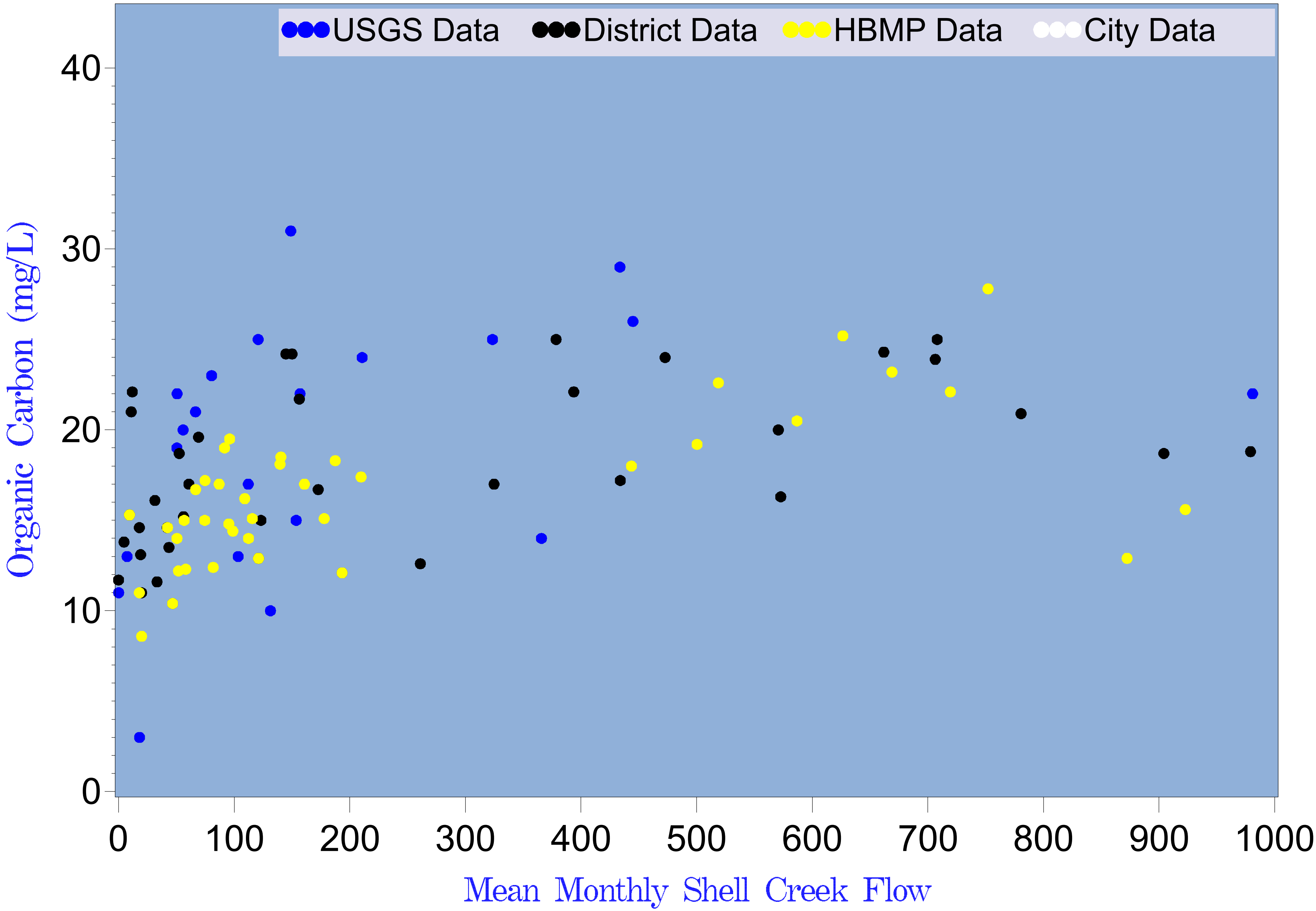


Figure 6.83 Organic carbon versus Shell Creek flow at USGS site 2298202

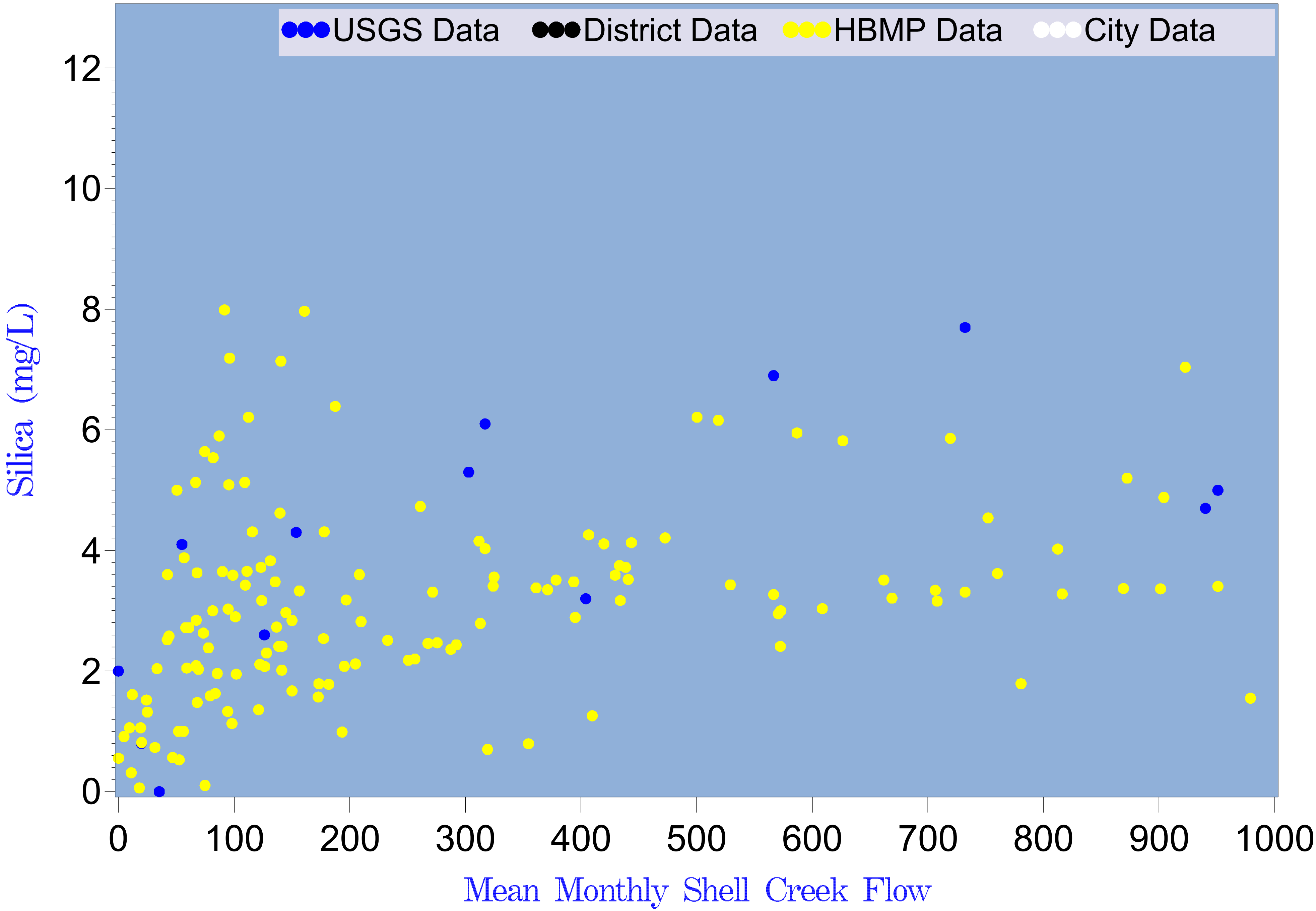


Figure 6.84 Silica versus Shell Creek flow at USGS site 2298202

