Assessment of

Overland Runoff Nonpoint Source Pollution

Ohio River Valley Water Sanitation Commission

2003

Assessment of Overland Runoff Nonpoint Source Pollution Impacts on the Ohio River including a Ranking of Major Tributaries by NPS Pollutant Contribution

Evaluation of Pollutant Loads in High Runoff Flows vs. Flows with Low Runoff Content

Ohio River Valley Water Sanitation Commission

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Abstract

The participation of six states is necessary in planning abatement of nonpoint source (NPS) pollution impacts on the Ohio River. Nonpoint source impacts on the Ohio River indirectly involve eight additional states whose borders contain headwaters of Ohio River tributaries. The Ohio River Valley Water Sanitation Commission (ORSANCO) has in place a Nonpoint Source Work Group to facilitate communication between the six states on the mainstem of the Ohio. The mission of the Work Group is planning a coordinated approach to nonpoint source abatement on the Ohio River. To facilitate their efforts ORSANCO staff produced this report, *Assessment of Overland Runoff Nonpoint Source Pollution Impacts on the Ohio River Including a Ranking of Major Tributaries by NPS Pollutant Contribution*.

The Assessment provides a general description of nonpoint source pollution on the Ohio River and a comparison of the Ohio's 21 major tributaries. Nonpoint source pollution impacts have been assessed using the principles of hydrograph separation to identify sample data collected when the Ohio River was minimally impacted by runoff. Average loads for the 10-year period from January 1992 to December 2001 were calculated for the river at low runoff flows and compared to 10-year averages at all other flows. The difference has been labeled "overland runoff nonpoint source pollution." Exceptions for NPDES permitted stormwater sources and groundwater are detailed in the section entitled "Scope of the Assessment."

The Assessment revealed eleven pollutants for which more than 40 percent of total load is contributed by overland runoff. These pollutants are suspended solids, iron, aluminum, manganese, lead, zinc, total phosphorus, nitrite/nitrate, magnesium, sulfate, and chloride. Average runoff loads and total loads for each of the eleven pollutants are presented in the text in Section 3, "Impact Assessment."

The Assessment is intended for state-level nonpoint source managers, specifically members of the ORSANCO Nonpoint Source Work Group, to facilitate their interpretation of Ohio River monitoring data and the impact of major tributaries on Ohio River water quality. A ranking of tributaries is illustrated for five parameters. The parameters were chosen for differences in tributary order and usefulness in indicating land use issues that contribute to runoff pollution impacts for the Ohio River.

The reader is encouraged to use this report for relative comparison of the loads of the runoff pollutants identified. The assessment was not designed to provide exact runoff contributions; however, the differences in runoff contributions are reasonably correct. Annual loading values reported herein are the results of 10-year averages; the usefulness of these values is best limited to the relative differences between pollutants and locations.

Introduction

The following assessment of nonpoint source impacts on the Ohio River has been carried out at the request of the ORSANCO Nonpoint Source Work Group. The Assessment is intended to identify relative nonpoint source pollution problems on the Ohio River and gauge their impacts by simple estimation of the mass loading of nonpoint source pollutants. A process of hydrograph analysis (described in Section 2: Methods) has identified eleven pollutants with major overland runoff sources in the Ohio River. Greater than forty percent of the load for each of the 11 pollutants has been linked to overland runoff flows by hydrograph analysis. Each of 20 major Ohio River tributaries has been ranked by its contribution to the Ohio River load of the eleven specified runoff pollutants.

ORSANCO Nonpoint Source Program Background

1990 "Assessment of Nonpoint Source Pollution of the Ohio River"

This report is the second ORSANCO nonpoint source pollution assessment. It follows the 1990 Commission publication "Assessment of Nonpoint Source Pollution of the Ohio River." Some findings of the 1990 report include:

- Contributions due to nonpoint sources are causing degradation of designated uses in certain reaches of the Ohio River.
- Agricultural and resource extraction activities have the greatest impact on water quality of the Ohio River.
- The dominant nonpoint sources are resource extraction in the upper 350 miles of the Ohio River and agriculture in the lower 350 miles. A combination of effects is found in the middle 281 mile of the Ohio River.

1995 Nonpoint Source Pollution Abatement Strategy

The Commission's Nonpoint Source Task Force, formed in January 1993, represented local, state and federal environmental agencies; agricultural agencies, agribusiness, mining and public interests. In 1995 the NPS Task Force produced ORSANCO's nonpoint source program plan, titled "A Strategy for Nonpoint Source Pollution Abatement on the Ohio River." Three goals are outlined in the unpublished 1995 working document:

- Determine the degree of water quality impairment of the river resulting from nonpoint sources of pollution.
- Achieve a coordinated approach to abate NPS pollution.
- Actively encourage public participation.

If NPS impacts were determined to exist, subsequent steps in the abatement process would be to determine sources, necessary load reductions, and long term monitoring protocols.

ORSANCO Nonpoint Source Work Group

The Commission formed a subcommittee called the Nonpoint Source Work Group to follow up on the strategy produced by the Task Force. For four years the work group's primary focus was communication between the basin states' nonpoint source program managers. This assessment, requested in 2001, is intended as a tool for the work group in planning a coordinated approach to nonpoint source pollution abatement in the Ohio River Basin.

Purpose and Scope of this Report

2002 NPS Assessment Purpose

The ORSANCO Nonpoint Source Work Group felt future efforts in abatement would be well served by a fresh assessment of NPS impacts on the Ohio River. Secondly, the committee requested a ranking of tributaries by their nonpoint source pollutant contribution for use in planning an approach to NPS abatement. ORSANCO has also made conclusions about the impact of the identified nonpoint source pollutants based on the 2001 305(b) report (ORSANCO, 2002). Annual loads from runoff have not been calculated for this assessment due to insufficient frequency of samples collected in the ORSANCO Bimonthly Sampling program.

Scope of the Assessment

Geographic

The impact assessment encompasses the entire length of the Ohio River mainstem and its 21 major tributaries, i.e., all tributaries with watersheds larger than 1,000 square miles.

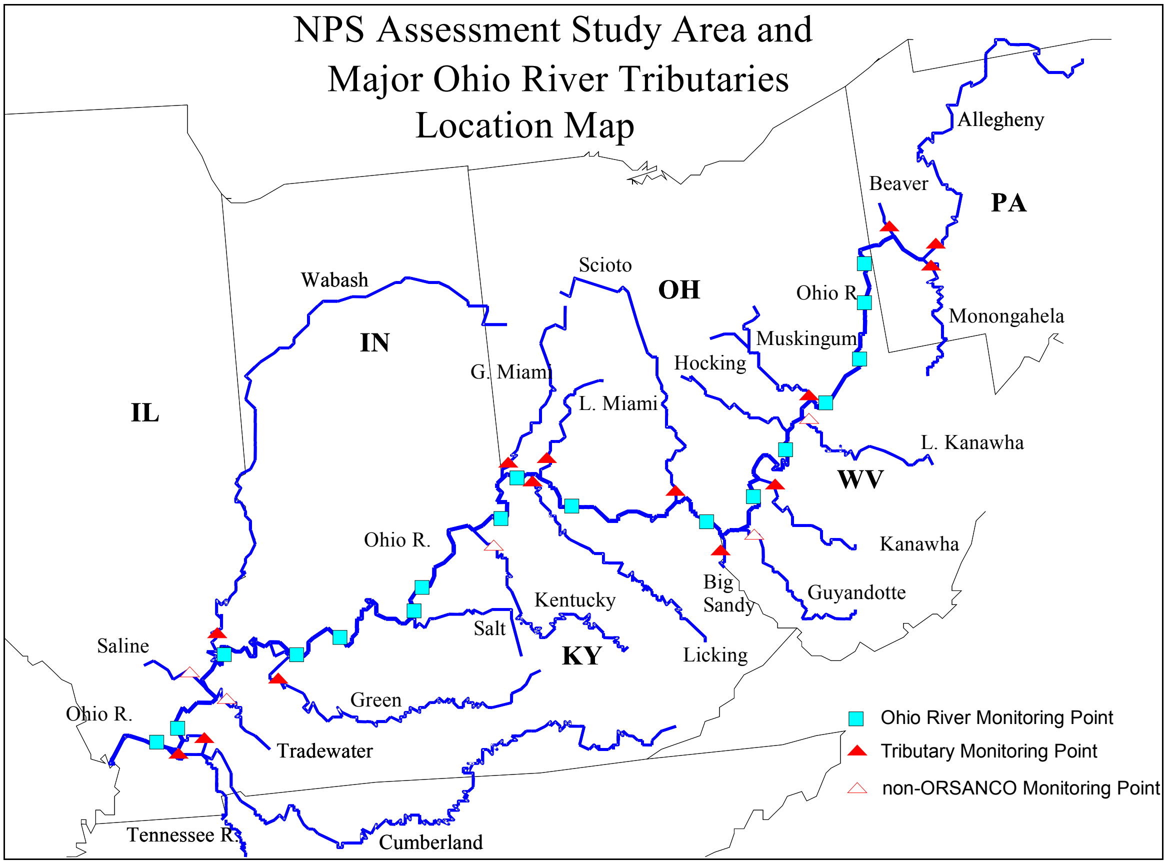
Temporal

Ten years of monitoring data for each of the ORSANCO Ohio River mainstem sampling stations have been analyzed for a relationship between pollutant concentration and flow or a large portion of load attributable to overland runoff. The period of interest is January 1, 1992 to December 31, 2001.

Monitoring Data

ORSANCO's Bimonthly Monitoring Program, in existence since 1976 and formerly called the Manual Sampling program, is the foundation for monitoring data used in this assessment. Through the Bimonthly Sampling Program, ORSANCO collects six samples per year; the 10-year sample population for all monitoring points was roughly 60 samples (N=60). For tributaries not sampled by ORSANCO, a similar record of monitoring data was sought from sources described below in Sampling Data.

Figure 1.1 Study Area Map



Assessment Method

The assessment is based on the identification of pollutants whose loads increase with runoff flow. No attempt to quantify total point source contributions of pollutants to the Ohio River was made. Once a pollutants' percent of load from runoff had been estimated the nonpoint source impact of that pollutant was considered to be its runoff load in the Ohio River. As such, the assessment does not attempt to separate the contribution of NPDES[1]-permitted storm water pollution sources. There is no attempt to quantify nonpoint source pollution contributed via ground water.

Construction Activity

Construction activity, although governed nationally by erosion control protocols, is a considerable source of suspended sediment in stormwater. The 10-year scope of this study is assumed to outlast the effect of most construction activity.

Combined Sewer Overflows

In large metropolitan areas the influence of combined sewer overflows (CSOs) on water quality is detrimental. The contribution of this NPDES-permitted activity to nonpoint source pollutant loads has been well documented on the Ohio River in

[1] National Pollutant Discharge Elimination System

other ORSANCO reports. For the purposes of this assessment, CSO impacts are combined with other overland runoff and stormwater pollution. Communities with combined sewer systems and CSOs are identified in Appendix J.

Groundwater Pollution

The extent of low flow loads contributed by groundwater will be inseparable from that of point sources in this assessment. Groundwater pollution from leaking underground storage tanks (USTs), wells and other conduits to groundwater is well documented. In the Ohio River Basin, however, quantification of the extent of this problem is beyond the scope of this project. Onsite treatment systems, drinking water, agricultural and industrial use groundwater wells, and oil and natural gas wells are all possible conduits for pollutants entering groundwater.

Photo by E. Hobbins

A debris mat, including a loose navigation buoy, downstream of Louisville, Kentucky near the mouth of the Salt River (railroad trestle at right).

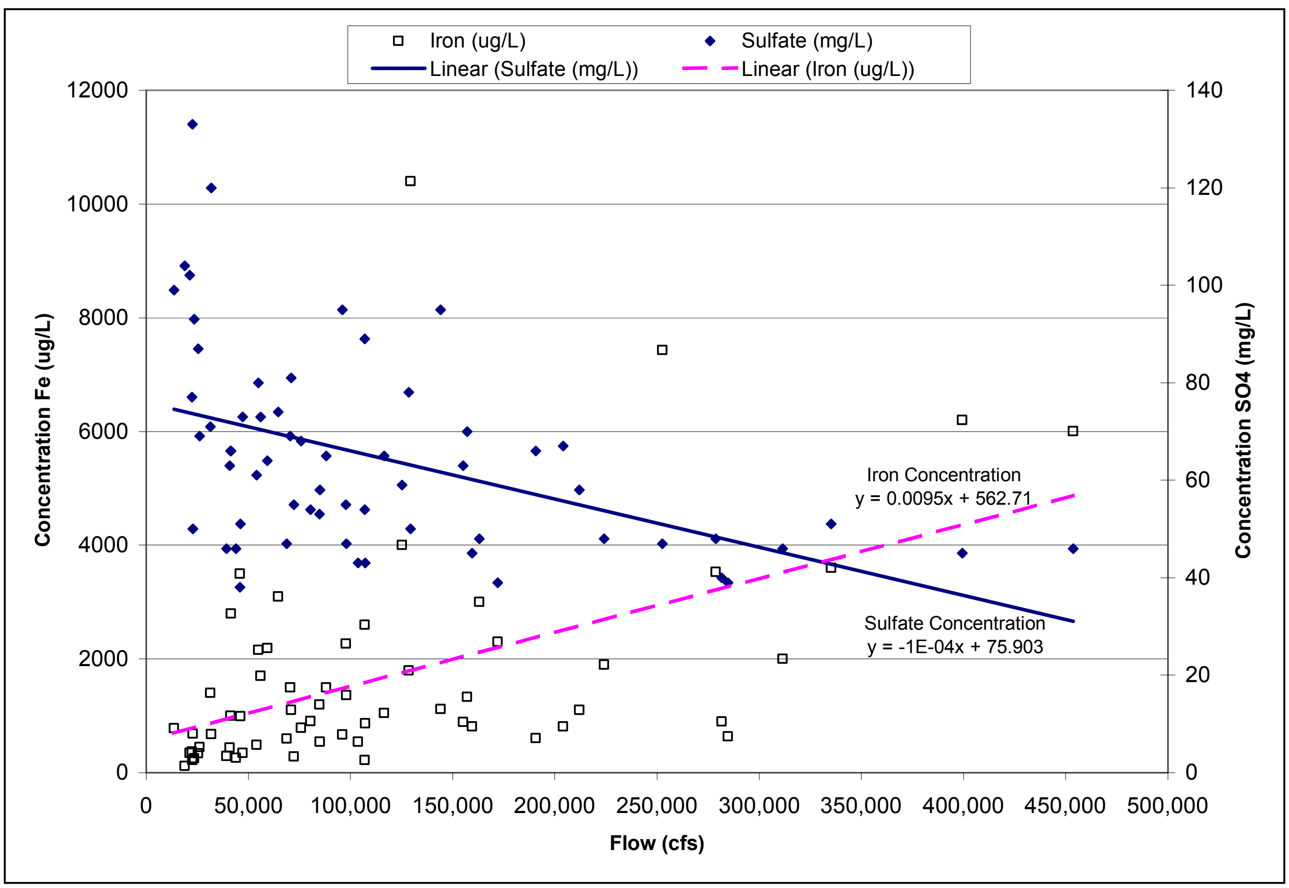
Methods for Assessment of Impacts

This analysis of ORSANCO bimonthly and other monitoring data is based on the identification of samples collected during periods of low runoff (see discussion of hydrograph analysis, page 8). Daily loads have been calculated for each sample from January 1992 through December 2002. These daily loads, once separated by percentage of runoff content, show by comparison of averages the contribution of overland runoff to nonpoint source pollutant loads.

Identification of Runoff-Related Pollutants

Runoff-related nonpoint source pollution is clearly indicated by a positive regression slope when concentration is plotted vs. flow. In contrast, a point source discharge independent of stormwater is diluted by increased runoff. Figure 2.1 shows the positive slope of the iron concentration in ug/L when plotted against flow and the corresponding negative slope of the sulfate concentration (mg/L) regression line in the same ten-year sample set (n = 62). No pollutant monitored by the ORSANCO Bimonthly Sampling Program is strictly point source in origin. The degree of runoff-source was assessed and a set of pollutants chosen for size of runoff contribution and importance to water quality.

Fig 2.1 - Iron and Sulfate Concentrations vs. Flow
Ohio River Mile 531.5, Markland Dam N = 62; 1/27/1992- 9/16/2001



Positive flow/concentration correlations indicate in certain terms that a pollutant is contributed to the river system by nonpoint sources. In many cases, however, the correlation between concentration and flow is inconclusive. To address this scenario, the comparison of pollutant loads at high runoff vs. loads at low runoff is used to indicate the pollutants that have runoff-related nonpoint sources. The difference between average pollutant load during low runoff conditions and the load during high runoff flows has been attributed to overland runoff, the major source of nonpoint source pollution investigated here.

As noted in Purpose and Scope of this Report (Section 1, Introduction), NPDES-permitted storm water sources have not been separated from overland runoff and are included in the non-point source loads calculated here.

Daily Loads

Daily loads have been calculated with the ORSANCO Bimonthly Sampling Program data because the frequency of sampling (six samples per year) is insufficient to support preferred methods of annual load calculation. Annual loads are of questionable accuracy unless calculated from a monitoring frequency of greater than 24 samples per year (Baier, Cohn, Gilroy, 1995)[2].