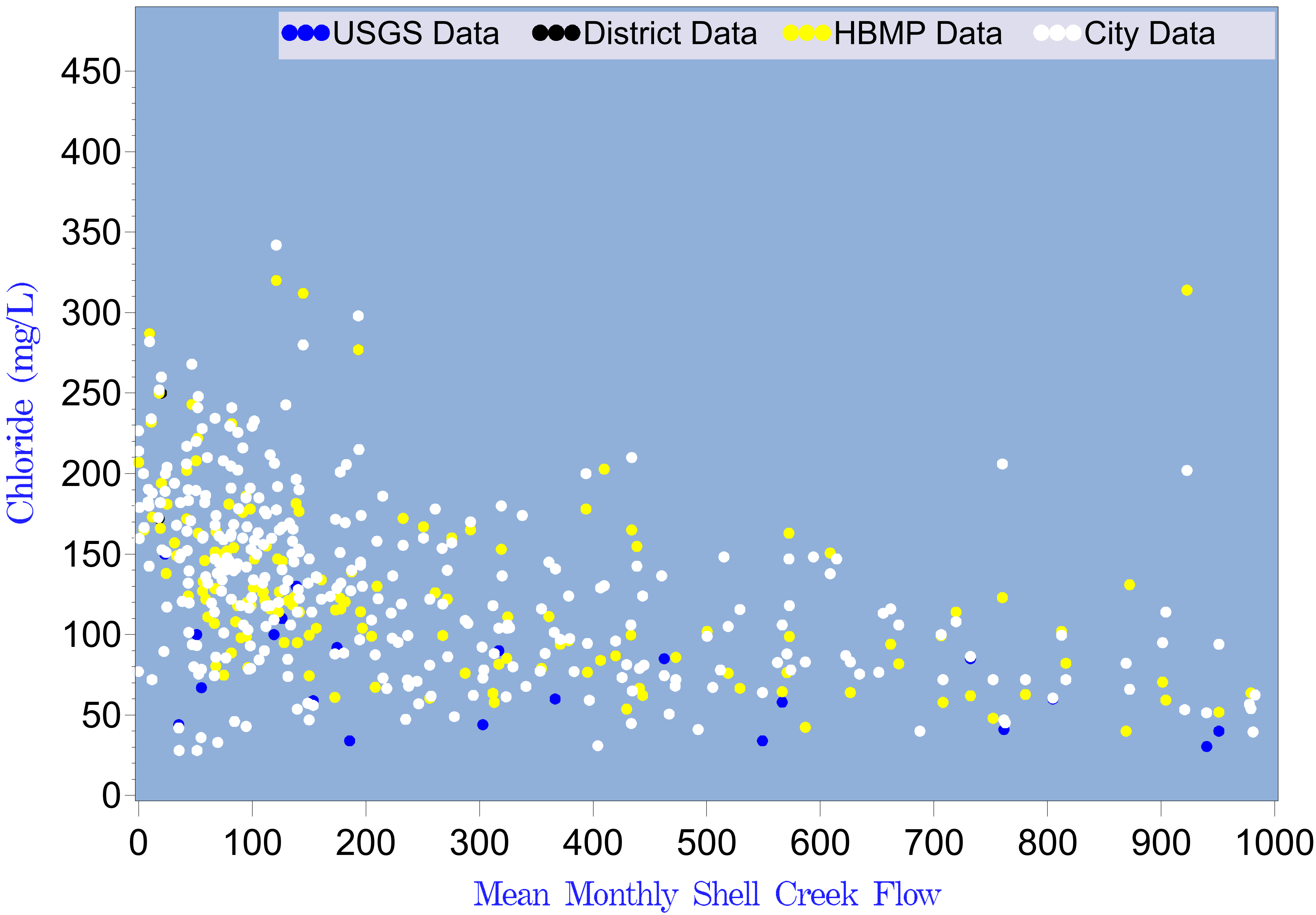


Figure 6.85 Chloride versus Shell Creek flow USGS site 2298202

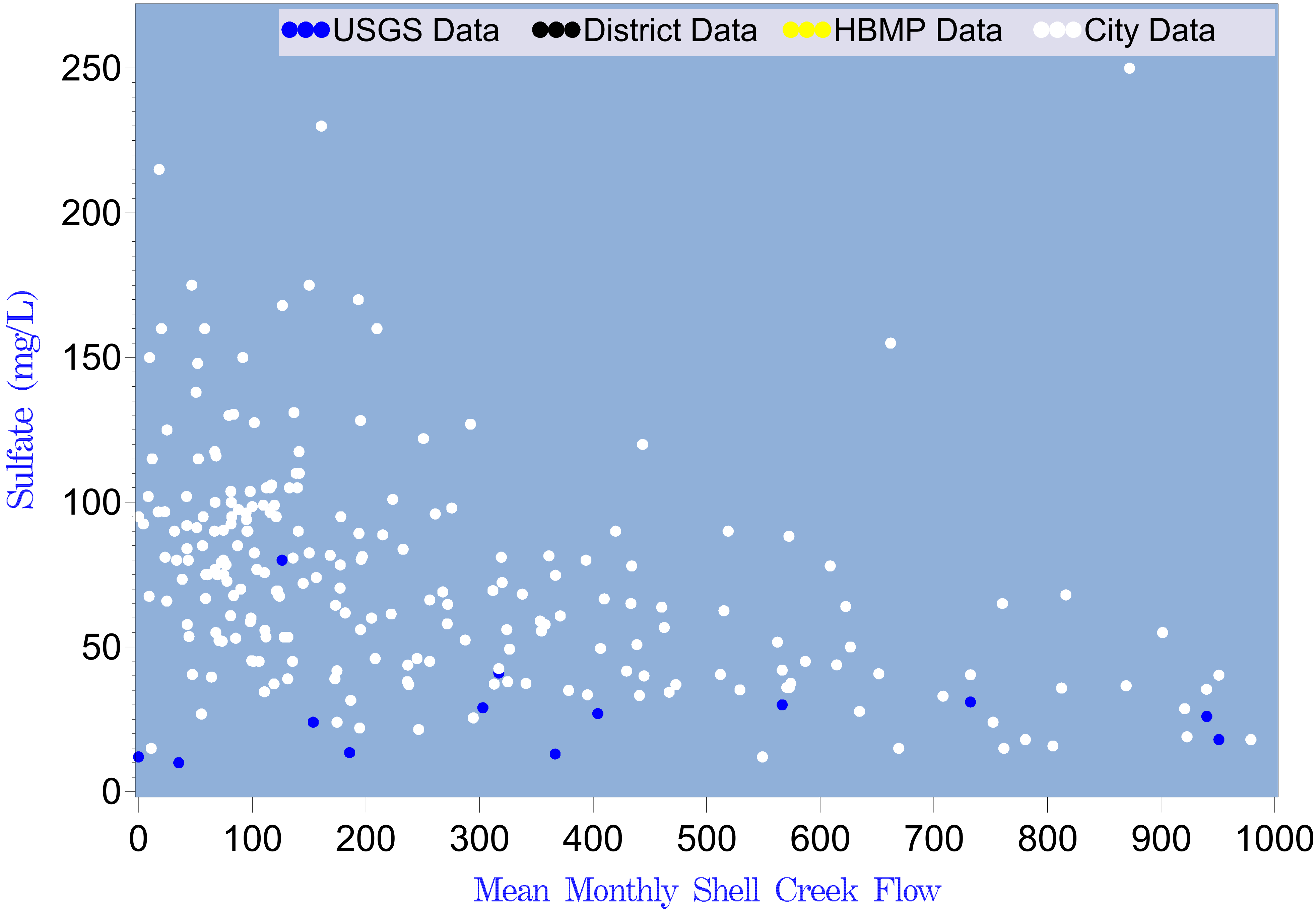
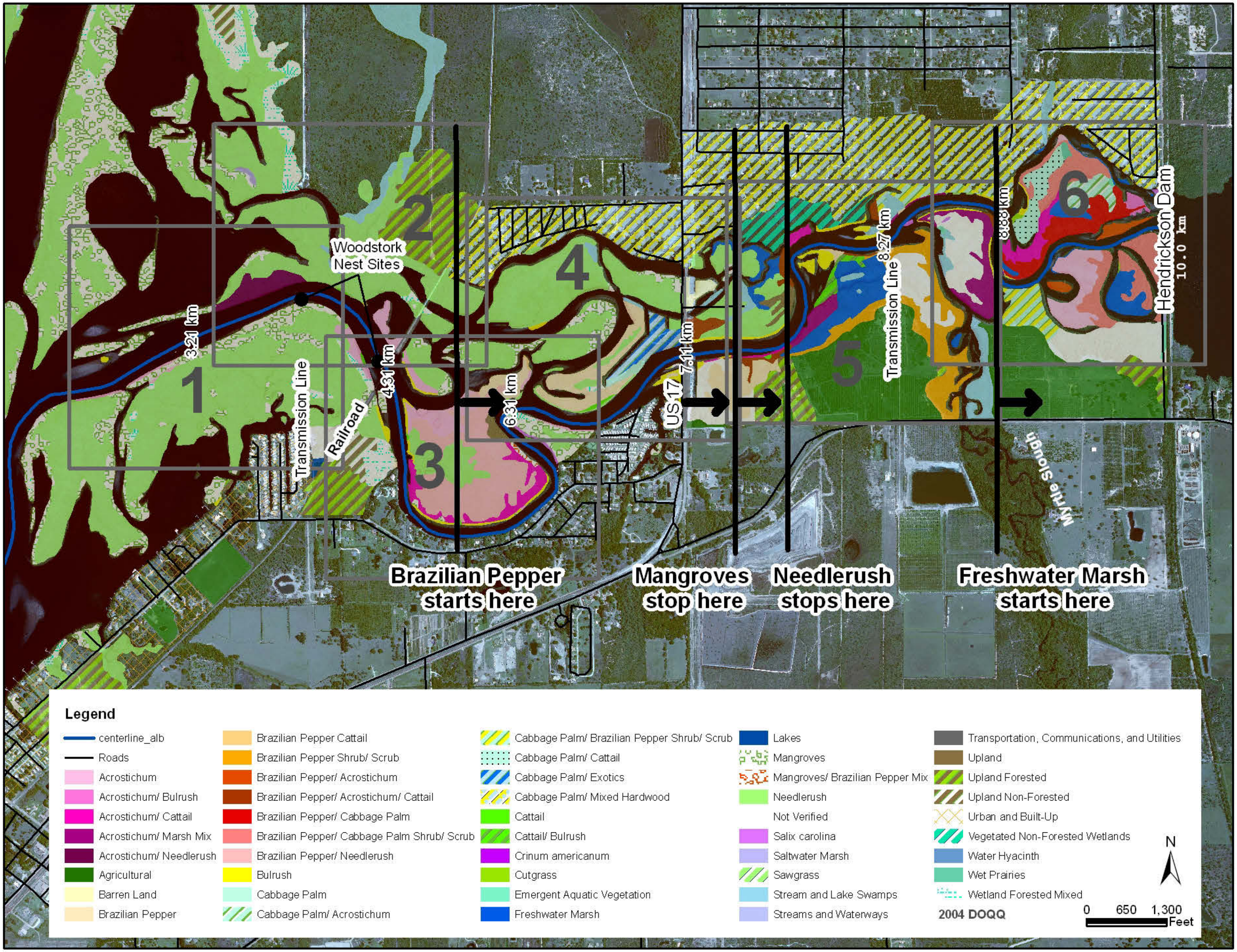


Figure 6.86 Sulfate versus Shell Creek flow USGS site 2298202

Appendix H

Tidal Shell Creek Vegetation Maps

Figure 7.1



Woodstork Nest Sites
3.21 km
4.31 km
6.31 km
7.11 km
8.27 km
8.88 km
10.0 km
Transmission Line
Railroad
US 17
Hendrickson Dam
Myrtle Slough
1
2
3
4
5
6
Brazilian Pepper starts here
Mangroves stop here
Needlerush stops here
Freshwater Marsh starts here
Legend
centerline_alb
Roads
Acrostichum
Acrostichum/ Bulrush
Acrostichum/ Cattail
Acrostichum/ Marsh Mix
Acrostichum/ Needlerush
Agricultural
Barren Land
Brazilian Pepper
Brazilian Pepper Cattail
Brazilian Pepper Shrub/ Scrub
Brazilian Pepper/ Acrostichum
Brazilian Pepper/ Acrostichum/ Cattail
Brazilian Pepper/ Cabbage Palm
Brazilian Pepper/ Cabbage Palm Shrub/ Scrub
Brazilian Pepper/ Needlerush
Bulrush
Cabbage Palm
Cabbage Palm/ Acrostichum
Cabbage Palm/ Brazilian Pepper Shrub/ Scrub
Cabbage Palm/ Cattail
Cabbage Palm/ Exotics
Cabbage Palm/ Mixed Hardwood
Cattail
Cattail/ Bulrush
Crinum americanum
Cutgrass
Emergent Aquatic Vegetation
Freshwater Marsh
Lakes
Mangroves
Mangroves/ Brazilian Pepper Mix
Needlerush
Not Verified
Salix carolina
Saltwater Marsh
Sawgrass
Stream and Lake Swamps
Streams and Waterways
Transportation, Communications, and Utilities
Upland
Upland Forested
Upland Non-Forested
Urban and Built-Up
Vegetated Non-Forested Wetlands
Water Hyacinth
Wet Prairies
Wetland Forested Mixed
2004 DOQQ
N
0 650 1,300 Feet

Figure 7.2

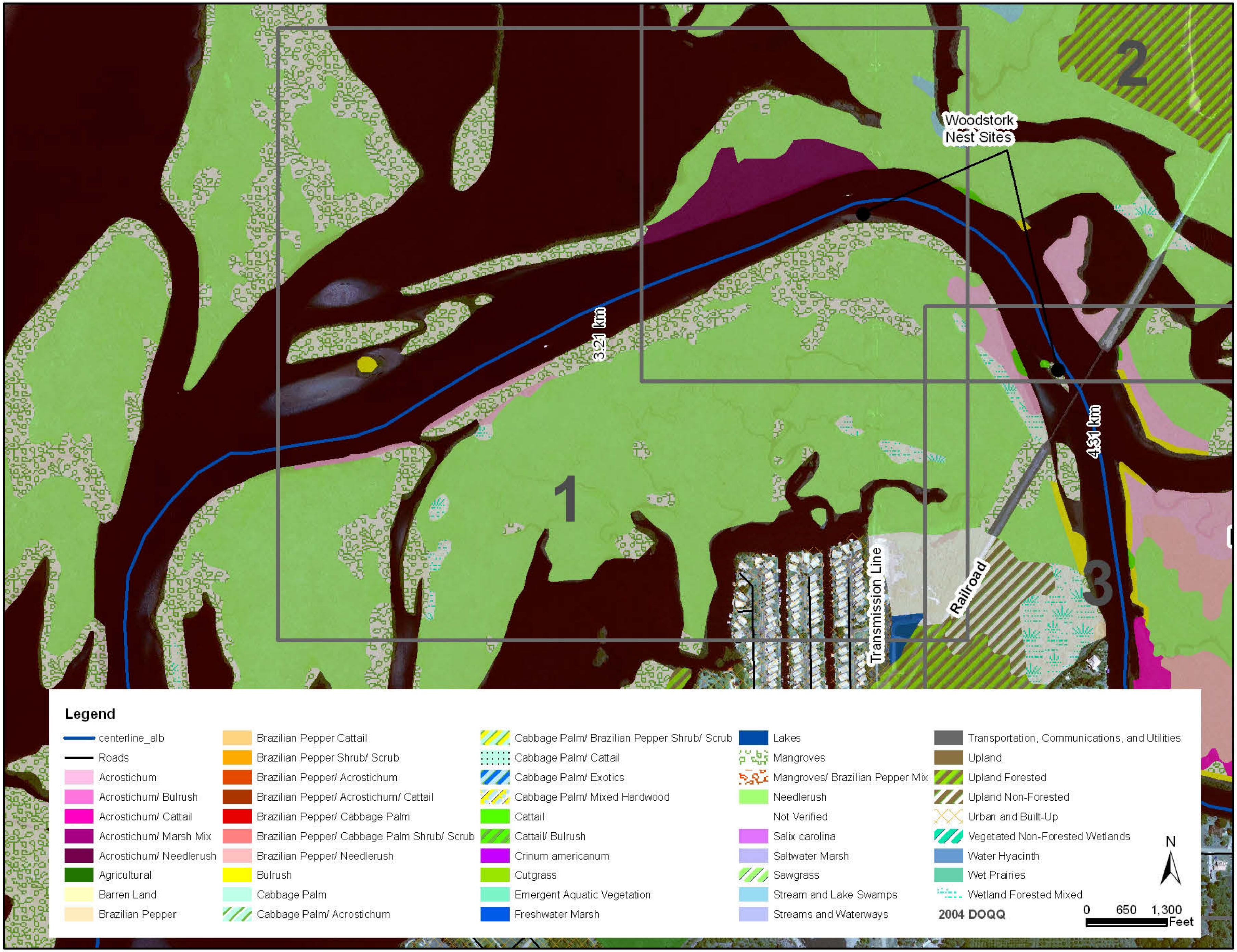
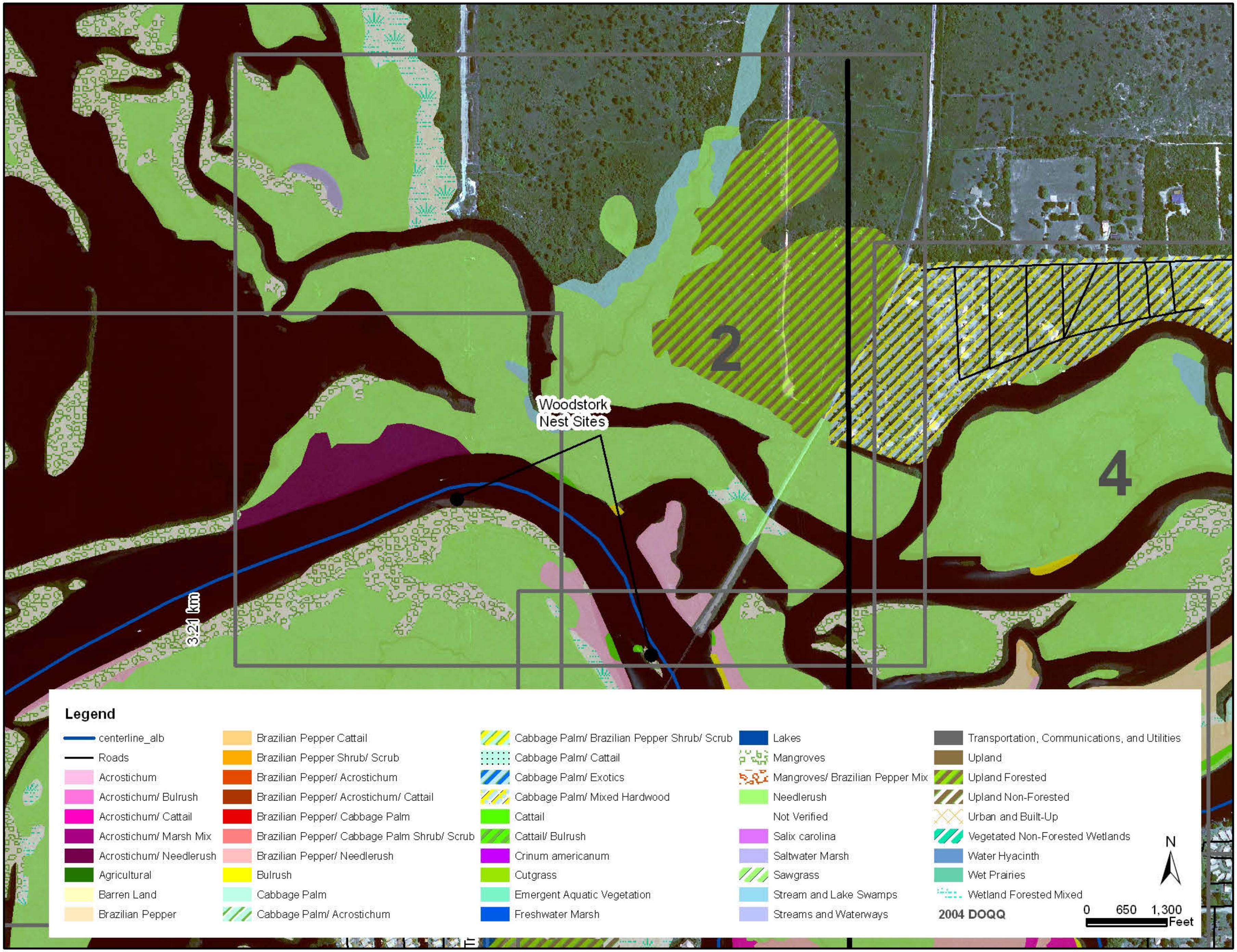