Daily loads for ORSANCO bimonthly sampling data were calculated using National Weather Service modeled flow because the locations provided by NWS most closely match the sample locations. A comparison of this modeled flow data vs. observed flows is presented in Figure 2.2.

Flow Data

Samples collected bimonthly from 1992-2001 were separated into two groups based on analysis of daily flows during the same period of record. Ten years of daily flows were compiled for each station using National Weather Service data for the majority of locations and dates. U. S. Army Corps of Engineers FLOWSED data was used for all stations during 1992 and 1993 and for the complete 10-year record for New Cumberland, Metropolis, and J. T. Myers bimonthly sampling stations. Hydrographs were constructed for each monitoring point and are presented in Appendix B.

Observed vs. Modeled Flow

The most accurate and complete record of stream discharge data, including the Ohio River, was assumed to be that gathered by United States Geological Survey (USGS) streamflow gauges. Daily mean flow for USGS gauging stations is calculated from hourly stage observations. Unfortunately this flow record is unavailable or discontinued at many of ORSANCO's monitoring stations[3]. Other sources of flow data with the required daily frequency and desired locations are the National Weather Service (NWS) and United States Army Corps of Engineers (USACE) models.

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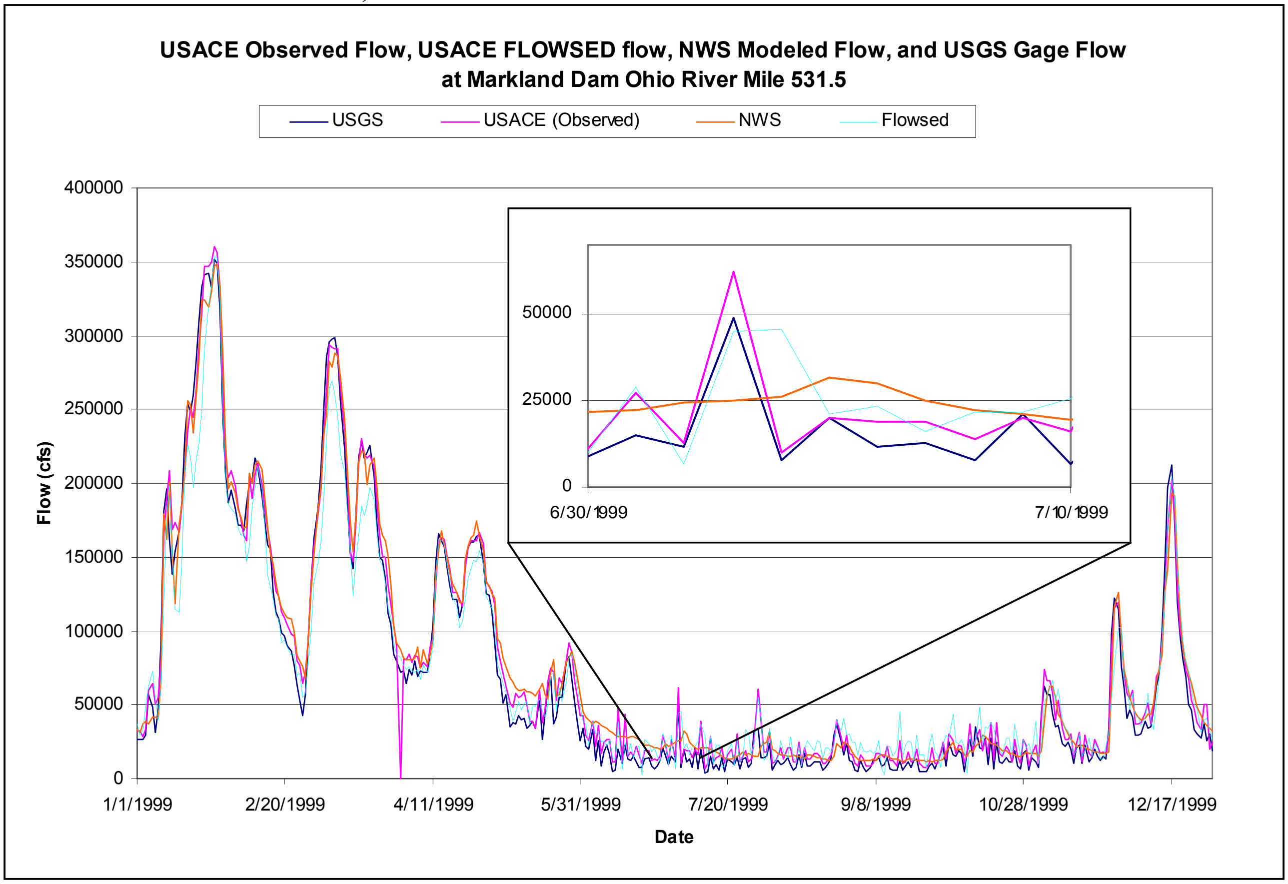
[2] G. Baier, T. Cohn, E. Gilroy, Instructions for Using the Estimator Software, 1995

[3] Of the original 22 gauging stations on the Ohio River all but seven have been discontinued. USGS, (2002), retrieved from http://waterdata.usgs.gov/nwis/inventory.

Fig 2.2 - Comparison of Daily Flow Data
Ohio River Mile 531.5, Markland Dam 1/1/1999 – 12/31/1999



National Weather Service flow data is provided by the National Weather Service Ohio River Forecast Center in Wilmington, Ohio. The National Weather Service model uses precipitation, snowmelt, soil moisture, and discharges from dams and navigational locks among its data sources. It is clear from figure 2.2, a comparison of flow data including USGS observed flow, that the River Forecast Center (RFC) produces a reasonably accurate product and one appropriate for use in calculating pollutant loads.

National Weather Service flow data was used preferentially for the record's ability to moderate the high frequency fluctuations observed in Ohio River flow (see Fig 2.2). The daily fluctuations complicate the hydrograph analysis discussed below. The National Weather Service Ohio River Forecast Center data has also been the traditional provider of flow data published with the ORSANCO bimonthly monitoring data in the ORSANCO semiannual *Quality Monitor*. NWS modeled data was therefore appropriate for consistency with previous ORSANCO analyses and with the published record of the Bimonthly Sampling Program.

Sampling Data

Bimonthly Sampling Program

Sampling Stations

The ORSANCO Manual Sampling Program, begun in 1976, is now named the Bimonthly Sampling Program. The quality, consistency, and longevity of this record is unique in the Ohio River Basin. The Bimonthly Sampling program currently uses seven ORSANCO field personnel at 31 monitoring points: seventeen locations on the mainstem and fourteen points on tributaries. Bimonthly sampling stations are shown in Appendix C.

Sample Frequency

The Bimonthly Sampling Program was designed to provide long-term trend monitoring of the Ohio River. Samples are collected six times a year, in January, March, May, July, September, and November. Sample dates are chosen well in advance, and independent of flow forecasts. For this reason the bimonthly record contains infrequent samples from storm event flow peaks. The record does show good variability in flows for each sample location.

Sample Parameters

Bimonthly Sampling Program sample parameters include suspended solids, sulfate, hardness, nutrients, chlorides, phenolics, cyanide, and total recoverable metals (Magnesium, Cadmium, Copper, Iron, Lead, Manganese, Mercury, Zinc, Arsenic, Aluminum).

STORET Monitoring Data

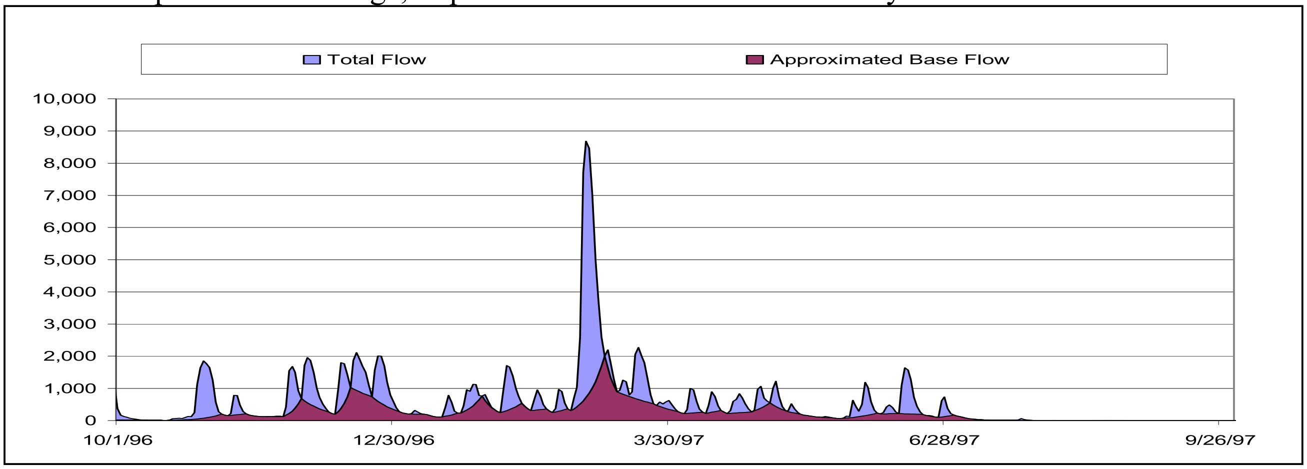
Other agency monitoring data for tributaries not included in the ORSANCO Bimonthly Sampling Program have been retrieved from U.S. EPA's Legacy Data center (LDC) and Storage and Retrieval (STORET) water quality data management system. Information used in this report and retrieved from either of these U.S. EPA databases originated with state agencies or the U.S. EPA. The agency source of data used is presented in tabular form in table 4.1 and with all results in Appendix A.

Hydrograph Analysis

Monitoring data used in this analysis was separated into two groups: samples collected under high runoff conditions and samples collected under low runoff conditions. This distinction was made to compare the effect of overland runoff, the major portion of nonpoint source pollution in most watersheds, including the Ohio River. The average pollutant load under low runoff conditions has been subtracted from the average pollutant load at high runoff, to arrive a load resulting from overland runoff.

Samples were separated into the two flow groups by hydrograph analysis. The PART software (Rutledge, 1998), intended for a different and specific process called hydrograph separation, does so using an algorithm to analyze daily flow data for a specified period of antecedent recession. The PART program assigns base flow equal to streamflow for days meeting the requirement, and by interpolation, assigns a base flow discharge for every other day of the flow record.[4]

Figure 2.3 -Hydrograph Separation by PART software: Tradewater River at Olney 255 square mile drainage, required antecedent recession is 3 days



Avoiding misuse of the PART software to quantify base flow discharge, the software and its algorithm were used only to identify days on which a monitoring station on the Ohio River was *less impacted* by overland runoff. Hydrograph separation for the Ohio River by the PART software was rejected for the following reasons:

Hydrograph separation is a process used in smaller watersheds (<500sq. mi.) to identify, through the use of multi-year hydrographs, the component of stream flow known as "base flow." Analysis of multiple years of flow data for a basin of uniform climate, runoff, and retention characteristics yields a constant flow regression index measured in days: the time it takes for a precipitation event to pass through the drainage system. Precipitation travels first as overland runoff, later as interflow (short residence-time soil moisture), and finally as groundwater.

The size of the drainages contributing to flow at each Ohio River monitoring point negates the applicability of traditional hydrograph separation. The Ohio River monitoring point with the least contributing drainage area is the New Cumberland Lock and Dam, with a drainage of over 24,000 square miles. This area is large enough that most precipitation events have dissimilar effects across the contributing drainage area. Flow regulation through tributary impoundments and mainstem navigation dams, municipal and industrial discharges, and withdrawals also contributes to flow characteristics that make base flow separation by recession index impossible.

The separation of samples by runoff content was effected by a combination of the recession index algorithm of PART software (Rutledge, 1993) and manual hydrograph inspection. In general, samples taken in the late recession stage of a hydrograph peak or

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[4] Rutledge, A.T., Computer Programs for Describing the Recession of Ground-Water Discharge and for Estimating Mean Ground-Water Recharge and Discharge from Streamflow Records—Update, U.S. Geological Survey, Water-Resources Investigations Report 98-41481998

in the declining or flat portion of the trough were assessed as low-runoff samples. The recession index used in the PART algorithm was determined by manual inspection of ten-year hydrographs for storm event peaks and their associated recession. From this analysis it was determined that the Ohio River's large basin responds faster to most precipitation events than the standard calculating factor (equation 2-1) would indicate.

Hydrograph separation techniques based on the work of Linsley, et. al., (1958), including the PART software, use a standard factor to determine from the area of the basin, the time base of direct runoff in days. The equation used:

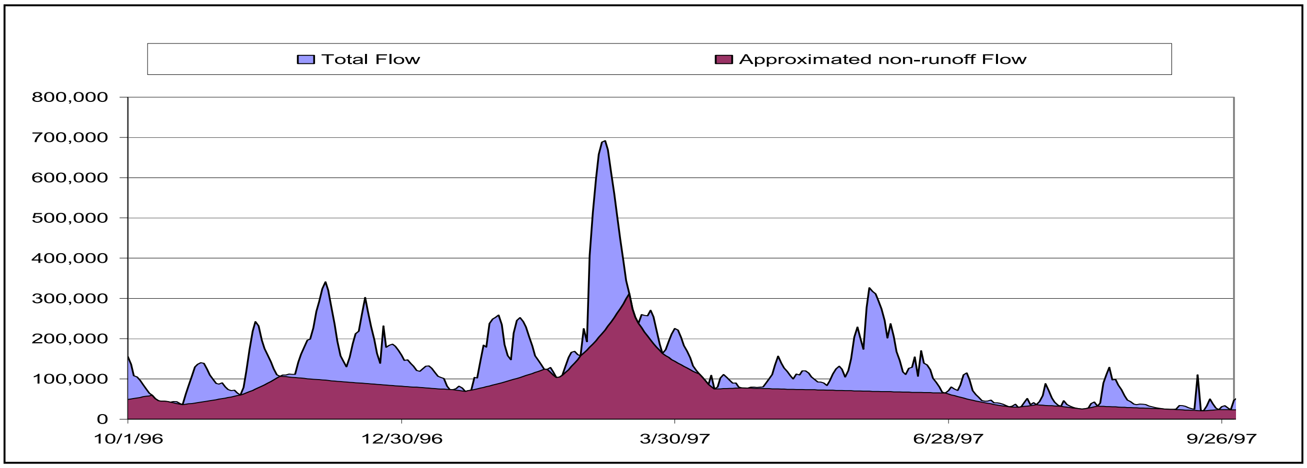
$$N = A^{0.2} \qquad \text{(equation 2.1)}$$

Where: A = the drainage area in square miles
N = the time base in days of direct runoff.[5]

Linsley, Kohler, and Paulhus in their 1958 publication also note that N is probably better determined by manual inspection of many hydrographs.

Manual inspection of Ohio River hydrographs for the previous 10 years yielded a shorter time base for the largest drainages than the estimating equation above. The drainage areas of ORSANCO Bimonthly Sampling Program stations range from 24,000 square miles at New Cumberland Lock and Dam to 185,575 square mile at Metropolis, Illinois. The Linsley recession estimation equation (2-1) and PART software give a possible range of seven to thirteen days for these drainages[6]. Manual inspection of 10-year hydrographs shows a more likely recession time of eight days at New Cumberland and ten days at Metropolis. The PART (Rutledge, 1998) software was used to analyze 10-year flow records for the recession periods determined by manual inspection.

Figure 2.4 -Hydrograph Analysis by PART software: Ohio River at Markland Dam 83,554 square mile drainage, required antecedent recession is nine days



[5] Linsley, et. al. Hydrology for Engineers, Second edition, 1958, McGraw-Hill, Inc.

[6] PART software allows the user to choose days of recession in integers from N to N+2

Table 2.1 Recession Index in Days Used for Runoff Analyisis

Station Name	Mile Point	Drainage Area (mi^2)	$A^{0.2}$	Recession Index Applied[1]
New Cumberland	54.4	24,000	7.517	8
Pike Island	84.2	24,700	7.560	8
Hannibal	126.4	25,745	7.623	8
Willow Island	161.8	27,516	7.725	8
Belleville	203.9	39,231	8.293	8
R.C. Byrd	279.2	52,914	8.805	8
Greenup	341.0	61,524	9.074	9
Meldahl	436.2	71,251	9.345	9
Anderson Ferry	477.5	71,417	9.349	9
Markland	531.5	83,554	9.647	9
Louisville	600.6	91,657	9.827	9
West Point	625.9	92,000	9.835	9
Cannelton	720.7	96,508	9.929	9
Newburgh	776.0	97,984	9.959	9
J.T. Meyers	846.0	108,254	10.160	10
Smithland	918.5	144,673	10.767	10
Metropolis	938.9	185,575	11.316	10

[1]Index in days determined from manual inspection of hydrographs

Flow Condition Separation

The output of PART was compared to sample dates to separate the monitoring record into the two major flow conditions: high runoff and low runoff. A sample was included in the low runoff group if on the collection date, the PART software determined that "base flow" was greater than 0.9 times total flow. For nearly all Ohio River monitoring points this separation resulted in a third of the 60-sample total population for the 10-year period being removed to the low-runoff group. One-year hydrographs with sample dates and runoff classifications are plotted in appendix B.