Woodstork Nest Sites
3.21 km
4.31 km
1
2
3
Transmission Line
Railroad
Legend
centerline_alb
Roads
Acrostichum
Acrostichum/ Bulrush
Acrostichum/ Cattail
Acrostichum/ Marsh Mix
Acrostichum/ Needlerush
Agricultural
Barren Land
Brazilian Pepper
Brazilian Pepper Cattail
Brazilian Pepper Shrub/ Scrub
Brazilian Pepper/ Acrostichum
Brazilian Pepper/ Acrostichum/ Cattail
Brazilian Pepper/ Cabbage Palm
Brazilian Pepper/ Cabbage Palm Shrub/ Scrub
Brazilian Pepper/ Needlerush
Bulrush
Cabbage Palm
Cabbage Palm/ Acrostichum
Cabbage Palm/ Brazilian Pepper Shrub/ Scrub
Cabbage Palm/ Cattail
Cabbage Palm/ Exotics
Cabbage Palm/ Mixed Hardwood
Cattail
Cattail/ Bulrush
Crinum americanum
Cutgrass
Emergent Aquatic Vegetation
Freshwater Marsh
Lakes
Mangroves
Mangroves/ Brazilian Pepper Mix
Needlerush
Not Verified
Salix carolina
Saltwater Marsh
Sawgrass
Stream and Lake Swamps
Streams and Waterways
Transportation, Communications, and Utilities
Upland
Upland Forested
Upland Non-Forested
Urban and Built-Up
Vegetated Non-Forested Wetlands
Water Hyacinth
Wet Prairies
Wetland Forested Mixed
2004 DOQQ
N
0 650 1,300
Feet

Figure 7.3


Woodstork
Nest Sites
2
4
3.21 km
Legend
centerline_alb
Roads
Acrostichum
Acrostichum/ Bulrush
Acrostichum/ Cattail
Acrostichum/ Marsh Mix
Acrostichum/ Needlerush
Agricultural
Barren Land
Brazilian Pepper
Brazilian Pepper Cattail
Brazilian Pepper Shrub/ Scrub
Brazilian Pepper/ Acrostichum
Brazilian Pepper/ Acrostichum/ Cattail
Brazilian Pepper/ Cabbage Palm
Brazilian Pepper/ Cabbage Palm Shrub/ Scrub
Brazilian Pepper/ Needlerush
Bulrush
Cabbage Palm
Cabbage Palm/ Acrostichum
Cabbage Palm/ Brazilian Pepper Shrub/ Scrub
Cabbage Palm/ Cattail
Cabbage Palm/ Exotics
Cabbage Palm/ Mixed Hardwood
Cattail
Cattail/ Bulrush
Crinum americanum
Cutgrass
Emergent Aquatic Vegetation
Freshwater Marsh
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Mangroves
Mangroves/ Brazilian Pepper Mix
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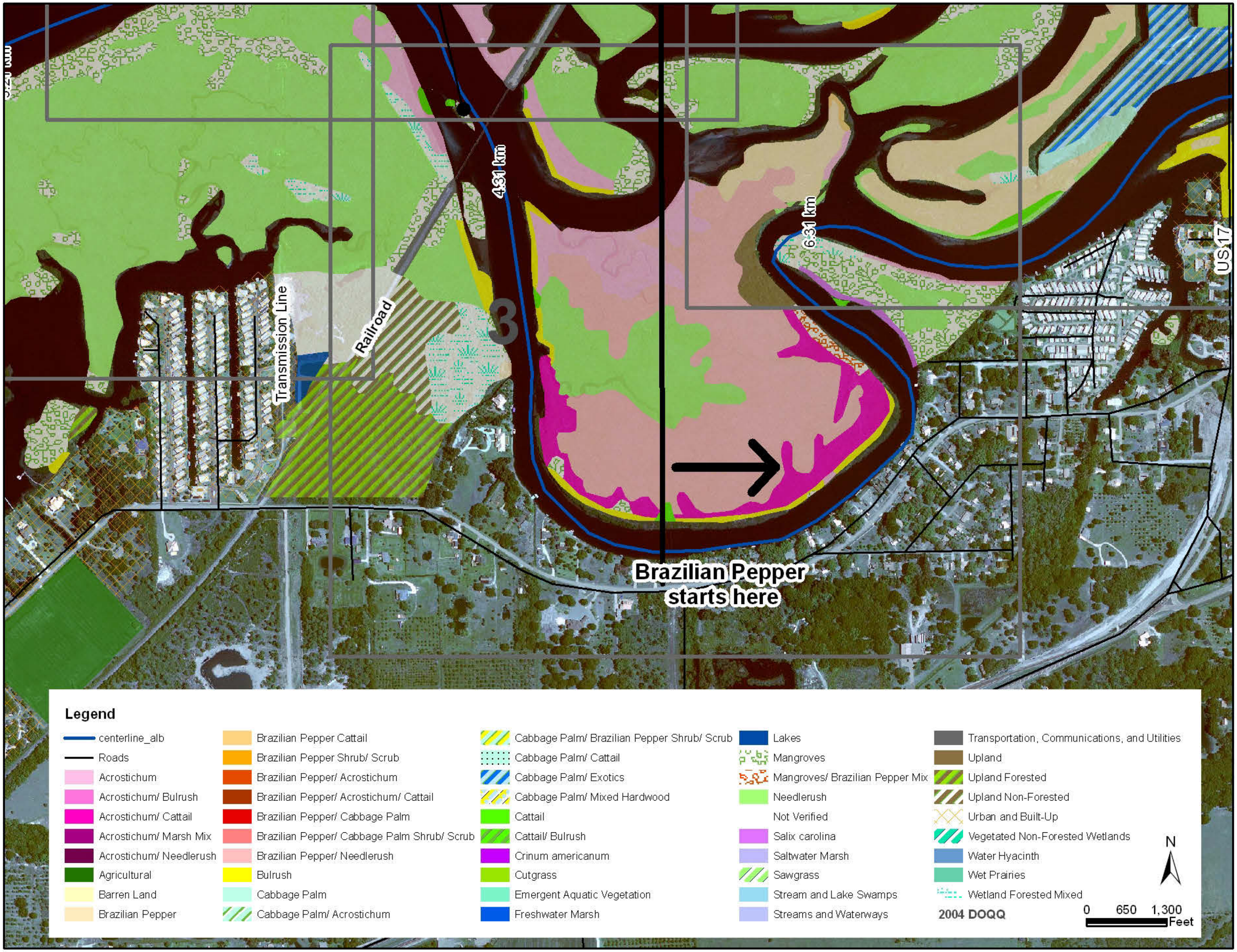
Vegetated Non-Forested Wetlands
Water Hyacinth
Wet Prairies
Wetland Forested Mixed
2004 DOQQ
N
0 650 1,300
Feet

Figure 7.4



4.31 km
6.31 km
US 17
Transmission Line
Railroad
3
Brazilian Pepper starts here
Legend
centerline_alb
Roads
Acrostichum
Acrostichum/ Bulrush
Acrostichum/ Cattail
Acrostichum/ Marsh Mix
Acrostichum/ Needlerush
Agricultural
Barren Land
Brazilian Pepper
Brazilian Pepper Cattail
Brazilian Pepper Shrub/ Scrub
Brazilian Pepper/ Acrostichum
Brazilian Pepper/ Acrostichum/ Cattail
Brazilian Pepper/ Cabbage Palm
Brazilian Pepper/ Cabbage Palm Shrub/ Scrub
Brazilian Pepper/ Needlerush
Bulrush
Cabbage Palm
Cabbage Palm/ Acrostichum
Cabbage Palm/ Brazilian Pepper Shrub/ Scrub
Cabbage Palm/ Cattail
Cabbage Palm/ Exotics
Cabbage Palm/ Mixed Hardwood
Cattail
Cattail/ Bulrush
Crinum americanum
Cutgrass
Emergent Aquatic Vegetation
Freshwater Marsh
Lakes
Mangroves
Mangroves/ Brazilian Pepper Mix
Needlerush
Not Verified
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Saltwater Marsh
Sawgrass
Stream and Lake Swamps
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Transportation, Communications, and Utilities
Upland
Upland Forested
Upland Non-Forested
Urban and Built-Up
Vegetated Non-Forested Wetlands
Water Hyacinth
Wet Prairies
Wetland Forested Mixed
2004 DOQQ
N
0 650 1,300
Feet