Low Runoff Loads

Average "low runoff" loads were calculated using the linear regression of pollutant concentration vs. the natural log of flow for the low runoff sample set. The concentration taken from the regression at the average low runoff flow was multiplied by the average low runoff flow to calculate a load. The calculated low runoff load was subtracted from the average load at all flow conditions to quantify the overland runoff contribution of the pollutant. This calculated value was used to arrive at the percentage of pollutant's load from overland runoff.

Samples were further divided into wet and dry seasons to account for differences in load, due to the great disparity in winter and summer flow. This data is presented in tabular form in appendix D.

Impact Assessment

Loads 1992-2002

Daily loads have been calculated for each sample day in the 10-year period from January 1992 to December 2001. For the 31 ORSANCO Bimonthly Sampling Program sample locations, sample populations for the analysis averaged 62 samples. Using hydrograph analysis, samples from each location were split into two groups: 1) samples taken during low runoff conditions and 2) samples collected in times of greater overland runoff. The criterion for this separation was based on antecedent days of flow recession as described previously in Section 2 of this report.

Monitoring Results

Complete results for the ten-year period at each monitoring station are presented in Appendix A and include the discharge number used to calculate a daily load from each sample.

Non-Detect Data

Due to high incidence of non-detect results and extended periods of missed analyses, five parameters: phenolics, cyanide, cadmium, mercury and arsenic were excluded from the hydrograph analysis and calculation of average loads. The presence of non-detect data is minor, however, in the parameters this report identifies as runoff-related nonpoint source pollutants. For the loading analysis all non-detect samples have been deleted except where the number of non-detections is greater than 5 percent. Three of the main runoff pollutants: lead, zinc, and phosphorus, have great enough incidences of non-detect data that a method was required to calculate accurate statistical parameters. Table 3.1 presents the number and percentage of non-detects in the ORSANCO Bimonthly Sampling Program data from 1992-2001. Sample populations reflect the number of samples taken over 10 years at 31 monitoring points in the Ohio River basin.

Table 3.1 Percentages of Non-Detects for Selected Parameters

Parameter	Detection limit	Sample Population	Number of Non-Detects	Percent of Non-Detects
Chloride (mg/l)	5	1477	1	0.1%
Magnesium (mg/l)	0.5	1470	1	0.1%
Sulfate (mg/l)	1	1538	3	0.2%
Manganese (ug/l)	10	1483	10	0.7%
Iron (ug/l)	(20 -- 100)	1482	15	1.0%
Nitrite/Nitrate (mg/l)	(0.02 -- 0.05)	1539	19	1.2%
Aluminum (ug/l)	(10 -- 100)	1473	49	3.3%
Suspended Solids (mg/l)	(1 -- 5)	1539	82	5.3%
Zinc (ug/l)	(10 -- 20)	1482	522	35.2%
Total Phosphorus (mg/l)	(0.05 -- 2.5)	1538	543	35.3%
Lead (ug/l)	(1 -- 5)	1464	581	39.7%

Percentage of non-detections for lead was 40 percent, phosphorus 35 percent, and zinc 35 percent. For these three parameters non-detections were substituted with three values: zero, the detection limit, and one-half of the detection limit. Loads for these parameters are presented graphically using all three substitutions (Appendix E). In the Appendix A (available online at www.orsanco.org) concentration tables, the "<" non-detect notation is included. One-half of the detection limit was used in tables for calculated runoff and total daily load. The effect of the substitution for non-detects is greatest for phosphorus because actual detections are frequently much greater than the detection limit. In the text, references to concentration or load averages use one-half of the detection limits unless otherwise specified.

Load Calculations

Each analytical result has been multiplied by the daily mean discharge in cubic feet per second to yield a load for a 24 hour period. The equation:

$$\text{Lbs/day} = (\text{C mg/L})\ (\text{Q ft}^3\text{/sec})\ (5.39\ \text{L} \cdot \text{day}^{-1}\text{/lb})$$

Where:
C is parameter concentration (mg/L)
Q is flow (cfs)

Non-point Source Pollutants

Eleven parameters included in the monitoring results of the ORSANCO Bimonthly Sampling Program have been identified as runoff-related nonpoint source pollutants. Two general methods for identifying nonpoint source pollutants have been used. Both are described in more detail in the Methods portion (Section 2) of this report:

- A positive slope in the regression of parameter concentration vs. the natural log of flow
- Subtraction of low-runoff sample day loads with loads on all other days to infer a load from runoff

The first, a positive relationship in concentration vs. the natural log of flow, yielded four pollutants. The second, using the analysis of 10-year hydrographs to find an average load of pollutants on low-runoff days and subtract it from the load on higher runoff days, confirmed the initial four and yielded positive results for the commonly accepted agricultural nutrient pollutants phosphorus and nitrate/nitrate. The hydrograph analysis method also indicates substantial runoff loadings for chloride, magnesium, sulfate, lead and zinc.

A positive regression slope by the simple least-squares method when concentration is plotted vs. natural log of flow indicates a pollutant with a runoff component. Pollutants whose concentration increased with flow at every station on the Ohio River are aluminum (total Al), iron (total Fe), manganese (total Mn), and suspended solids (TSS). This relationship was confirmed by linear regression analysis of the full 10-year monitoring data set for each station (N ~ 60). The criterion for inclusion in this group of four was a positive slope in the linear regression of concentration vs. the natural log of flow at all seventeen Ohio River bimonthly monitoring points. The hydrograph analysis process, identifying the contribution of runoff to the load of pollutants, strongly confirmed each of these four pollutant's load results from overland runoff.

Chloride, magnesium, and sulfate exhibit an opposite trend. These pollutants did not have a positive correlation with flow at any monitoring point. For parameters with negative or mixed results by regression analysis, comparison of loads in the two sample groups of low runoff and high runoff conditions shed some light on their sources. Also conspicuously missing from the regression analysis-generated list of four are the commonly accepted nonpoint source pollutants from the often-applied agricultural nutrients, phosphorus and nitrogen. These two pollutants emerge from the hydrograph-based runoff analysis showing roughly 50 percent of their loads from overland runoff.

Chloride, magnesium, and sulfate have been included in the list of eleven runoff pollutants. Loads of these pollutants are measured in the thousands of tons per day, in contrast to point source loadings that are much smaller. For example, total nitrogen point source loads in the Ohio River, from 3,600 sources, reach only 325 tons/day (USEPA, 1998)[7]; while the chloride load at Metropolis averages 28,000 tons/day. Sulfate and chloride, in addition to their massive loadings, are singled out because of their recognized nonpoint sources, mine drainage for sulfate and road salt/fertilizer usage for chloride. The major source of magnesium is likely sediment erosion. Magnesium is a secondary plant nutrient (plants require less magnesium than nitrogen, phosphorus, potassium, carbon, hydrogen and oxygen) and the seventh most abundant element in the earth's crust.[8]

It is clear that the pollutants whose concentrations increase with flow are at the top of the list in percentage of load from overland runoff. Lead and zinc, two metals with a weakly positive flow/concentration correlation (found at 12 and 16, respectively, of 17 Ohio River stations) follow the top four with more than half of their load resulting from overland runoff. Table 3.2 presents eleven pollutants, each with loads that have a large overland runoff non-point source component.

Table 3.2 Percentage of Pollutant Load from Runoff as Determined by Hydrograph Analysis

Pollutant	Percent of daily load from Runoff
Suspended Solids	87 %
Iron	84%
Aluminum	81%
Manganese	74%
Lead	74%
Zinc	70%
Total Phosphorus	55%

[7]USEPA, 1998. Documentation of phase I and Phase II Activities in Support of Point Source Nutrient loading Analysis in the Mississippi River System, Nonpoint Source Control Branch, Washington, D.C.

[8] CRC Handbook of Chemistry and Physics, 66th Edition, CRC Press, Inc. 1985, pg F-145

Nitrite/Nitrate	47%
Magnesium	45%
Sulfate	43%
Chloride	39%

The percentage reported in Table 3.2 is the average percent of load from runoff during both wet and dry seasons at all Ohio River monitoring stations. These results by monitoring station and parameter are presented in Appendix D.

Impact of Nonpoint Source Pollutants

The impact of the nonpoint source pollutants identified by this analysis is considered the total load of the pollutant at the mouth of the Ohio River. The estimated portion of each of the pollutants' load from nonpoint sources varies. However, it is most important to note simply the existence of a nonpoint source contribution to each of the pollutant's load.

Although the effects of these overland runoff pollution problems are not often felt in this river system (see 305b discussion below) the Ohio River is a source of the nutrients that create hypoxia problems in the Gulf of Mexico (see the daily average tonnages for each parameter in Appendix F). Due to human impacts, the remaining wetlands, forests and grasslands are unable to mitigate soil erosion and ensure balance in nutrient processes. The geographic concentration of humans, animals, and cropland in the Ohio River Basin requires a plan to address nonpoint source pollution impacts on the Gulf of Mexico if not the Ohio River itself. Loads of all identified NPS parameters are presented graphically and in tabular form in Appendices E and F.

305(b) Listed Impairments

ORSANCO's 2001 Ohio River 305(b) report lists none of the runoff-related pollutants identified above. Lead, however, exceeded the ORSANCO water quality criteria at Anderson Ferry, West Point and J. T. Myers sampling sites in 2001. The number of exceedences, one sample at each station, was less than the criterion for listing (10 percent of samples for the year); therefore no segments were listed for lead impairment in 2001.

For ORSANCO's *Biennial Assessment of Ohio River Water Quality Conditions for Water Years 2000 and 2001*, it was determined enough "clean" technique sample collection and analysis for dissolved metals data existed, that only violations of criteria based on the samples collected by the new clean method qualified for 305(b) impairment listings. The sampling method used for previous years of total recoverable metals bimonthly sampling includes all of the data for this nonpoint source study period of 1992 through 2001. Use of the total recoverable metals data to determine violations of lead criteria for 2001 would have generated six exceedences at the three above-mentioned sample points, and added one at Metropolis, Illinois.

Suspended Solids

ORSANCO monitoring for total suspended solids (TSS) employs EPA Method 160.2. Loads of suspended solids (average load per day in all seasons) in the Ohio River vary from 3,200 tons per day at Hannibal Lock and Dam (harmonic mean flow 20,500 cfs) to

42,000 tons per day at Metropolis (harmonic mean flow 175,000 cfs). Sedimentation in all streams, including the Ohio River system, reduces the viability of bottom substrate habitat for mussels and other benthic fauna. TSS from soil erosion is also a carrier of many of the other nonpoint source pollutants discussed here. Of the 42,441 tons/day load at Metropolis, Ill. the hydrograph analysis indicates 36,900 tons/day (87 percent) is the result of overland runoff.

Iron

ORSANCO's bimonthly sampling program has traditionally analyzed samples for total recoverable iron content using EPA method # 200.7, Determination of Trace Metals by Inductively Coupled Plasma (ICP). In the future all metals analysis for the Bimonthly Sampling Program will be done using the "clean" collection and analysis method (EPA 1600 series). Based on the older method, iron concentrations in the Ohio River are highest at Greenup Lock and Dam, just downstream of the primary iron-producing region in the Ohio River Basin. Iron loads in the Ohio River reach nearly 2,000 tons/day at Metropolis, Ill.; spiking sharply after the Kanawha River's confluence with the Ohio (from 262 to 684 tons/day) and doubling again from R.C. Byrd Lock and Dam (684 tons/day) to Greenup (1390 tons/day). Loads do not increase beyond the level at Greenup until the addition of Wabash River waters and Cumberland/Tennessee Rivers. The pattern of loadings (please refer to Appendix E, Fig. 4) indicates localized iron contamination in Ironton, Cincinnati, and Louisville. The iron load in these places is elevated above what can be seen in Appendix E, graph 4 to show a steady increase in iron loads from Pittsburgh to Metropolis. The percent of iron load from runoff is highest at Greenup and declines only slightly in the Cincinnati area to less than 70 percent. The runoff analysis indicates over the whole length of the Ohio River 84 percent of the iron load is from runoff.

Aluminum

Aluminum concentrations for all data included in this report have been analyzed by the total recoverable metals method. In the future aluminum analyses will also be done by "clean" methods and EPA 1600 series analysis for metals. In 1993, a third (31 percent) of the primary aluminum production capacity of the United States was in the Ohio River Valley (EPA, 1995)[9]. Aluminum, perhaps because of mining and production in the Ohio Valley, ranks third among pollutants in percent of load contributed by overland runoff. Total daily loads of aluminum average between 84 tons per day at Hannibal Lock and Dam, and 1,500 tons/day at Metropolis, Ill. Aluminum, however, clearly has point source contributions in addition to its nonpoint source overland runoff load.

Unlike any of the other twelve "runoff pollutants," aluminum concentrations peak (average 1.5 mg/L) and loads increase in the Cincinnati, Ohio, area between Meldahl Lock and Dam and the Anderson Ferry (downstream of Cincinnati) monitoring point. The tributary loads of the Little Miami, Licking, and Great Miami Rivers do not balance

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[9] EPA Office of Compliance Sector Notebook Project, Profile of the Nonferrous Metals Industry, EPA/310-R-95-010, September 1995, Office of Compliance, Office of Enforcement and Compliance Assurance, Washington, DC

this increase. A corresponding decrease in the percent of the aluminum load from runoff in this location indicates localized sources of aluminum that are not runoff-related. Overall 81 percent (1240 tons/day) of the 1,531-tons/day average at Metropolis is the result of overland runoff.

Manganese

Manganese data from the Bimonthly Sampling Program is generated using EPA method 200.7 for total recoverable metals. Manganese load averages in the Ohio River vary from 21 tons/day at the Willow Island monitoring station to 93 tons/day at Metropolis, Ill. The load of manganese is not very great in total mass, yet the correlation with runoff flows is among the strongest studied here with 74 percent of load in high runoff flows. Manganese loads mirror aluminum loads with a substantial increase in the Cincinnati area. Because manganese is used to prevent corrosion of aluminum, the industrial use of these metals is closely associated. It is likely the same point source explanation exists for manganese in the Cincinnati area as for aluminum.

Lead

Sampling results reported in this study (using total recoverable data from EPA method 200.8) would generate violations of ORSANCO water quality criteria for lead. Instream loads of total recoverable lead are highest at West Point, Ky 25 miles downstream of Louisville, where the average concentration over the ten-year period is 4.29 ug/L. Total recoverable lead concentrations on the ten-year average are higher at all sampling points than the Chronic Criterion at worst-case hardness (50mg/L) that is 1.32 ug/L[10]. Average daily lead loads (substituting half the detection limit for non-detects) are greatest at Metropolis, reaching 5,782 tons. About 4,000 tons of that average daily load result from overland runoff (74 percent) according to the hydrograph analysis.

Zinc

Zinc loads have been calculated with ten years of total recoverable zinc data analyzed by EPA method 200.7. The dataset includes 35 percent non detect values. Zinc loads (using half the detection limit for non-detects) show a longitudinal pattern unlike any of the other runoff parameters. From the first Ohio River monitoring point (mile 54.4), loads are steady (approximately 4.5 tons/day) until the addition of the Kanawha River waters. Loads below the Kanawha do not increase or decrease from 9.0 tons/day until the Anderson Ferry monitoring point below Cincinnati. Zinc loads gradually decrease from 14 tons/day to 10 tons/day at Cannelton Lock and Dam. Zinc loads do not exceed their Cincinnati level until the Wabash enters at Ohio River mile 848.

The unusual pattern in Zinc loads is due to eight major tributaries having only slight loads. Each increase in Ohio River load is preceded by the confluence of a tributary with a multi-ton/day load. Although the runoff correlation (percent of load from runoff) is strong for zinc at 70 percent, overall its non-uniform pattern indicates that even runoff loads are somewhat localized.

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[10] ORSANCO Pollution Control Standards for Discharges to the Ohio River, 2000 revision. Cincinnati , Ohio, October 12, 2000.

Total Phosphorus

Phosphorus is analyzed by U.S. EPA method 365.4 for total phosphorus which includes its insoluble compounds with Ca, Fe, and Al as well as the large portion of phosphorus in the environment that is sorbed to clay and soil particles. Phosphorus is very chemically reactive, and is so likely to form insoluble compounds that its main transport to surface waters is erosion of soil particles by runoff. Due in part to this chemical tendency, phosphorus has the greatest relative percent difference (90 percent) in its percent of total load from runoff between wet and dry seasons of all the runoff pollutants identified here.

From October to April, 64 percent of the average daily load of 30 tons (6.7 tons/day at mile 54.4, 70 tons/day at mile 938.9) total phosphorus is contributed by overland runoff. The highest average concentration (0.13 mg/L) of total phosphorus has been observed at the Louisville, Kentucky monitoring point (Ohio River mile 600.6). The Tennessee and Wabash rivers carry the greatest loads of total phosphorus to the Ohio River: a daily average of 13.5 and 12.6 tons respectively. Averaged over the whole year, the Ohio River's phosphorus load at Metropolis is 71 tons/day, of which half (55 percent) comes from overland runoff.