Figure 7.5

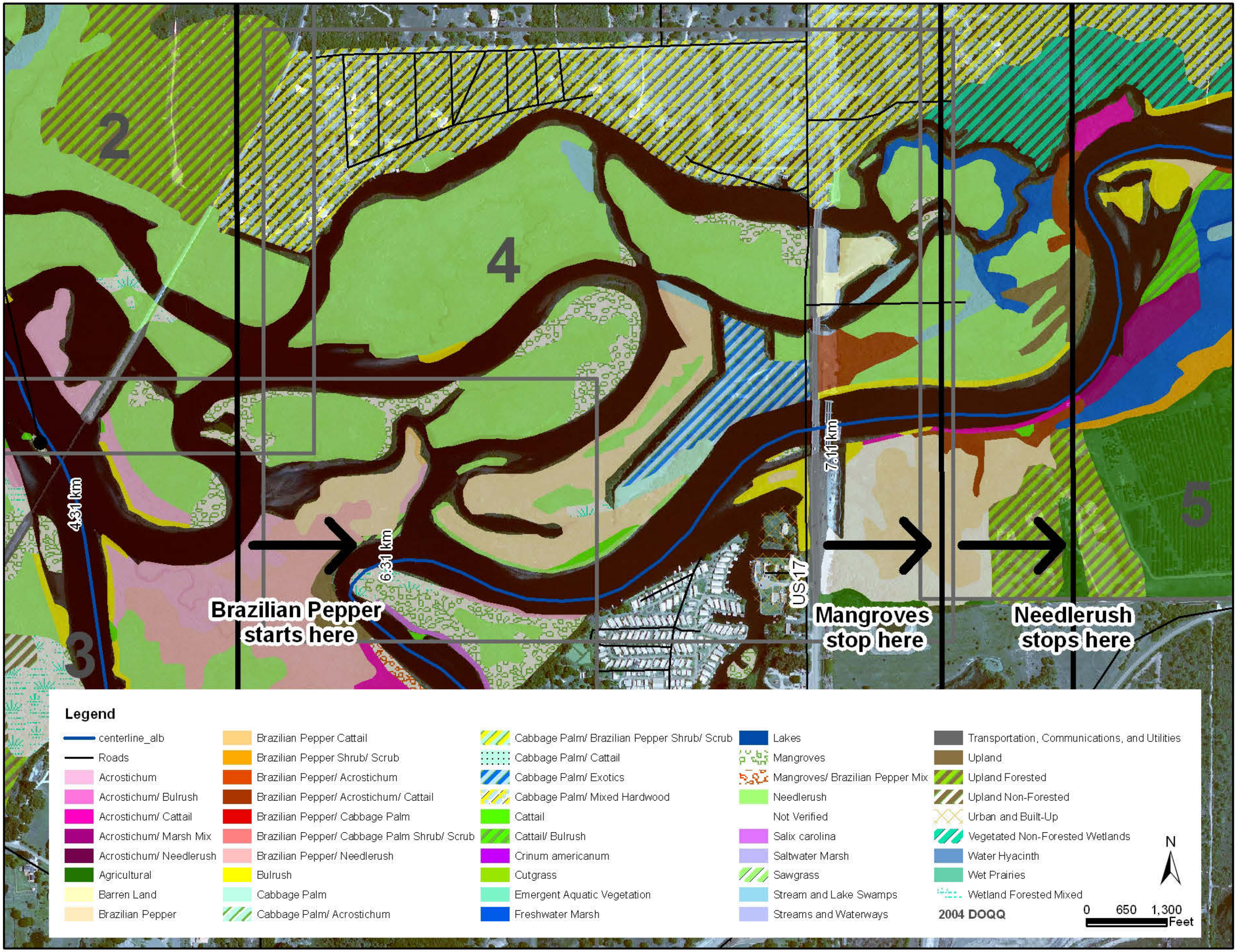
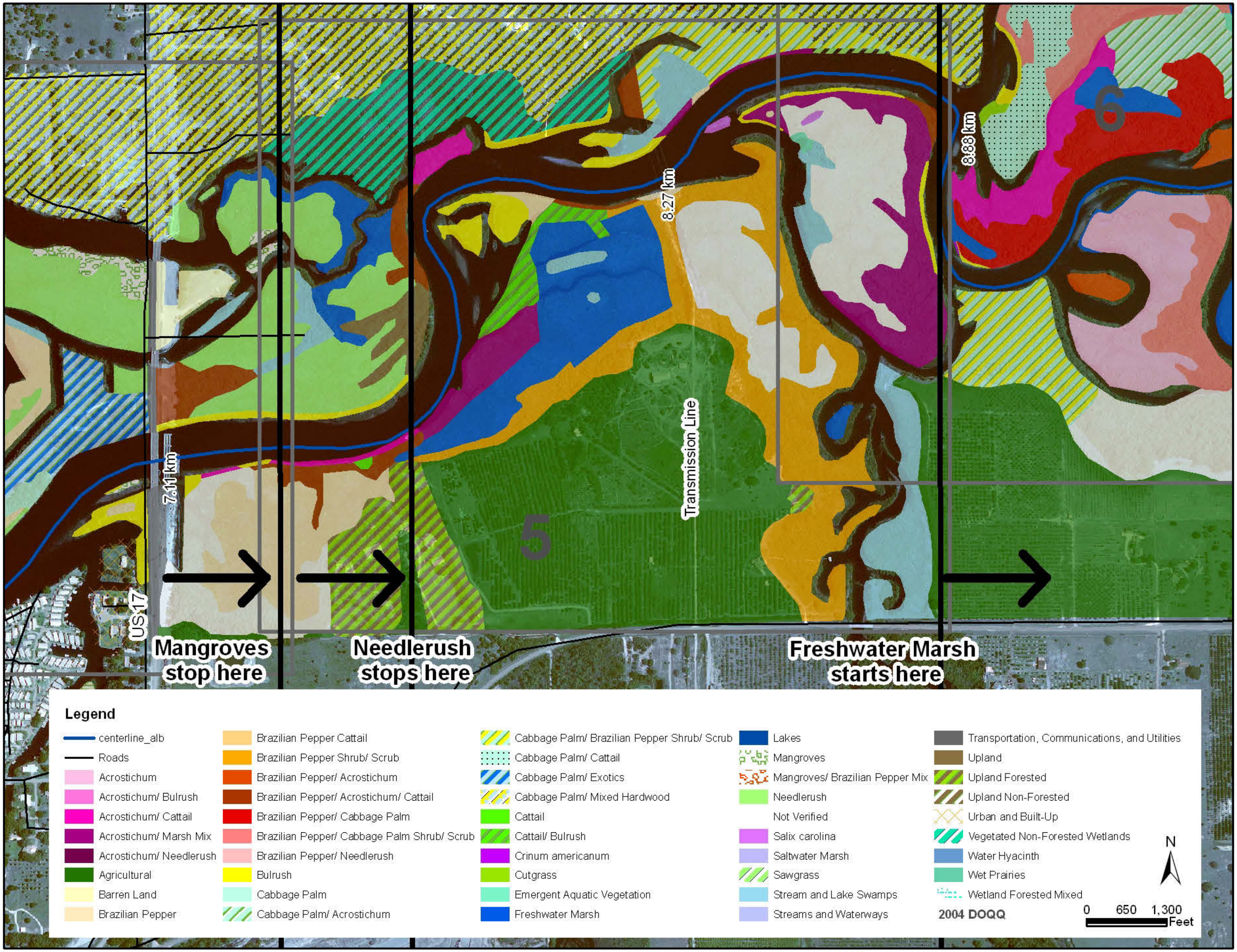

2
4
3
5
4.31 km
6.31 km
7.11 km
US 17
Brazilian Pepper starts here
Mangroves stop here
Needlerush stops here
Legend
centerline_alb
Roads
Acrostichum
Acrostichum/ Bulrush
Acrostichum/ Cattail
Acrostichum/ Marsh Mix
Acrostichum/ Needlerush
Agricultural
Barren Land
Brazilian Pepper
Brazilian Pepper Cattail
Brazilian Pepper Shrub/ Scrub
Brazilian Pepper/ Acrostichum
Brazilian Pepper/ Acrostichum/ Cattail
Brazilian Pepper/ Cabbage Palm
Brazilian Pepper/ Cabbage Palm Shrub/ Scrub
Brazilian Pepper/ Needlerush
Bulrush
Cabbage Palm
Cabbage Palm/ Acrostichum
Cabbage Palm/ Brazilian Pepper Shrub/ Scrub
Cabbage Palm/ Cattail
Cabbage Palm/ Exotics
Cabbage Palm/ Mixed Hardwood
Cattail
Cattail/ Bulrush
Crinum americanum
Cutgrass
Emergent Aquatic Vegetation
Freshwater Marsh
Lakes
Mangroves
Mangroves/ Brazilian Pepper Mix
Needlerush
Not Verified
Salix carolina
Saltwater Marsh
Sawgrass
Stream and Lake Swamps
Streams and Waterways
Transportation, Communications, and Utilities
Upland
Upland Forested
Upland Non-Forested
Urban and Built-Up
Vegetated Non-Forested Wetlands
Water Hyacinth
Wet Prairies
Wetland Forested Mixed
2004 DOQQ
N
0 650 1,300
Feet