Nitrite/Nitrate

The nitrite/nitrate portion of nitrogen loads in the Ohio River is analyzed in the ORSANCO Bimonthly Sampling Program by EPA method 353.2. These forms of anionic nitrogen are unlikely to attract the negatively charged particles in soil. The ions are highly soluble in water and therefore leach easily out of soils in excess groundwater. The nitrate form of nitrogen is also directly available to plants, and is the most damaging in surface waters due to eutrophication and the de-oxygenation associated with the "dead zone" in the Gulf of Mexico. Total nitrite/nitrate nitrogen loads in the Ohio River are greatest at Metropolis, Ill. reaching an average of 942 tons/day. Nitrate loads in the upper river are constant at about one hundred tons per day from New Cumberland (mile 54.4) to Willow Island (mile 161.8). From that point downstream loads increase steadily with a slight peak at both Meldahl and Markland Dams. Hydrograph analysis indicates just under fifty percent of the nitrite/nitrate load comes from overland runoff. This compares to 65 percent from runoff calculated using the U.S. EPA estimated point source number (325 tons/day) and the Ohio River total load at Metropolis. (USEPA, 1998)

Magnesium

Magnesium is the central ion in chlorophyll *a* and ubiquitous in the environment. ORSANCO monitoring data for magnesium is also the result of EPA method 200.7, Magnesium's prevalence in the environment explains why the Ohio River load of magnesium increases as steadily as discharge, matching location for location the increase in flow. Yields (tons/square mile) of magnesium are nearly constant on the Ohio River; the maximum relative percent difference between the highest and lowest yield values is just 40 percent (average for the eleven runoff pollutants is 97 percent). The total load of magnesium at Metropolis is 7,250 tons/day; hydrograph analysis suggests 45 percent of that load is due to overland runoff.

Sulfate

Sulfate is analyzed by EPA method 375.4. Sulfate is a generally accepted indicator of acid mine drainage and, not surprisingly, its highest concentrations in the Ohio River are seen primarily in the mining districts of Pennsylvania, Ohio and West Virginia. Sulfate concentration averages 80 mg/L at Hannibal, Willow Island and Belleville dams. Average concentration falls to about 65 mg/L at all other Ohio River monitoring points. Ohio River sulfate loads start at more than 6,000 tons/day at mile 54.4 and increase to 35,000 tons/day at Metropolis. Continual stack emissions of sulfur from coal burning power plants and industries contribute to deposition and resulting runoff over the entire Ohio River Basin. The percent of the sulfate load from runoff is highest, reaching 60 percent, at R. C. Byrd Lock and Dam 75 miles downstream of Belleville and 15 miles downstream of the Kanawha River confluence. The average for the rest of the Ohio River is much lower; overall only 43 percent of the sulfate load can be matched to days of high runoff. The weaker than expected correlation between sulfate loads and overland runoff is due in part to the difference between upper and lower river land uses in the Ohio basin.

Chloride

Chloride is analyzed by EPA method 325.3. Chloride is second to phosphorus in difference between runoff load in the wet and dry seasons. This is likely a reflection of the use of chlorides as fertilizer binding agents and wintertime road amendments. The solubility of chloride may be a mediating factor in its lingering load over the course of the year. Average daily loads of chloride in the Ohio range from 2,200 tons/day at Ohio River mile 54.4 to nearly 28,000 tons/day at Metropolis, Ill. at Ohio River mile 938.9. Chloride loads and concentrations increase at Smithland Dam below the confluence of the Wabash River. The average daily concentration of chloride at J. T. Myers is 22 mg/L while at Smithland Dam concentrations average 46 mg/L. This increase in concentration is likely a result of the widespread use of muriate of potash (KCl) as a source of potassium fertilizer in the Wabash River basin.

Photo by E. Hobbins

Ranking of Major Tributaries by NPS Pollutant Contribution

Twenty-one tributaries to the Ohio River have watersheds greater than 1,000 square miles. With the exception of the Hocking River, average daily loads and yield for these drainages have been calculated for the period from January 1992 through December 2001. Average daily loads calculated from 10 years of bimonthly samples are presented graphically in Appendix G. Average daily loads, yields, and numerical ranking of tributaries based on all loads are presented in Appendix H. Tributary yield graphs are presented in Appendix I.

The ORSANCO Bimonthly Sampling Program monitors 14 of the 21 major tributaries. ORSANCO monitoring points are near each tributary's confluence with the Ohio River and designed to capture a large percent of the waterway's total drainage. State agency data from STORET was used for five of the tributaries not monitored by ORSANCO. Unfortunately, a search of other agency data for the Hocking River did not reveal any comparable monitoring data from sample points capturing the majority of the drainage.

The 21 major tributaries, their drainage area, mile point of confluence with Ohio River, and source of monitoring data for this analysis are presented in table 4.1.

Table 4.1 Major Ohio River Tributaries (i.e. watersheds >1,000 mi^2)

Tributary Name	Confluence Mile Point (ORM)	Drainage Area (mi^2)	Agency Source of Monitoring Data
Allegheny River	0.0	11,700	ORSANCO
Monongahela River	0.0	7,400	ORSANCO
Beaver River	25.4	3,130	ORSANCO
Muskingum River	172.2	8,040	ORSANCO
Little Kanawha River	184.6	2,320	WV DEP
Hocking River*	199.3	1,190	USGS, COE, OEPA
Kanawha River	265.7	12,200	ORSANCO
Guyandotte River	305.2	1,670	WVDEP, USGS
Big Sandy River	317.1	4,280	ORSANCO
Scioto River	356.5	6,510	ORSANCO
Little Miami River	464.1	1,670	ORSANCO
Licking River	470.2	3,670	ORSANCO
Great Miami River	491.1	5,400	ORSANCO
Kentucky River	545.8	6,970	KY DNREP
Salt River	629.9	2,890	KY DNREP
Green River	784.2	9,230	ORSANCO
Wabash River	848.0	33,100	ORSANCO
Saline River	867.3	1,170	IL EPA, USGS
Tradewater River	873.5	1,000	KY DNREP
Cumberland River	920.4	17,920	ORSANCO
Tennessee River	934.5	40,910	ORSANCO

* Insufficient data was located for this tributary to be included in the load ranking

Tributary Loads

The Wabash River, second only to the Tennessee River in drainage area, contributes the greatest average daily loads of many of the previously identified runoff pollutants. The Tennessee River, with drainage area about 20 percent larger than the Wabash, does not contribute as great a load because of the Kentucky Dam impoundment 22 miles upstream of its confluence with the Ohio River. Also notable, however, the Allegheny and Monongahela rivers necessarily contribute 100 percent of the Ohio River's initial load. Also entering the Ohio River upstream of the first Ohio River mainstem sampling point is the Beaver River (enters at mile 25.4).

Other tributaries with the potential to contribute a large percentage of the Ohio River's load are the Kanawha and Kentucky Rivers. The Kanawha's 12,200 square mile drainage causes a near doubling of loads in the Ohio River between the Belleville and R.C. Byrd dams. At this point, the total drainage of the Ohio River including the Kanawha basin is 52,900 square miles. The Kentucky River similarly causes a sharp increase in the Ohio River metals load between Markland Dam and Louisville. The Scioto River in Ohio contributes large loads of nitrite/nitrate, ammonia and magnesium. For those three pollutants only, the Ohio River load increases between the Greenup and Meldahl Lock and Dams, where the Scioto River enters the Ohio.

The Saline River in Illinois and the Beaver River in Pennsylvania are standouts in terms of pollutant mass per square mile of drainage (yield). In the upper Ohio River the load contributed by the Beaver is often substantial when compared to the greater drainages of the Allegheny and Monongahela. For sulfate, phosphorus and suspended solids the Saline has the greatest yield of all 19 tributaries surveyed. The Saline is also second only to the Beaver in yields of some metals (including aluminum, iron, manganese).

All land use statistics in the following tributary descriptions are taken from a 1997 United States Department of Agriculture National Resources Inventory, revised in December 2000 (USDA, 2000).

The Tributaries

Allegheny River

The Allegheny, with the Monongahela, forms the beginning of the Ohio River at Point State Park in Pittsburgh, Pennsylvania. The Allegheny drainage of 11,700 square miles begins in north central Pennsylvania, encompasses a 1,955 square mile area in New York State, and turns southwest to drain the western third of Pennsylvania. The ORSANCO monitoring point on the Allegheny used in this assessment is located at the Pittsburgh Water Intake Structure (river mile 7.4). Monitoring data for the Allegheny reveals the impacts of mining activity, with a sulfate load equaling that of the much larger Tennessee River. In a comparison of yields (Appendix I) the Allegheny also shows elevated loads of the metals manganese and magnesium. The Allegheny's manganese load is greater than any other major tributary of the Ohio River.

Monongahela River

Forming the Ohio River with the Allegheny in Pittsburgh, the Monongahela (7,400 mi^2 drainage area), drains the southwest quarter of Pennsylvania and a large portion of central

West Virginia. The Monongahela drainage, by virtue of the Youghiogheny River, also drains a portion of far western Maryland. The ORSANCO monitoring point on the Monongahela used for this assessment is located at the Pennsylvania American Water Company Becks Run Road intake station, South Pittsburgh (river mile 4.5). The Monongahela enters the Ohio with loadings from the mining country of West Virginia. Only the Wabash River exceeds the sulfate loads present in the Monongahela.

Beaver River

The Beaver River has a largely industrialized 3,130 square mile drainage area in northeastern Ohio and the central west of Pennsylvania. The ORSANCO monitoring point on the Beaver used in this assessment is located in the inlet chamber of the Beaver Water Works treatment building at Beaver Falls, Pennsylvania (river mile 5.3). The Beaver River yields (mass/unit area) are greater than all other major tributaries in aluminum, iron, manganese and lead. Beaver River loads are sizable in iron, lead, and sulfate. Despite its being only the fourteenth largest tributary out of 21, it ranks second in total load per day for those pollutants.

Muskingum River

Draining just over 8,000 square miles in southeast Ohio, the Muskingum enters the Ohio River at mile 172.2 in Marietta, Ohio. A large portion of the Muskingum drainage is managed as the Wayne National Forest. The Muskingum watershed also includes an area of mine-disturbed land comparable to the West Virginia drainages of the Monongahela and Big Sandy Rivers (ORSANCO, 1994)[11]. The ORSANCO monitoring point on the Muskingum used in this assessment is located under the Route 7 Bridge at Marrietta, Ohio (river mile 0.8). Monitoring data from the Muskingum shows its mixed land uses. Phosphorus, chloride and nitrite/nitrate loads are all as great or greater than half the other major tributaries; as is the sulfate load, which ranks fifth out of 20.

Little Kanawha River

Entering the Ohio at mile 184.6, the Little Kanawha drainage covers 2,320 square miles of central West Virginia to the south and east of the Monongahela River tributaries. The West Virginia Department of Environmental Protection collects the Little Kanawha monitoring data used in this assessment, at Elizabeth, West Virginia (approximately river mile 26). The Little Kanawha yields very little of the agricultural pollutants, but like the Beaver River, has demonstrated metals problems and exceeds all tributaries except the Tennessee in total recoverable lead loads.

Hocking River

Like the Muskingum, much of the Hocking River's 1,190 square mile watershed is managed as part of the Wayne National Forest. No comparable record of monitoring data was found for the Hocking River. Therefore, it is eliminated from further discussion of its ranking in terms of nonpoint source overland runoff pollution.

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[11] ORSANCO (1994), *Ohio River Fact Book*, Cincinnati, Ohio, December 1994.

Kanawha River

Contributing 25 percent of the Ohio River flow at its confluence with the Ohio at mile 265.7, the Kanawha River drains a 12,200 square mile area of the Appalachian Mountains in West Virginia, Virginia and northeast Tennessee. The ORSANCO monitoring point on the Kanawha used in this assessment is located at the Winfield Dam hydroelectric plant (river mile 31.1). Water quality monitoring data reflects the mostly forested watershed. The Kanawha has some of the smallest pollutant yields of all the major tributaries. Due to its great size, however, loads of suspended solids, phosphorus and lead rank in the top five of the 20 major tributaries examined here.

Guyandotte River

With just 1,670 square miles of watershed that is over 80 percent forested, the Guyandotte exhibits characteristics similar to the larger Kanahwa River to its North. The Guyandotte enters the Ohio River at mile 305.2, very close to the entrance of the Big Sandy. In this location, the pollutant loads of the Guyandotte are not very clearly seen in the Ohio. The West Virginia Department of Environmental Protection and USGS collect the Guyandotte monitoring data used in this assessment at Huntington, West Virginia (river mile 2.8). The Guyandotte is often overshadowed by the massive input of the Kanawha River and its loads are combined with the Big Sandy waters before the next ORSANCO Ohio River Bimonthly monitoring point at Greenup Lock and Dam (Ohio River mile 341.0). Thus the Guyandotte's modest loads of sulfate and metals are barely noticeable.

Big Sandy River

The Big Sandy River which forms the West Virginia/Kentucky border drains 4,280 square miles in forested western West Virginia and eastern Kentucky. Like the Guyandotte, loads from the Big Sandy are dwarfed by the greater drainage of the similarly forested Kanawha River. The ORSANCO monitoring point on the Big Sandy used in this assessment is located outside the raw water intake structure of AEP – Kentucky Power Company at Louisa, Kentucky (river mile 20.3). The Big Sandy River carries the eighth largest load and fourth greatest yield of sulfate, a good indicator of the detrimental impacts of the mining industry.

Scioto River

The 6,510 square mile drainage of the Scioto is the first major agricultural drainage to enter the Ohio River. The Scioto watershed lies entirely within the state of Ohio, to the west of the Muskingum drainage. The ORSANCO monitoring samples collected on the Scioto are taken from the center of the Route 348 Bridge at Lucasville, Ohio (river mile 15.0). The Scioto's confluence with the Ohio River at mile 356.5 brings the first large load of nitrate. The Scioto River carries the fourth largest load of nitrite/nitrate despite its rank as the tenth largest of the major tributaries.

Little Miami River

Entering the Ohio River on the east side of metropolitan Cincinnati, the 1,670 square mile drainage of the Little Miami River represents agriculture as well as the sedimentation of suburban development. The Little Miami drainage is also entirely within the state of

Ohio, draining a swath of southwest Ohio just east of the Great Miami River drainage. The ORSANCO monitoring samples collected on the Little Miami are taken from the center of the Newtown Road Bridge in Newtown, Ohio (river mile 7.5). The Little Miami carries the smallest load of sulfate among the major tributaries, and carries no more of the agricultural nutrients than would be indicated by its rank in size among the agricultural basins of the middle and lower Ohio River.

Licking River

The Licking River drains a 3,670 square mile portion of central Kentucky and enters the Ohio River opposite downtown Cincinnati. Land use in the Licking River watershed is heavy on pastureland as opposed to cropped acreage. The ORSANCO monitoring point on the Licking used in this assessment is located at the Northern Kentucky Water intake at Covington, Kentucky (river mile 4.7). Monitoring data for the Licking shows its yield of suspended solids is slightly less than average for the major tributaries, at 564 pounds per square mile per day. The Licking's yield of suspended solids is also less than the average of the three most forested basins: the Kanahwa, Big Sandy and Guyandotte river basins.

Great Miami River

The Great Miami River, entering the Ohio River just downstream of Cincinnati at mile 491.1, drains 5,400 square miles of western Ohio and eastern Indiana. This watershed, with extensive area in suburban and industrial development, is large enough to encompass more than 3,000 square miles of agricultural land as well (comprising 60 percent of the total basin). The ORSANCO monitoring samples collected on the Great Miami are taken from the Route 50 Bridge at Cleves, Ohio, near the right descending bank (river mile 8.0). Great Miami River monitoring data fits the profile of an agricultural basin. The river contributes 77 tons of nitrite/nitrate and 4.6 tons of phosphorus to the Ohio River per day, making it fifth in phosphorus loading while in basin size it ranks only eleventh.

Kentucky River

In central Kentucky the largest waterway is the Kentucky River, draining 6,970 square miles that is primarily forested (yet nearly 30 percent pastureland). The Kentucky Division of Water collects monitoring data used in this assessment at Kentucky River Lock 2 at Lockport, Kentucky (river mile 31.0). The Kentucky River ranks sixth (just below the Great Miami) in phosphorus load. An average of 2,800 tons of suspended solids per day ranks the Kentucky River second behind the Wabash in suspended solids. The Kentucky River also carries the third largest load of iron of any tributary to the Ohio.

Salt River

The Salt River, with most of its lower basin occupied by Fort Knox (located southwest of Louisville, Kentucky), should have an interesting water quality profile. However, no comparable record of water quality data is available downstream of the Ft. Knox property. Monitoring data for the Salt has been taken from KYDNREP stations on the Salt at Shepardsville and at the Rolling Fork of the Salt near Lebanon Junction — both upstream of the military installation at Fort Knox. Salt River loads reported in this assessment are the sum of loads at each monitoring station, forming a virtual monitoring station approximating mile 11.5 where the two forks meet. Loads were added for samples collected on the same day, with no additional requirement for matching the time of sample collection.

Concentrations reported for the Salt have been calculated by dividing the combined mass of pollutant by the combined volume of discharge. The Salt River's average total phosphorus load, 6,876 lbs/day, is greater than thirteen of the major tributaries, earning it the second highest tributary yield in the basin.

Green River

The Green River's 9,230 square mile watershed in western Kentucky includes nearly equal areas of cropland, pasture, and forest. The ORSANCO monitoring point on the Green used in this assessment is located at the Big Rivers Electric Plant intake structure at Sebree, Kentucky (river mile 41.3). Yields of suspended solids in the Green River are well below the average for the major tributaries. The Green averages 1,500 tons of suspended solids per day, ranking thirteenth out of 20 tributaries.