Figure 7.6



6
8.88 km
8.27 km
7.11 km
Transmission Line
5
US 17
Mangroves stop here
Needlerush stops here
Freshwater Marsh starts here
Legend
centerline_alb
Roads
Acrostichum
Acrostichum/ Bulrush
Acrostichum/ Cattail
Acrostichum/ Marsh Mix
Acrostichum/ Needlerush
Agricultural
Barren Land
Brazilian Pepper
Brazilian Pepper Cattail
Brazilian Pepper Shrub/ Scrub
Brazilian Pepper/ Acrostichum
Brazilian Pepper/ Acrostichum/ Cattail
Brazilian Pepper/ Cabbage Palm
Brazilian Pepper/ Cabbage Palm Shrub/ Scrub
Brazilian Pepper/ Needlerush
Bulrush
Cabbage Palm
Cabbage Palm/ Acrostichum
Cabbage Palm/ Brazilian Pepper Shrub/ Scrub
Cabbage Palm/ Cattail
Cabbage Palm/ Exotics
Cabbage Palm/ Mixed Hardwood
Cattail
Cattail/ Bulrush
Crinum americanum
Cutgrass
Emergent Aquatic Vegetation
Freshwater Marsh
Lakes
Mangroves
Mangroves/ Brazilian Pepper Mix
Needlerush
Not Verified
Salix carolina
Saltwater Marsh
Sawgrass
Stream and Lake Swamps
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Transportation, Communications, and Utilities
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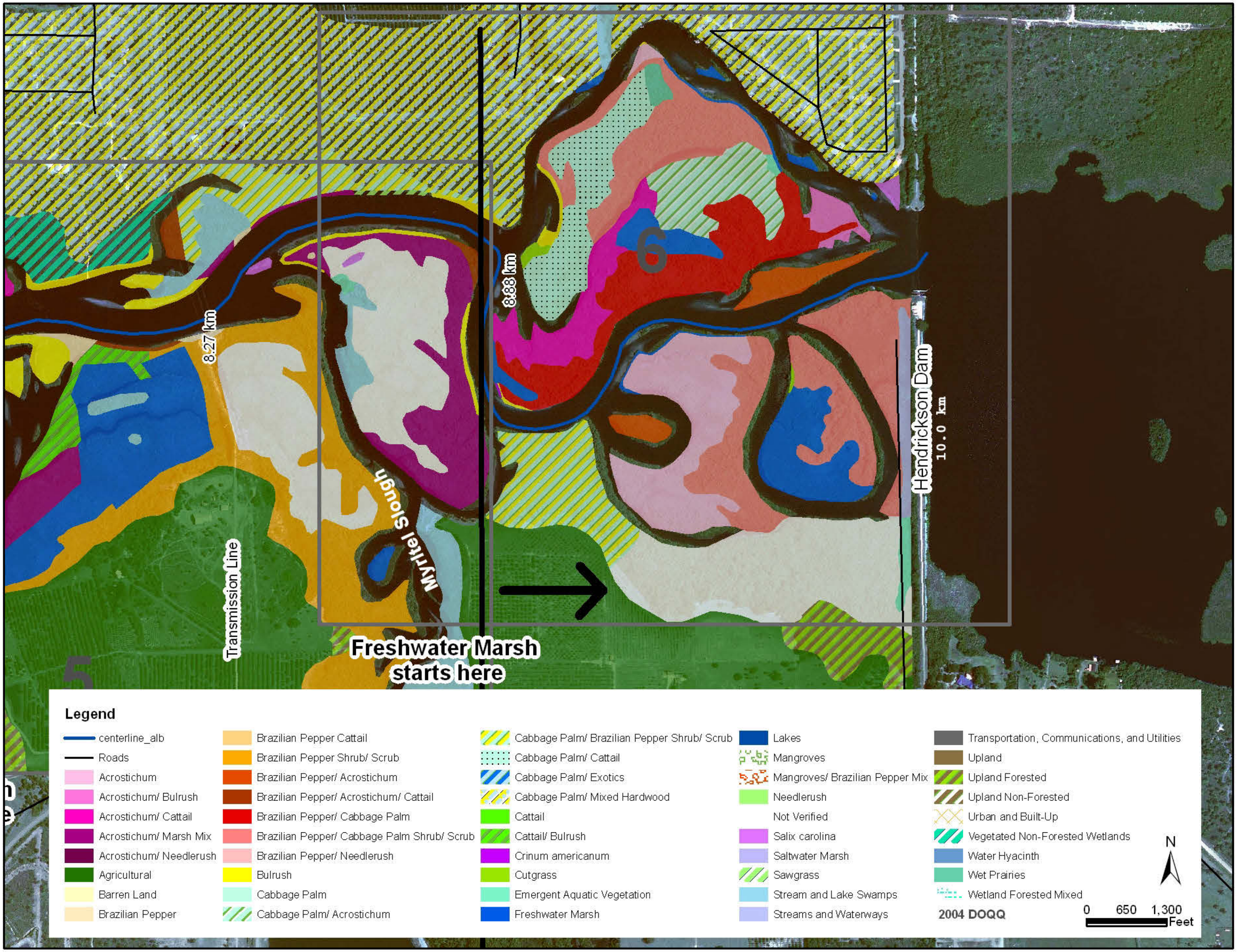
Upland Forested
Upland Non-Forested
Urban and Built-Up
Vegetated Non-Forested Wetlands
Water Hyacinth
Wet Prairies
Wetland Forested Mixed
2004 DOQQ
N
0 650 1,300 Feet

Figure 7.7


8.27 km
8.88 km
10.0 km
6
5
Hendrickson Dam
Myrtel Slough
Transmission Line
Freshwater Marsh starts here
Legend
centerline_alb
Roads
Acrostichum
Acrostichum/ Bulrush
Acrostichum/ Cattail
Acrostichum/ Marsh Mix
Acrostichum/ Needlerush
Agricultural
Barren Land
Brazilian Pepper
Brazilian Pepper Cattail
Brazilian Pepper Shrub/ Scrub
Brazilian Pepper/ Acrostichum
Brazilian Pepper/ Acrostichum/ Cattail
Brazilian Pepper/ Cabbage Palm
Brazilian Pepper/ Cabbage Palm Shrub/ Scrub
Brazilian Pepper/ Needlerush
Bulrush
Cabbage Palm
Cabbage Palm/ Acrostichum
Cabbage Palm/ Brazilian Pepper Shrub/ Scrub
Cabbage Palm/ Cattail
Cabbage Palm/ Exotics
Cabbage Palm/ Mixed Hardwood
Cattail
Cattail/ Bulrush
Crinum americanum
Cutgrass
Emergent Aquatic Vegetation
Freshwater Marsh
Lakes
Mangroves
Mangroves/ Brazilian Pepper Mix
Needlerush
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Salix carolina
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Upland Forested
Upland Non-Forested
Urban and Built-Up
Vegetated Non-Forested Wetlands
Water Hyacinth
Wet Prairies
Wetland Forested Mixed
2004 DOQQ
N
0 650 1,300
Feet

Appendix I

Figures from Mote Marine Report

Distribution of Macrobenthic Invertebrates in Shell Creek as Related to Salinity and Sediment Structure
(Culter, 2005)

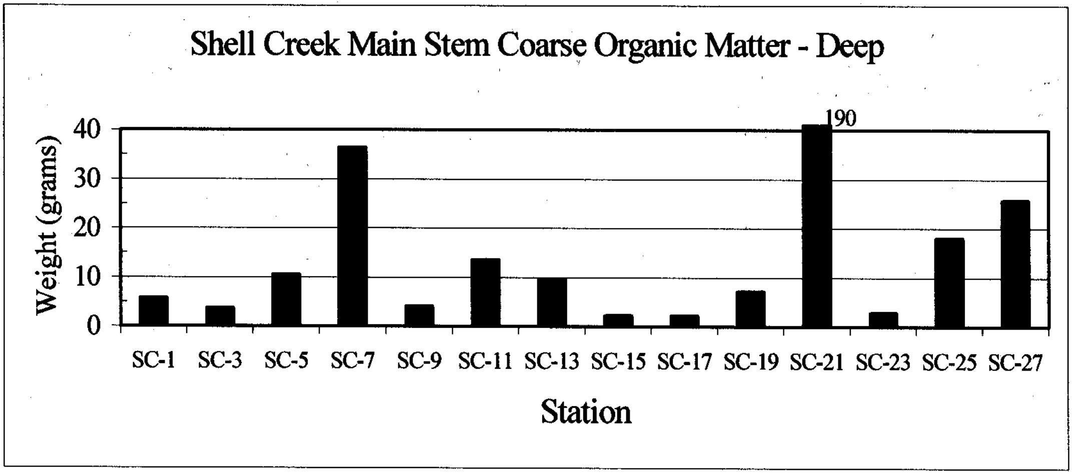

Figure 6. Coarse organic matter (grams dry weight) contained in each benthic sample for deep stations of the main stem of Shell Creek.