Wabash River

The second largest sub-basin in the Ohio River valley, the Wabash, drains 33,000 square miles of Indiana and Illinois. This land is predominantly cropland, more so than any of the other Ohio River tributaries. In Illinois, Pennsylvanian coal deposits underlie most of the Wabash drainage, and the extraction operations lead to sulfate loadings (ISGS, 1997)[12]. Commercial navigation on the Wabash ended in the mid-1800's. The ORSANCO monitoring point on the Wabash used in this assessment is located at the center of the Route 62 Bridge at Mount Vernon, Indiana (river mile 28.5). Due to an absence of navigation and flow augmentation dams, the Wabash carries runoff pollutants without interruption from the whole of its drainage. The Wabash tops the list with the greatest loads of suspended solids, sulfate, nitrite/nitrate, magnesium, aluminum, iron and manganese.

Saline River

With a drainage of only 1,170 square miles, the Saline River is the second smallest of the major Ohio River tributaries. The Saline carries substantial loads of mining runoff from southeast Illinois. The Illinois EPA and USGS collect Saline River monitoring data used in this assessment at Gibsonia, Illinois (river mile 9.3). In comparison to other major Ohio River tributaries, the Saline often rises to the top of the list in terms of load per square mile. The Saline has the highest yields of suspended solids, phosphorus and sulfate. Only the Beaver River exceeds the Saline's yields of iron and manganese. The Saline nearly matches the Beaver and Guyandotte's yield of aluminum at 42 pounds per square mile per day. The impact of the Saline River on loads of runoff pollutants in the Ohio River is hard to discern at less than 5 percent of the total suspended solids load at Smithland Lock and Dam, the nearest downstream monitoring point. Removing drainage

[12] ISGS, 1999, Availability of Coal Resources for Mining in Illinois, C. G. Treworgy and D. L. North, open File Seriies 1999-7, Department of Natural Resources, Illinois State Geological Survey, Champaign, IL

area from consideration, the Saline ranks no higher than twelfth in daily load among the 20 tributaries.

Tradewater River

The Tradewater is the smallest major Ohio River tributary, with drainage of roughly 1,000 square miles in western Kentucky. The Kentucky DNREPC collects Tradewater River monitoring data used in this assessment near Sullivan, Kentucky (river mile 15.2). Water quality data from the Tradewater River reveals minor impacts from forestry and mining. Tradewater River yields of all eleven runoff pollutants are below the average yield for the major Ohio River tributaries. The Tradewater has the least load of all 20 tributaries in suspended solids, chloride, nitrite/nitrate, phosphorus, sulfate, aluminum, iron, lead and zinc. Only the Little Kanahwa and Little Miami both carry lesser loads of manganese to the Ohio.

Cumberland River

The Cumberland is the third largest Ohio River tributary with a 17,920 square mile watershed. Cumberland drainage begins in south central Kentucky, covers a portion of northern Tennessee and turns north back into Kentucky before entering the Ohio River at mile 920.4. The Cumberland has two major impoundments, one located just thirty miles from the Cumberland's confluence with the Ohio River. The effect of the downstream impoundment, Barkley Dam, is to settle most suspended pollutants out of the water column. The ORSANCO monitoring samples on the Cumberland used in this assessment are taken from the raw water line at the Crittenden-Livingston Water Plant, Pinckneyville, Kentucky (river mile 16.0). In the Cumberland and Tennessee Rivers, yields are misleading due to the effect of the flood control dams near the Ohio River. The Cumberland's load of each of the 11 Ohio River runoff pollutants (except lead and zinc) is exceeded by both the Wabash and the Tennessee Rivers. The average of 607 pounds of lead per day from the Cumberland is the greatest lead load entering the Ohio River, and at 2.3 tons per day the Cumberland's load of zinc is exceeded only by the Tennessee River.

Tennessee River

The Tennessee River enters the Ohio just 46 miles above the Ohio's confluence with the Mississippi River. The Tennessee River drainage begins in northern Alabama, claims a small piece of northeast Mississippi, and drains most of western Tennessee before crossing Kentucky. ORSANCO collects monitoring data at Metropolis, IL, downstream of the Tennessee, so the Tennessee is included here as a contributor to the total load of the Ohio River as it enters the Mississippi. The Kentucky Dam, 22 miles upstream of the Ohio, captures the vast majority (about 90 percent) of the Tennessee River's drainage and with it most of the river's suspended load. The ORSANCO monitoring point on the Tennessee used in this assessment is located at a fleeting operation in Paducah, Kentucky (river mile 6.0). The Tennessee contributes just 5 percent of the Ohio River's suspended solids load at Metropolis. This figure is comparable to the percent of the Ohio's solids load contributed by the Saline River, a basin 35 times smaller than the Tennessee. The Tennessee does carry the greatest load of soluble pollutants like chloride and zinc. The Tennessee also carries a greater load of phosphorus, on average 13.5 tons per day.

Tributary Rankings by Selected Pollutants

Ranking the major tributaries of the Ohio by their nonpoint source pollution impact on the Ohio has been accomplished by analyzing their total loads of each of the pollutants identified as runoff problems in the Ohio River. Eleven pollutants were identified in the runoff analysis of Ohio River monitoring data: total suspended solids, chloride, nitrite/nitrate, phosphorus, sulfate, aluminum, iron, magnesium, manganese, lead and zinc. Tabular and graphical data comparing the loads of all 11 pollutants are presented in Appendices G and H. Ranking tributaries by each of these runoff pollutants would generate very similar results. Five rankings have been chosen for their differences in tributary order, and usefulness in indicating land use issues that contribute to runoff pollution impacts for the Ohio River.

Suspended Solids

Possibly the best indicator of all runoff pollution is Total Suspended Solids (TSS). Mining, logging, agriculture, and suburban sprawl can all cause increased loads of suspended sediment. Urban and industrialized areas contribute loads of suspended solids with a different chemical makeup than the rural land uses. High loads of solids, even without the addition of metals or other chemical contaminants from industrialized areas, are responsible for decreases in benthic habitat in waterways of all sizes.

The presence of high suspended solids loads can be the product of poorly managed land resources in all land classes. Some examples of land management that creates erosion are ineffective streamside buffer zones, lack of best management plans (BMPs) for silviculture and other cropping, mountaintop removal and strip mining, urban and suburban increases in impermeable land surface, and channelization of existing waterways.

Photo by E. Hobbins

The Kentucky River's inordinately large sediment load is seen here in fresh erosion of sediment left after spring high water. (Owen County, Kentucky)

Ohio River tributaries contribute 36,000 tons of the average 42,000 tons of suspended solids that the Ohio River carries into the Mississippi every day. The highest and lowest loads sampled in the 10-year period at Metropolis, IL were 244,974 tons (140 mg/L) on March 13, 1995 and 499.7 tons (7mg/L) on September 8, 1999. Two non-detects and two days of higher (160 and 178 mg/L) TSS concentrations have been recorded at Metropolis. The two days noted are simply the greatest and least loads recorded.

Tributary data shows the greatest suspended solids load from the Wabash River (33,100 sq. mi.) with an average of 7,500 tons per day. This basin carries more sediment to the Ohio River than even the larger Tennessee River basin (40,910 sq. mi.) because it lacks an impoundment like that on the Tennessee. A ranking of major tributaries by average suspended solids loads from 1992 through 2001 follows in table 4.2.

Table 4.2 Ranking of Major Ohio River Tributaries by Average Daily Load of Suspended Solids

Rank	Tributary Name	Confluence Mile Point	Drainage Area (sq. mi.)	Suspended Solids (tons/day)
1	Wabash	848	33,100	7,501.2
2	Kentucky	545.8	6,970	2,880.5
3	Beaver	25.4	3,130	2,712.9
4	Kanawha	265.7	12,200	2,508.1
5	Allegheny	0	11,700	2,249.9
6	Great Miami	491.1	5,400	2,241.6
7	Tennessee	934.5	40,910	2,155.8
8	Muskingum	172.2	8,040	2,054.5
9	Salt	629.9	2,890	1,984.0
10	Cumberland	920.4	17,920	1,702.8
11	Big Sandy	317.1	4,280	1,655.5
12	Scioto	356.5	6,510	1,576.1
13	Saline	867.3	1,170	1,556.4
14	Green	784.2	9,230	1,512.2
15	Monongahela	0	7,400	1,139.7
16	Licking	470.2	3,670	1,035.4
17	Little Kanawha	184.6	2,320	952.8
18	Guyandotte	305.2	1,670	789.2
19	Little Miami	464.1	1,670	483.4
20	Tradewater	873.5	1,000	249.7

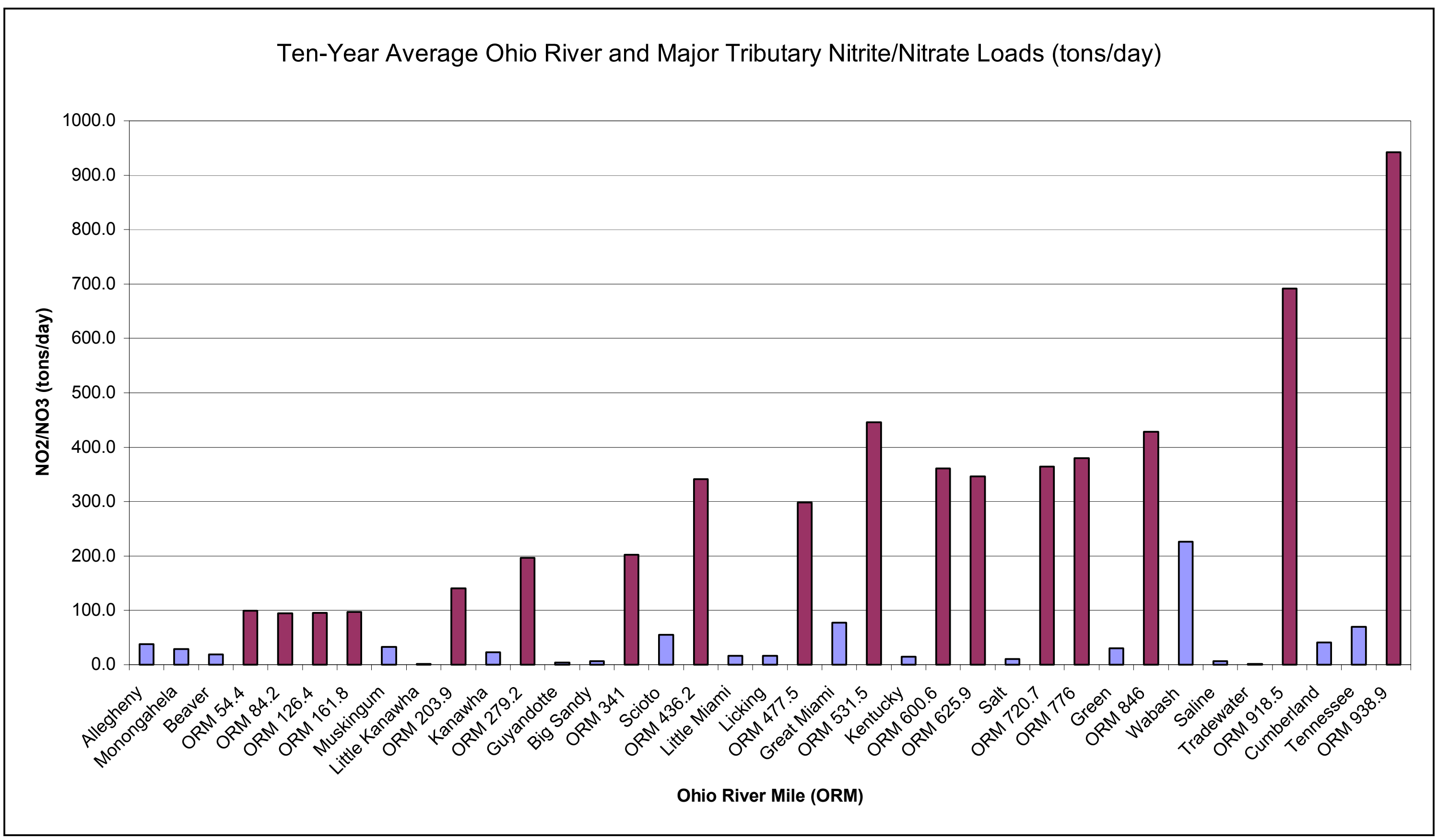
Nitrite/Nitrate

Excess nitrogen in water encourages the growth of algae and eventually causes hypoxia when the decomposition of algae uses up available oxygen. This is a concern in the Ohio River Valley because of the great impact Ohio River nutrient loads have on the Gulf of Mexico. In the Ohio River itself, nitrate and nitrite increase carbon demand for drinking water utilities and encourage algal blooms that can cause taste and odor problems requiring additional chlorine treatment. ORSANCO is currently beginning the process for developing nutrient criteria for the Ohio River.

The Wabash River carries the largest load of nitrite/nitrate to the Ohio River. Ranked by their 10-year average of daily loads, the Wabash is followed by the Great Miami, Tennessee, and Scioto Rivers. At a 10-year average of 225 tons per day nitrite/nitrate, the Wabash load is more than twice that of the Great Miami, the second largest nitrogen contributor. Using ORSANCO data from the nutrients program, in which Total Kjeldahl Nitrogen (TKN) was analyzed November through May only, nitrite/nitrate is 75 percent of the total nitrogen load in the Wabash, Great Miami and Scioto Rivers. Using that ratio, the Wabash River total nitrogen load entering the Ohio River is likely 300 tons per day on average.

Figure 4.1 shows the average daily load over the 10-year period at each Ohio River monitoring point and all major tributaries to the Ohio. Averaged over this length of time the daily loads of the tributaries are clearly seen in the daily load carried by the Ohio River. The impact of the Scioto, Great Miami, Wabash, and Cumberland and Tennessee rivers is reflected in the nitrite/nitrate load increase of the closest downstream Ohio River monitoring point.

Fig 4.1 Average Daily Loads of Nitrite/Nitrate at Ohio River Monitoring Points and Major Tributaries



A complete ranking (see ranking in tabular and graphic form in Appendices G and H) of tributaries by the 10-year average of daily nitrite/nitrate loads is Wabash (225 tons/day), Great Miami (77 tons/day), Tennessee (69 tons/day), Scioto (54 tons/day), Cumberland (41 tons/day), Allegheny (37 tons/day), Muskingum (32 tons/day), Green (30 tons/day), Monongahela (28 tons/day), Kanawha (22 tons/day), Beaver (18 tons/day), Little Miami (16 tons/day), Licking (16 tons/day), Kentucky (14 tons/day), Saline (6 tons/day), Big Sandy (6 tons/day), Guyandotte (4 tons/day), Little Kanawha (1.5 tons/day), Tradewater (1 ton/day).

Total Phosphorus

Like a ranking by nitrite/nitrate phosphorus loads primarily indicate agricultural impacts in the tributary basins. Possibly because of the differences in solubility of these pollutants, the order of tributaries when ranked by their average daily load of total phosphorus is very different from nitrate/nitrite.

Phosphorus is generally thought to be the limiting factor in freshwater systems (U.S. EPA, 1992)[13], limiting the algal blooms that cause taste and odor problems for drinking water utilities on the Ohio. Datasets for total phosphorus for the nineteen tributaries included 23% non-detects. The rank of tributaries presented in Table 4.3 substitutes non detects with one-half the detection limit.

Photo by E. Hobbins

Winter cover crops and conservation tillage, two agricultural Best Management Practices (BMPs) evident in Pope County, Illinois

Table 4.3 Ranking of Major Ohio River Tributaries by Average Daily Load of Total Phosphorus

Rank	Tributary Name	Average Phosphorus Load ND=1/2DL (lbs/day)	Average Phosphorus Concentration ND=1/2DL (mg/l)
1	Tennessee	27,029	0.072
2	Wabash	25,271	0.181

[13] USEPA, 1992, An Updated Summary of Status and Trends in Indicators of Nutrient Enrichment in the Gulf of Mexico, page 12, USEPA, Office of Water, Gulf of Mexico Program, Stennis Space Center, MS, EPA 800-R-92-004, September 1992.

3	Cumberland	17,367	0.100
4	Kanawha	15,475	0.166
5	Great Miami	9,177	0.238
6	Kentucky	8,630	0.108
7	Salt	6,868	0.205
8	Green	6,378	0.102
9	Allegheny	5,839	0.068
10	Muskingum	5,740	0.163
11	Monongahela	4,148	0.094
12	Scioto	3,864	0.170
13	Licking	3,763	0.174
14	Saline	3,707	0.151
15	Beaver	2,556	0.172
16	Big Sandy	1,833	0.072
17	Little Miami	1,478	0.166
18	Guyandotte	1,462	0.066
19	Little Kanawha	1,235	0.069
20	Tradewater	556	0.087

<u>Lead</u>

Of the eighteen metals routinely analyzed in ORSANCO bimonthly samples, there are just six metals identified by this analysis as “runoff pollutants.” Of these, lead is the metal of greatest concern. The human health effects of lead are well documented, and its toxicity is perhaps the best known among the general population. Before the use of the “clean” sampling method and dissolved metals analysis for 305(b) listed impairments, lead had been the cause of use impairments in the Ohio River.

Concentrations of lead are greatest in the Big Sandy River, averaging 5.33 ug/L in the 10-year period. The Tennessee River has the lowest concentrations (1.26 ug/L) but the third largest load at an average of 450 pounds per day. The greatest load of lead to the Ohio River is from the Cumberland River (600 lbs/day) followed by the Wabash River at 500 pounds per day.

At high turbidities, lead concentrations are highly variable. The averages given in the paragraph above eliminate three values that would have a great effect on the ranking. On January 8, 1998, ORSANCO sampled the Beaver River and a found lead concentration of 250 ug/L at a TSS concentration of 1,100 mg/L. Including this value in the Beaver River data set raises its average concentration to 9.64 ug/L. A more questionable sample was taken on the Little Kanawha May 13, 1996. This sample showed a lead concentration of 330 ug/L at a TSS concentration of 180 mg/L. Two weeks later the Little Kanawha was sampled at the same location and found to have a lead concentration of 5 ug/L at the same TSS concentration (180 mg/L). On the Guyandotte a lead concentration of 100 ug/L was found May 31, 1996 at a TSS of 80 mg/L. This sample has also been excluded from the averages used for ranking the tributaries. If each of these samples were included in the ranking of tributaries by lead concentration and loads the Little Kanawha, Beaver, and Guyandotte would top the list for highest concentration. They would also rank differently in average lead loads. Table 4.4 lists each tributary, its average daily lead load, and average lead concentration excluding the three values mentioned above.

Table 4.4 Ranking of Major Ohio River Tributaries by Average Daily Load of Lead

Rank	Tributary Name	Average Lead Load ND=1/2DL (lbs/day)	Average Lead Concentration ND=1/2DL (ug/L)
1	Cumberland	607	3.60
2	Wabash	501	3.15
3	Tennessee	449	1.26
4	Allegheny	250	1.59
5	Kanawha	231	8.88
6	Monongahela	211	2.03
7	Kentucky	202	2.24
8	Big Sandy	173	5.33
9	Great Miami	166	2.96
10	Green	149	2.24
11	Muskingum	146	2.03
12	Scioto	134	7.94
13	Guyandotte	107	5.73
14	Beaver	96	9.64
15	Salt	82	2.94
16	Licking	78	3.35
17	Saline	42	2.82
18	Little Miami	32	2.00
19	Little Kanawha	20	1.81
20	Tradewater	16	2.28

Sulfate

Sulfate loads are indicators of acid mine drainage in the Ohio River Valley. Host rock associated with most types of mining activity contains metal sulfide minerals. Oxidation of minerals and the formation of sulfuric acid is a natural process accelerated by extraction operations that expose large amounts of sulfide rock material as tailings and waste rock (USEPA, 1994)[14]. The Monongahela carries the second largest load of sulfate to the Ohio River, yet it is only the eighth largest drainage area of all the tributaries. The largest load of sulfate brought by a single tributary is the 3,378 tons of sulfate per day carried by the Wabash River. Sulfate concentrations in the Wabash are below the average for the 19 major tributaries (83.7 mg/L) at 57.7 mg/L. The highest average sulfate concentrations in the 10-year period have been recorded in the Saline River, a waterway draining part of Illinois' widespread coal mining region. The Tradewater, Little Kanawha, Big Sandy and Muskingum rivers follow closely in sulfate concentrations;

[14] USEPA, 1994 Technical Document, Acid Mine Drainage Prediction, Office of Solid Waste, Special Waste Branch, Washington DC, December 1994 EPA 530-R-94-036

each river with an average sulfate concentration greater than 100mg/l. Table 4.5 presents each tributary's load and average concentration during the 10-year period of 1992-2001.

Table 4.5 Ranking of Major Ohio River Tributaries by Average Daily Sulfate Load

Rank	NPS Assess Station	Average Sulfate Load (tons/day)	Average Sulfate Concentration (mg/L)
1	Wabash	3,378	56.2
2	Monongahela	2,797	91.4
3	Tennessee	2,388	14.7
4	Allegheny	2,387	57.5
5	Muskingum	1,977	107.2
6	Cumberland	1,925	22.0
7	Green	1,444	60.0
8	Big Sandy	1,202	126.2
9	Kanawha	1,035	32.8
10	Scioto	930	80.4
11	Kentucky*	844	55.5
12	Great Miami	761	57.8
13	Saline	552	353.6
14	Beaver	548	66.3
15	Little Kanawha	537	86.3
16	Licking	431	53.2
17	Guyandotte	425	70.9
18	Tradewater*	389	338.9
19	Salt*	268	19.7
20	Little Miami	190	41.2

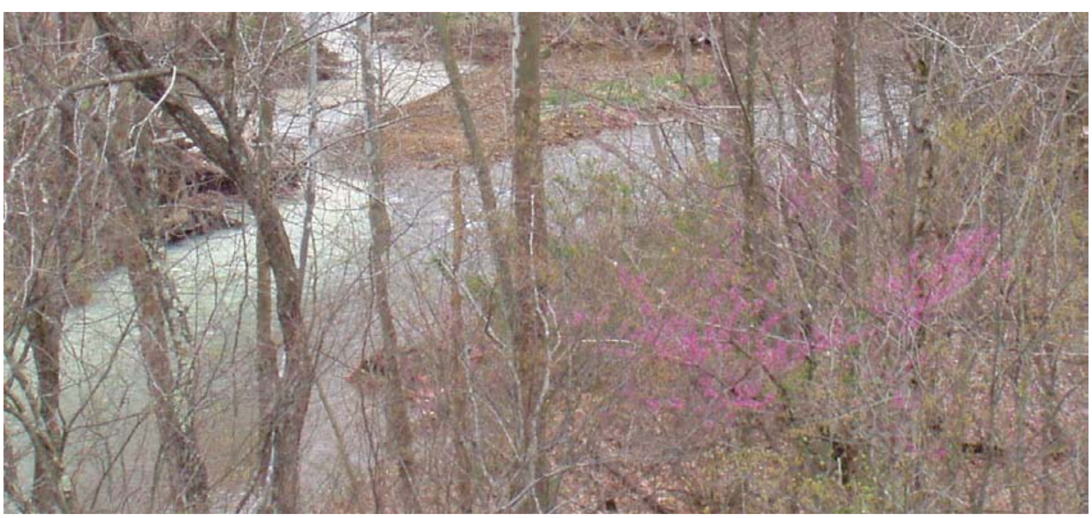


Photo by E. Hobbins

Different land uses produce varying stream loads, visible as the smaller tributary at left enters a larger stream, in Carter County, Kentucky.

Conclusions

Analysis of Ohio River monitoring data from January 1992 through December 2001 has revealed 11 pollutants with a substantial load from nonpoint sources. Total loads of these runoff pollutants are huge at Metropolis, Illinois, the most downstream Ohio River monitoring point included in this analysis. Notable findings beyond loadings specified in the document are:

- The contribution of nonpoint sources is substantial enough to cause water quality problems without the addition of point sources. NPS impacts on Ohio River water quality are felt at drinking water utility intakes on the Ohio River and downstream at the Gulf of Mexico in the form of hypoxia.
- Overland runoff carries loads of each of the eleven pollutants across the basin as a whole; however, with land use differences come changes in the pollutant of greatest concern for each sub-basin.
- Given a record of the length and frequency of the ORSANCO Bimonthly Sampling Program, limited but reasonable results can be obtained from the process of hydrograph analysis for the large drainage areas considered in this report.
- Results of the flow/concentration correlation method used in the ORSANCO 1990 NPS assessment are confirmed by this hydrograph analysis.
- As nonpoint sources become more central to the focus of ORSANCO and water quality managers across the basin, a shift in ORSANCO monitoring strategies to address nonpoint sources is appropriate.
- Collection of samples in matching pairs at peak flows and base flows for all monitoring stations would increase the robustness of this type of NPS monitoring and loading analysis.

It is imperative that resource managers and all readers of this document recognize the scope of the information contained herein. This document presents general information about the magnitude of nonpoint source pollutant load in the Ohio and its major tributaries. All loads presented are *daily averages* calculated from a 10-year period of bimonthly monitoring. Seasonal and annual variation is great and the ten-year period examined here is limited in its ability to overcome these variations. Therefore the loads are most useful in comparison of one tributary or location to another. Further calculations to convert loads presented here into annual loadings are not recommended.

A ranking of major tributaries by nonpoint source pollutant impact was done to facilitate discussion among the nonpoint source managers of the six states represented in the ORSANCO Nonpoint Source Work Group. This analysis has avoided a focus on comparison of tributary yields, i.e. tributary load divided by drainage area, because the goal of the ORSANCO NPS Work Group is to coordinate the efforts of each state in reducing the total nonpoint source load of the Ohio River.

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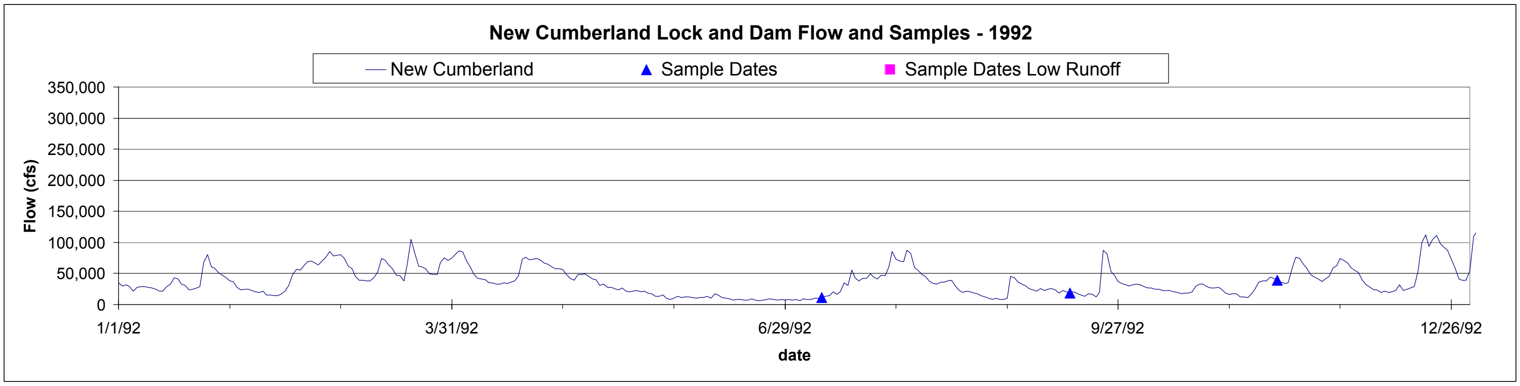
Appendix A
Monitoring Data 1992-2001

To reduce the amount of paper consumed by this report Appendix A will be available shortly on the ORSANCO website:

www.orsanco.org

Appendix B

Ohio River Hydrographs with Sample Dates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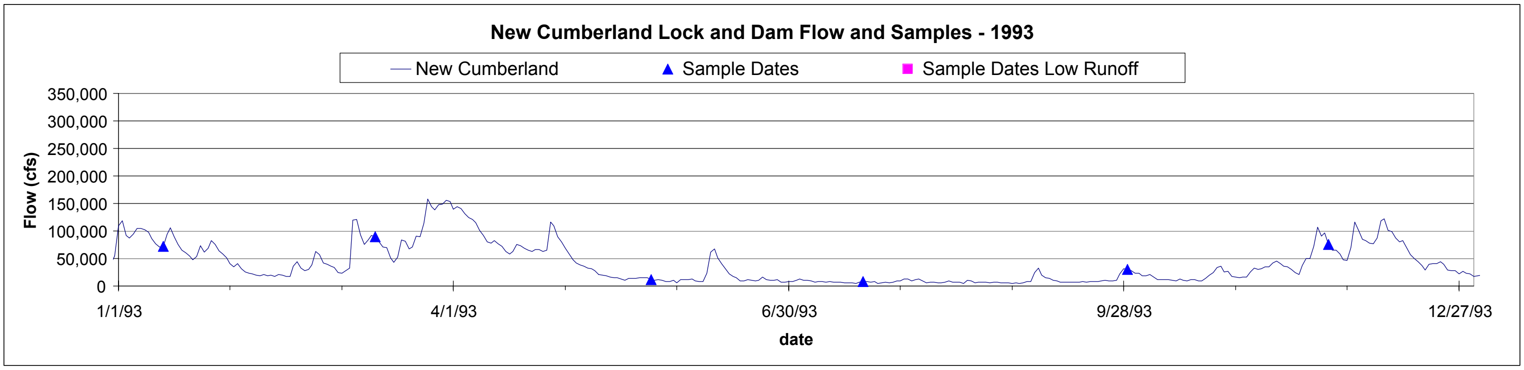
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New Cumberland
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Sample Dates Low Runoff
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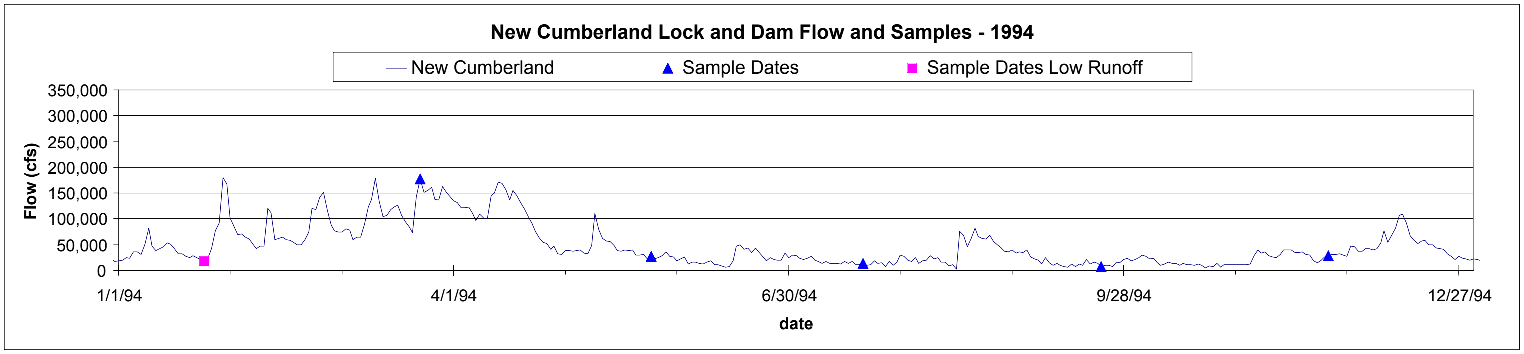
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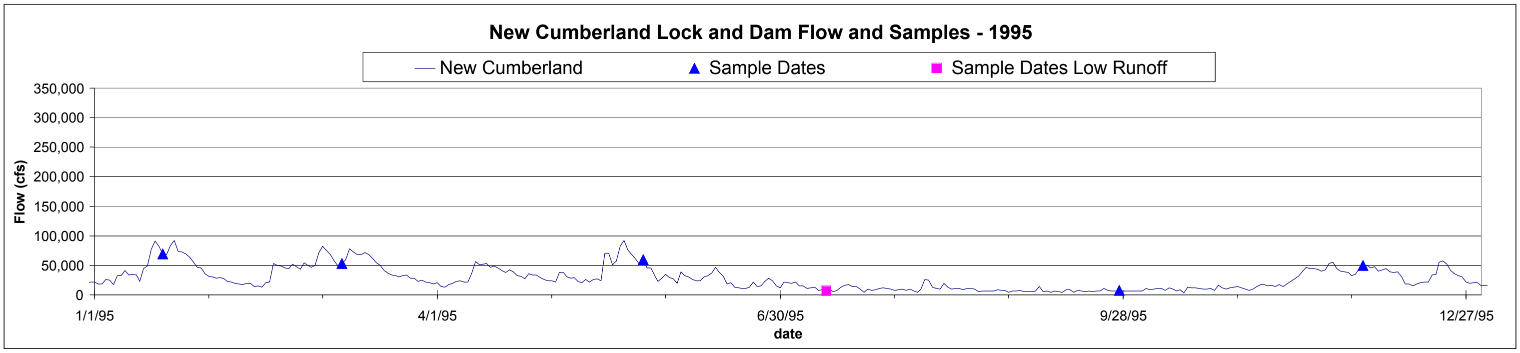
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6/30/95
9/28/95
12/27/95
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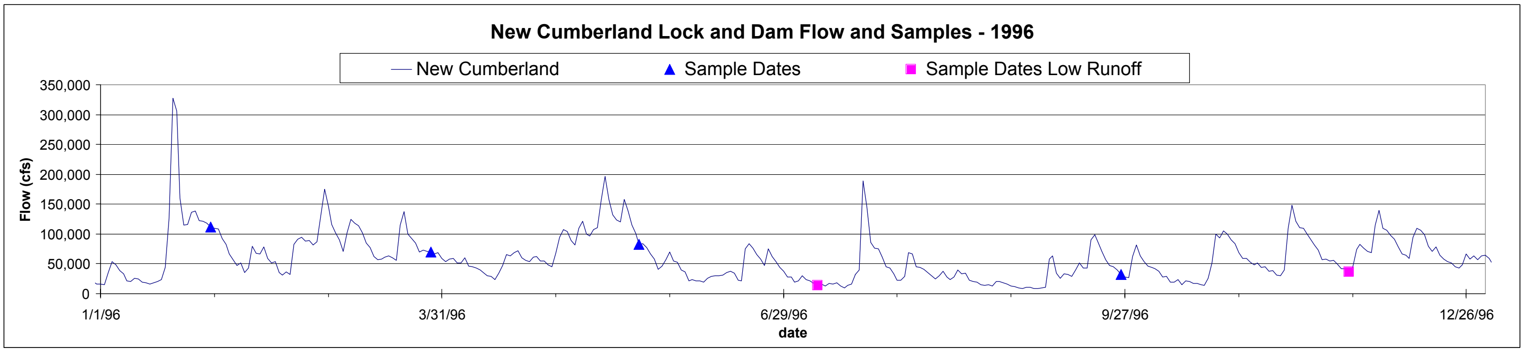
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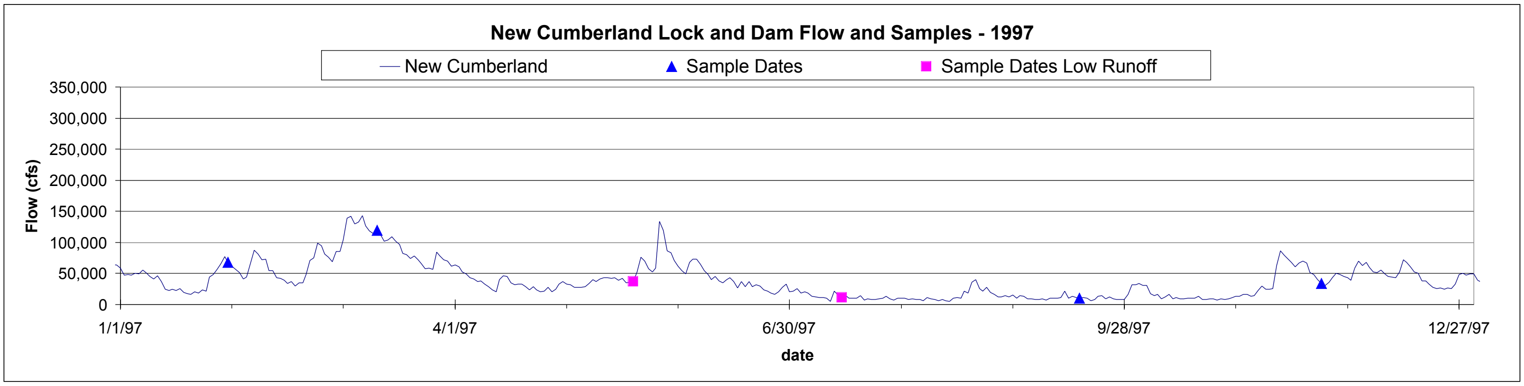