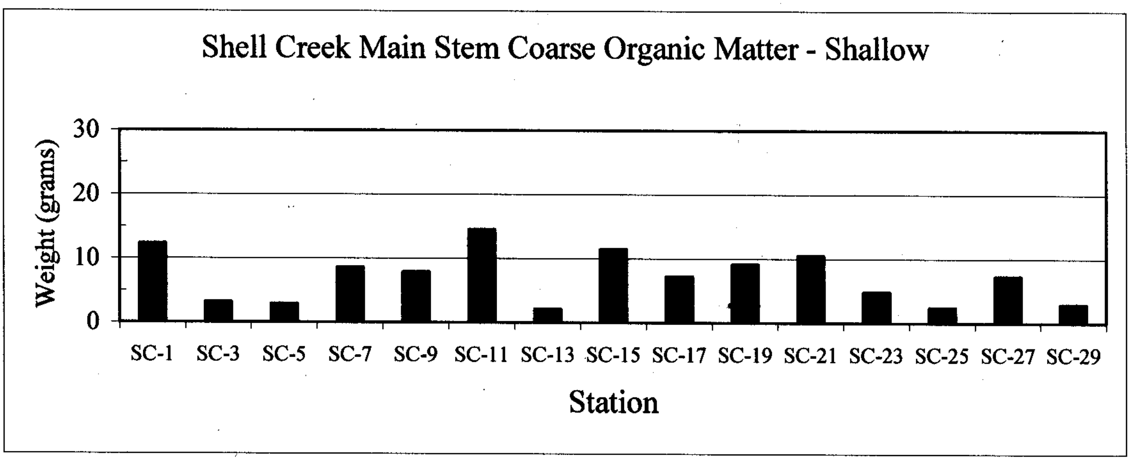

Figure 7. Coarse organic matter (grams dry weight) contained in each benthic sample for shallow stations of the main stem of Shell Creek.

Appendix J

Figures from USF Report

***An Assessment of the Effects of Freshwater Inflows on Fish and Invertebrate Habitat Use in the Peace River and Shell Creek Tributaries* (Peebles, 2002)**

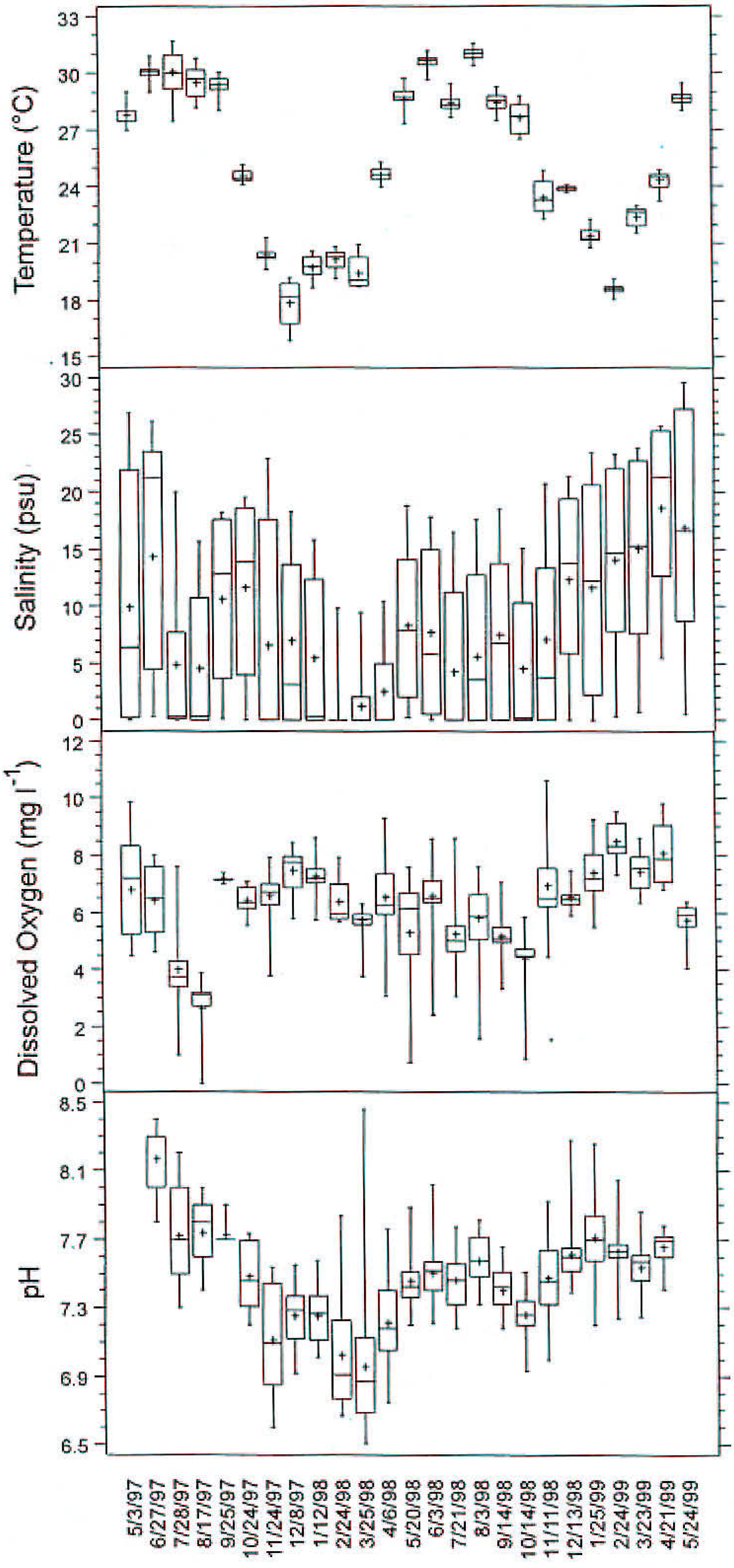

Fig. 3.2.1. Electronic meter data from the plankton-net surveys of the Peace River, where the cross identifies the mean, the horizontal line identifies the median, the box delimits the interquartile range, and the whiskers delimit the total range.

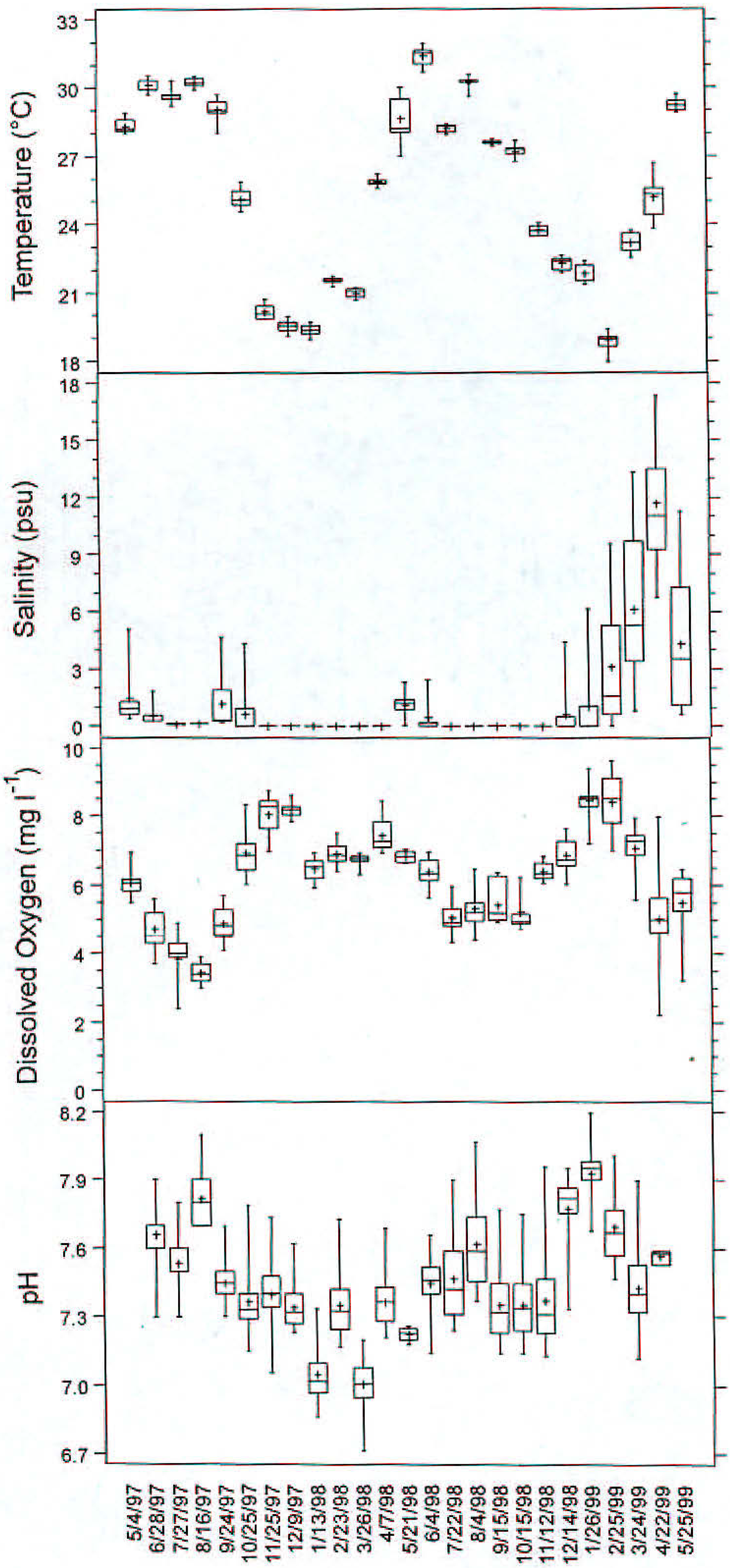

Fig. 3.2.2. Electronic meter data from the plankton-net surveys of Shell Creek, where the cross identifies the mean, the horizontal line identifies the median, the box delimits the interquartile range, and the whiskers delimit the total range.