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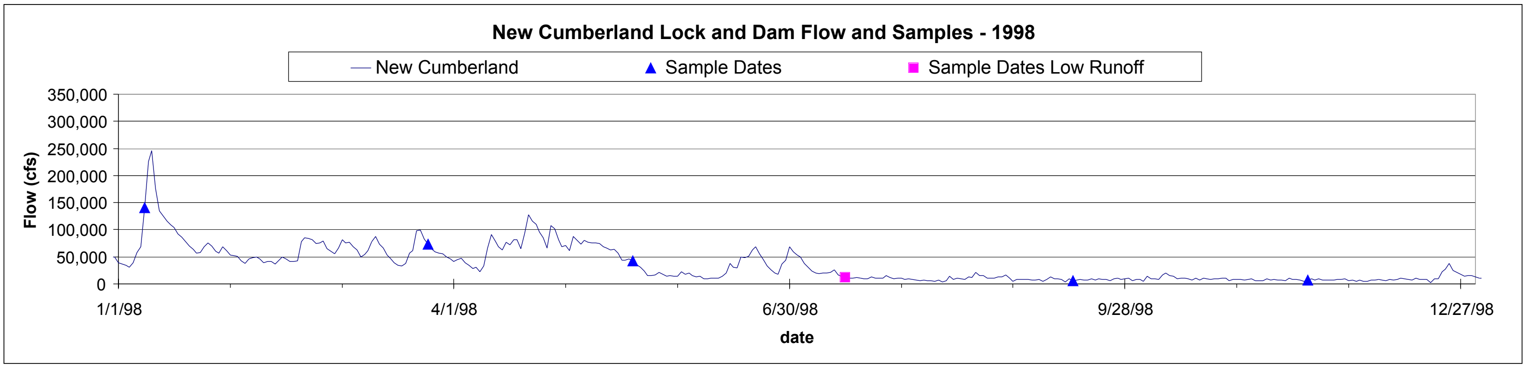

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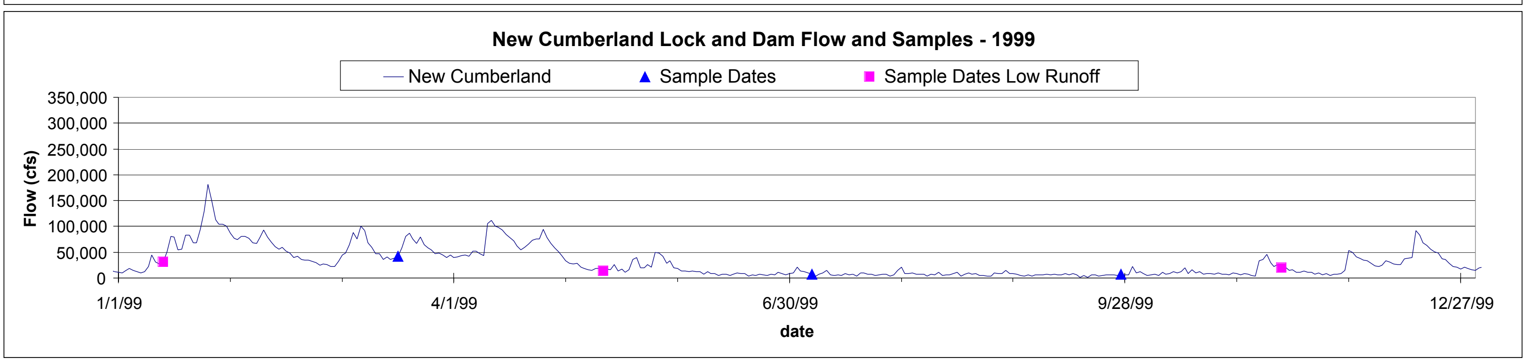

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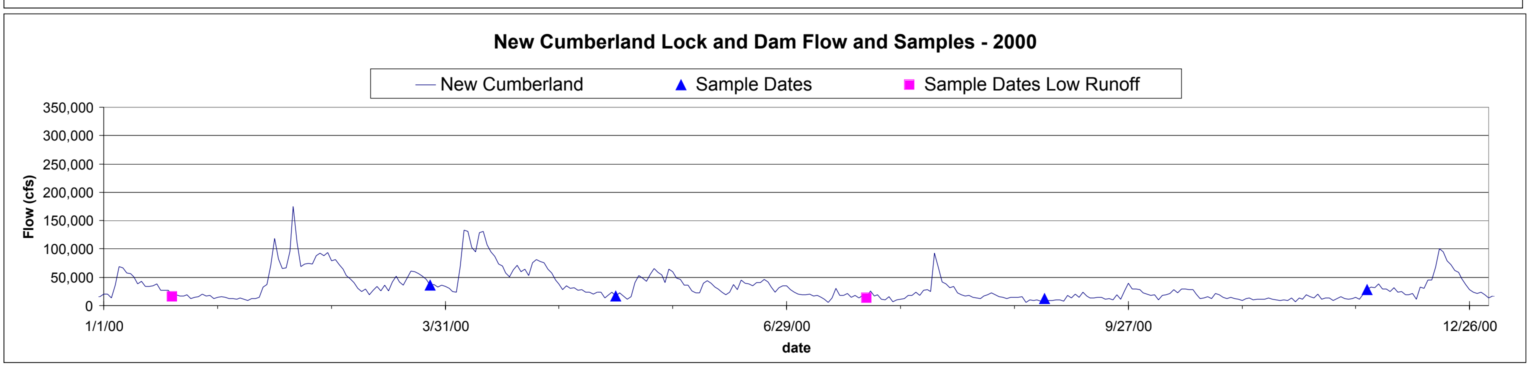

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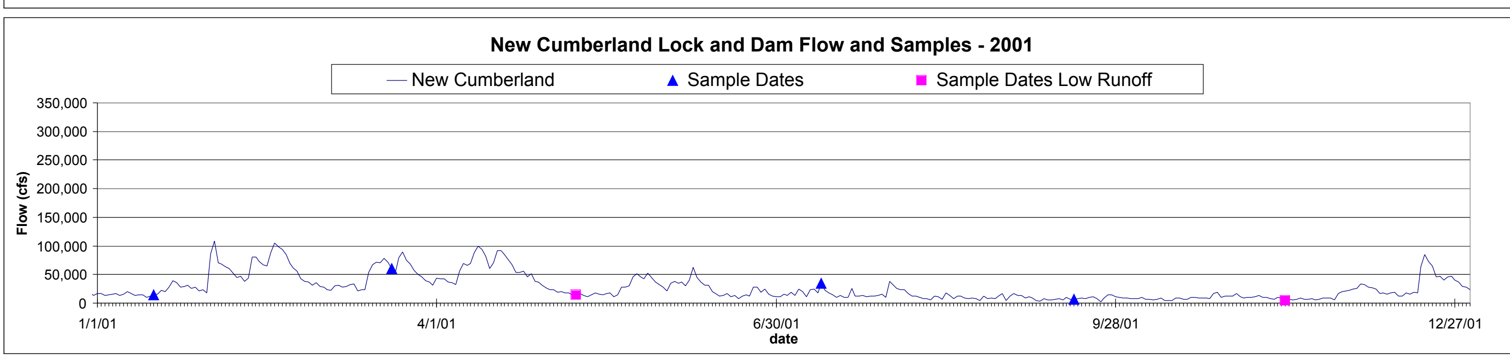

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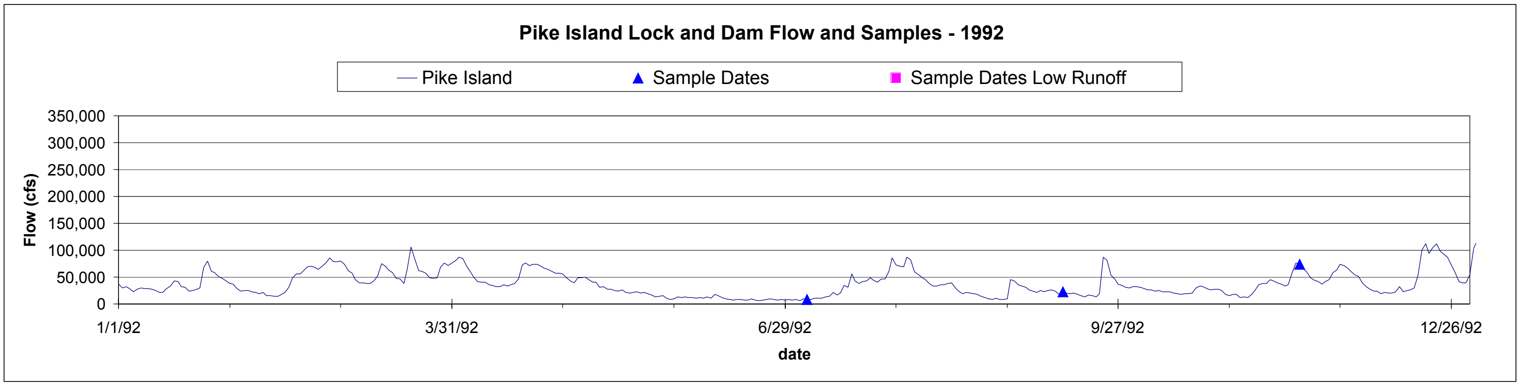
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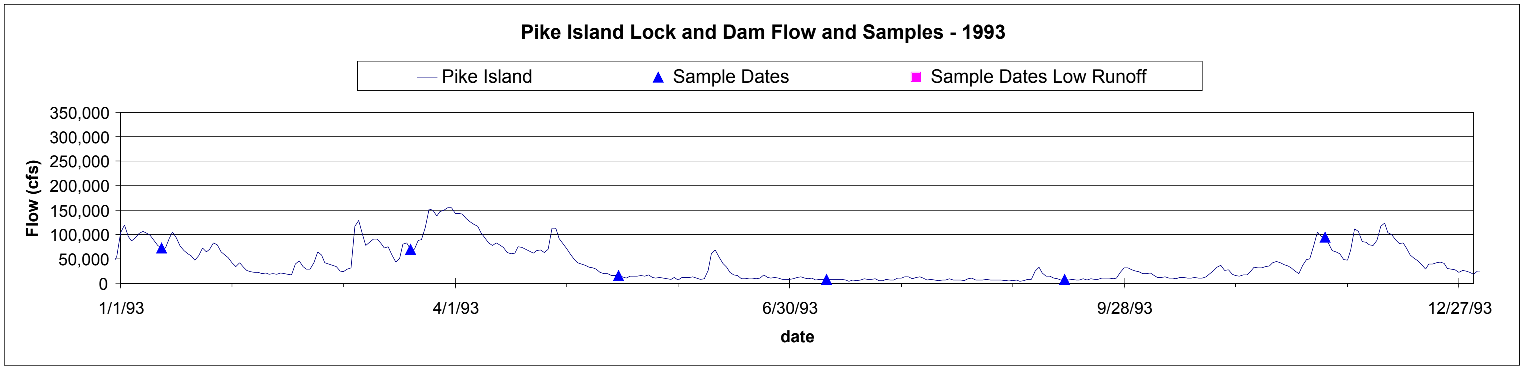
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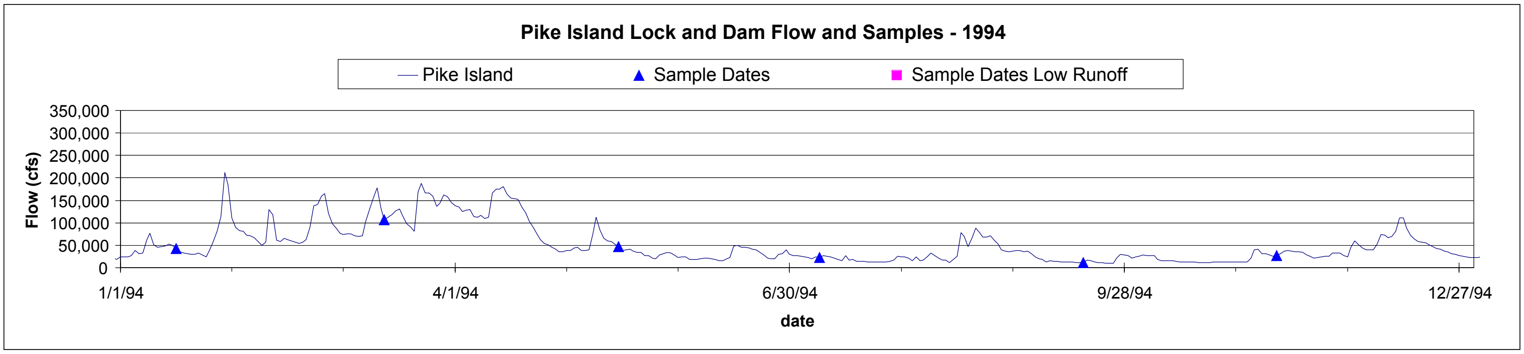
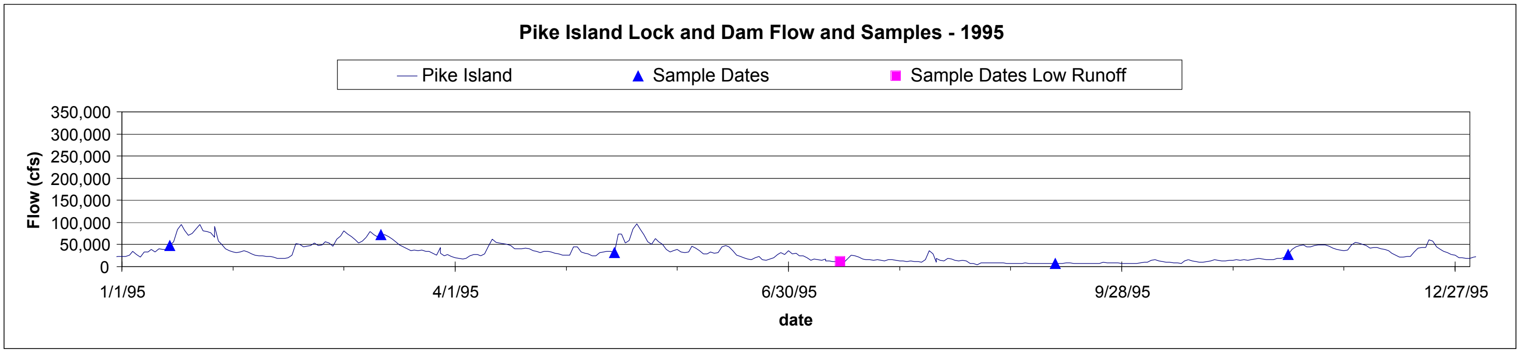
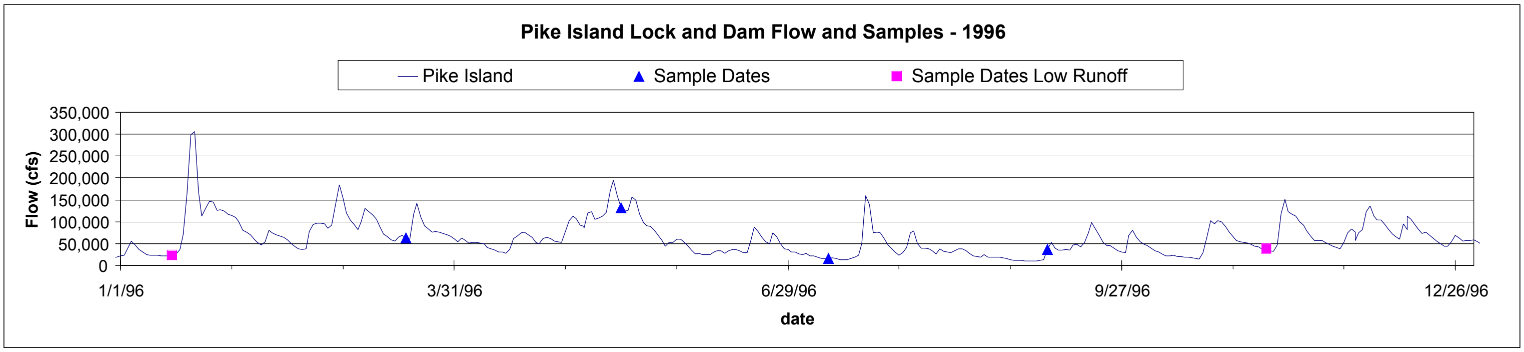
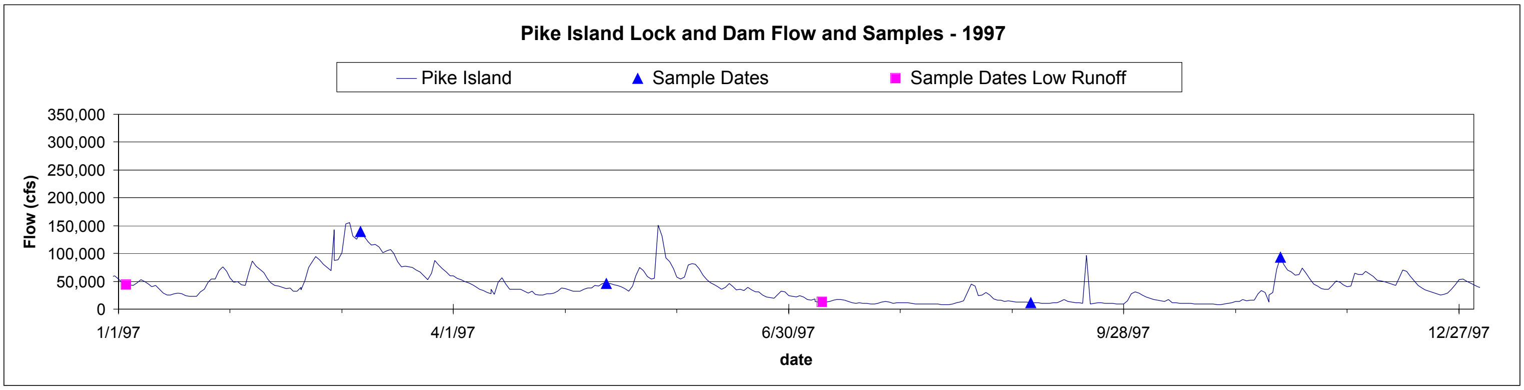
Pike Island
Sample Dates
Sample Dates Low Runoff
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Flow (cfs)
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date