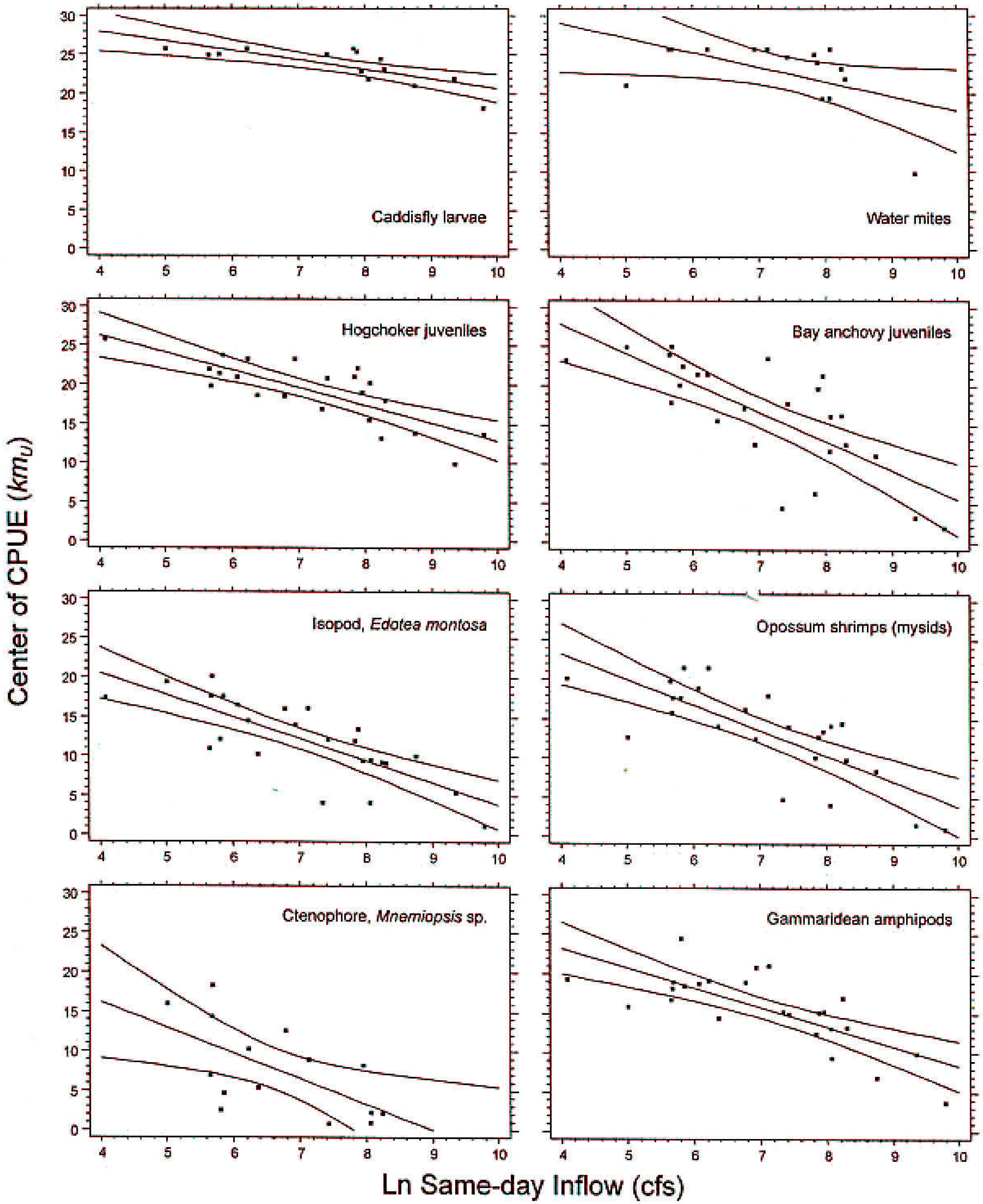

Fig. 3.7.1. Example regressions of organism location (km_U) vs. inflow (ln F), with 95% confidence limits for estimated means (Peace River, see Table 3.7.1).

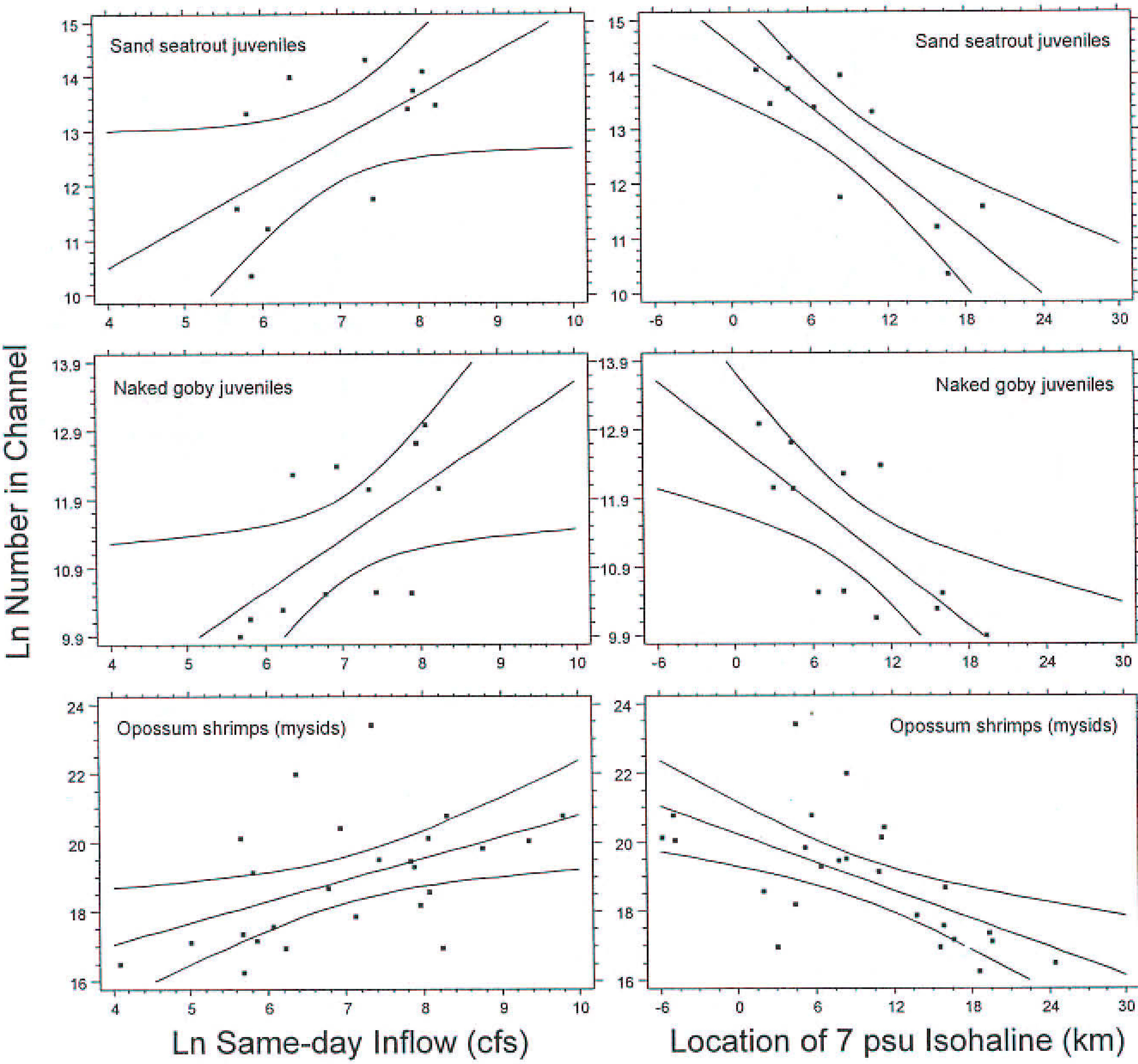

Fig. 3.8.1. Example regressions of organism number (ln *N*) vs. inflow (ln *F*) and 7 psu isohaline location, with 95% confidence limits for estimated means (Peace River, see Table 3.8.1).