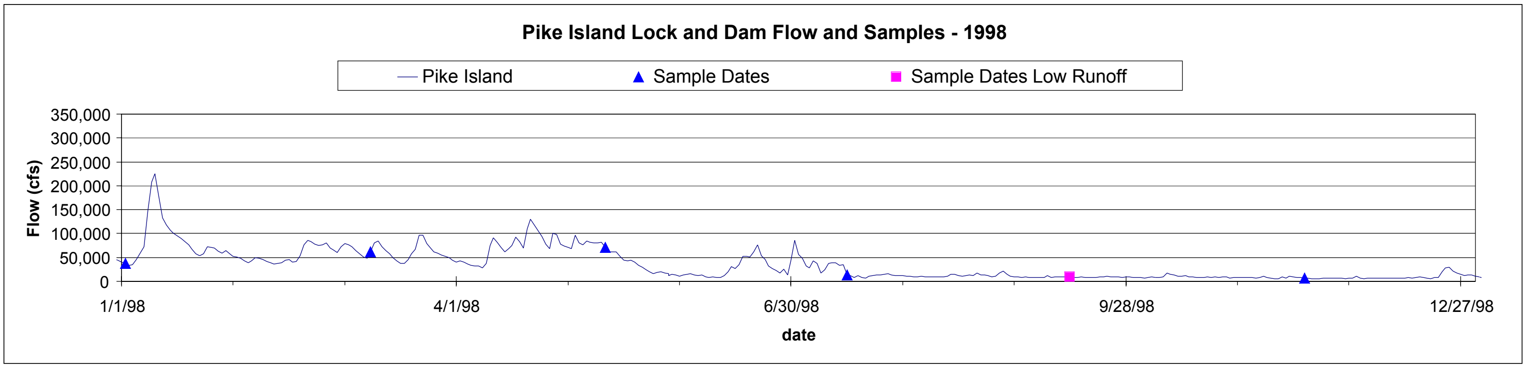

Pike Island Lock and Dam Flow and Samples - 1994
Pike Island
Sample Dates
Sample Dates Low Runoff
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Flow (cfs)
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date


Pike Island Lock and Dam Flow and Samples - 1995
Pike Island
Sample Dates
Sample Dates Low Runoff
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Flow (cfs)
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date

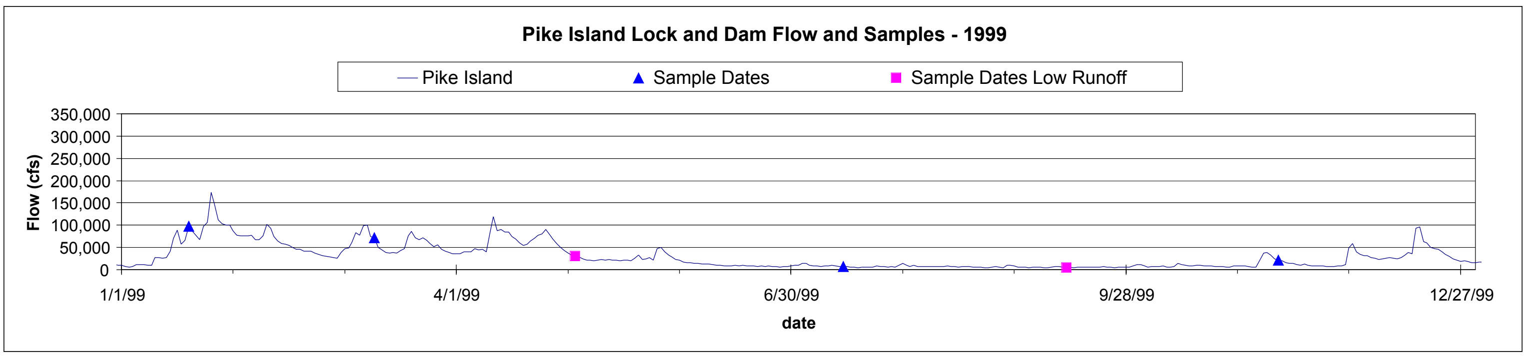

Pike Island Lock and Dam Flow and Samples - 1996
Pike Island
Sample Dates
Sample Dates Low Runoff
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Flow (cfs)
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date



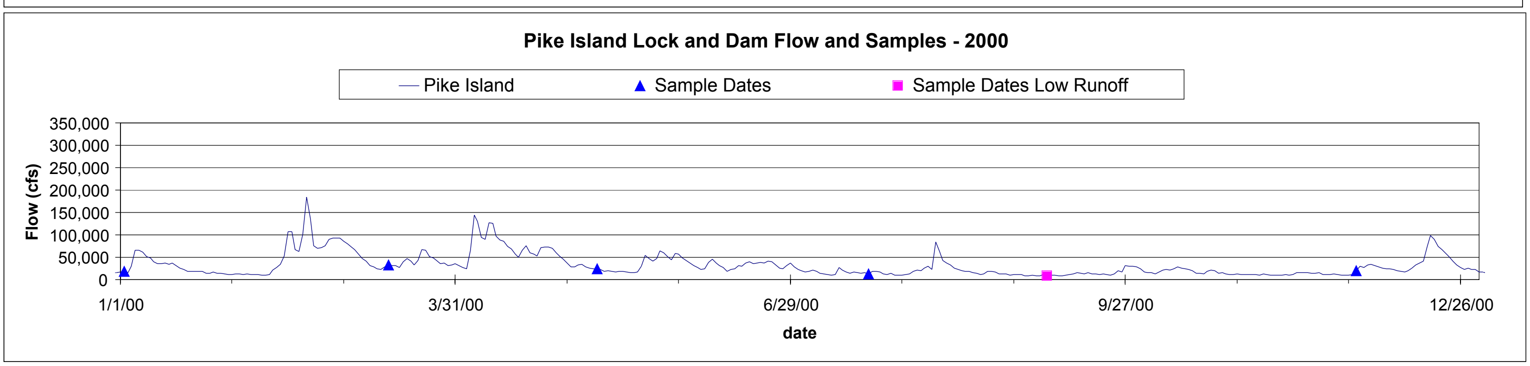
Pike Island Lock and Dam Flow and Samples - 1997
Pike Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date



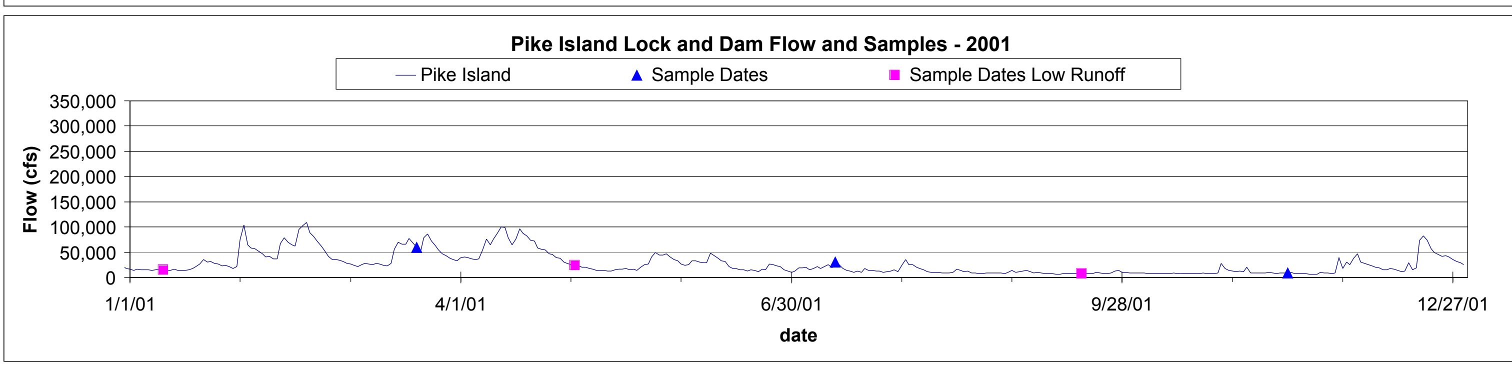
Pike Island Lock and Dam Flow and Samples - 1998
Pike Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date



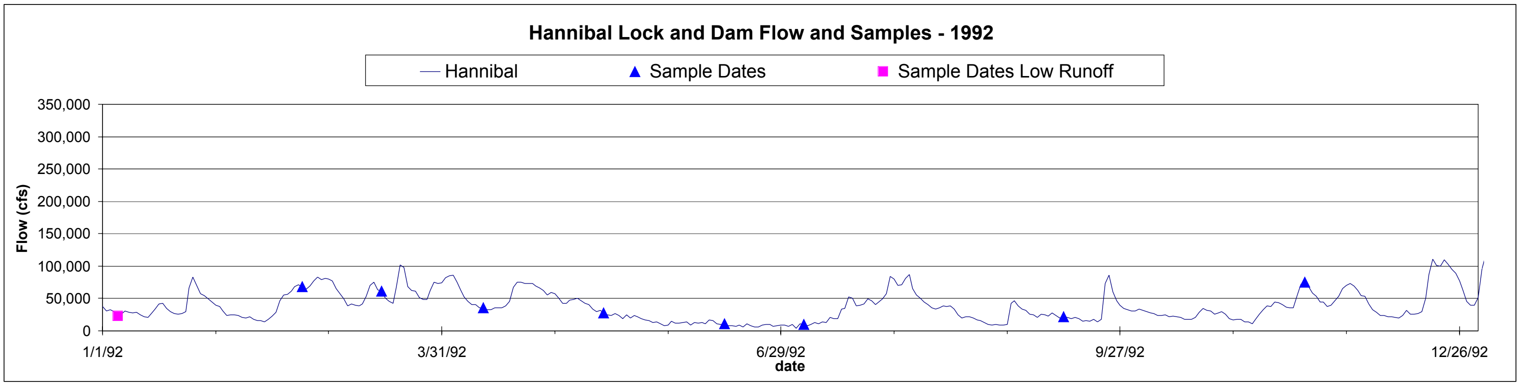
Pike Island Lock and Dam Flow and Samples - 1999
Pike Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date

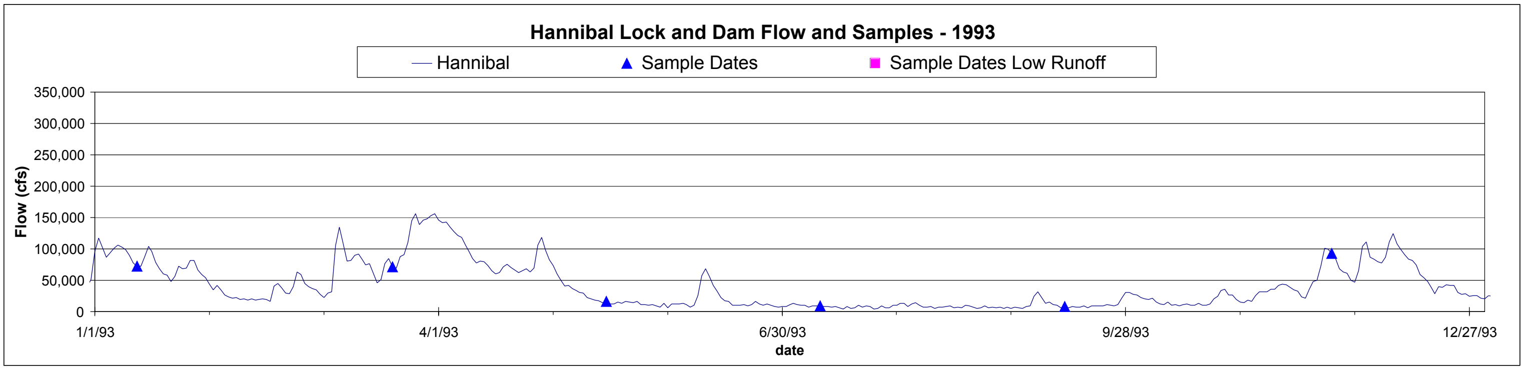


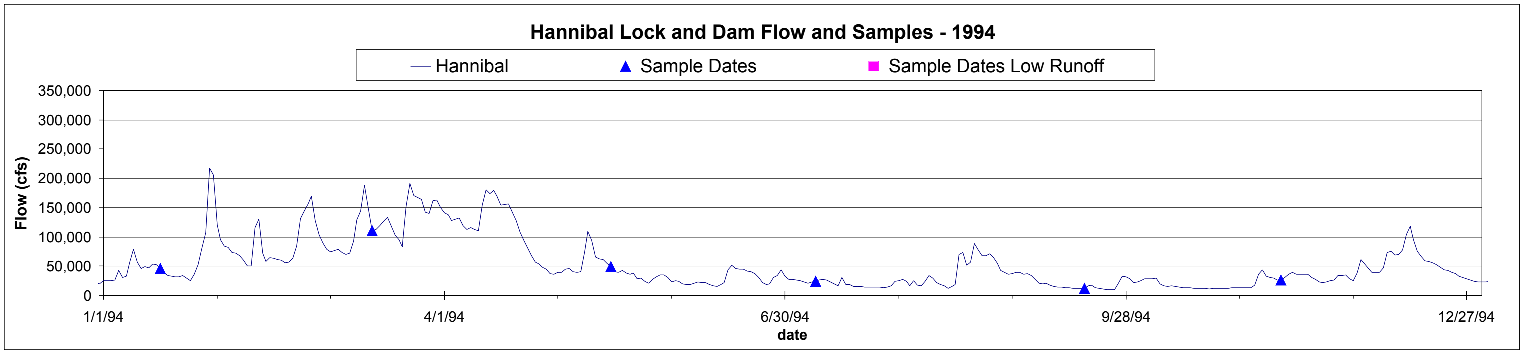
Pike Island Lock and Dam Flow and Samples - 2000
Pike Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

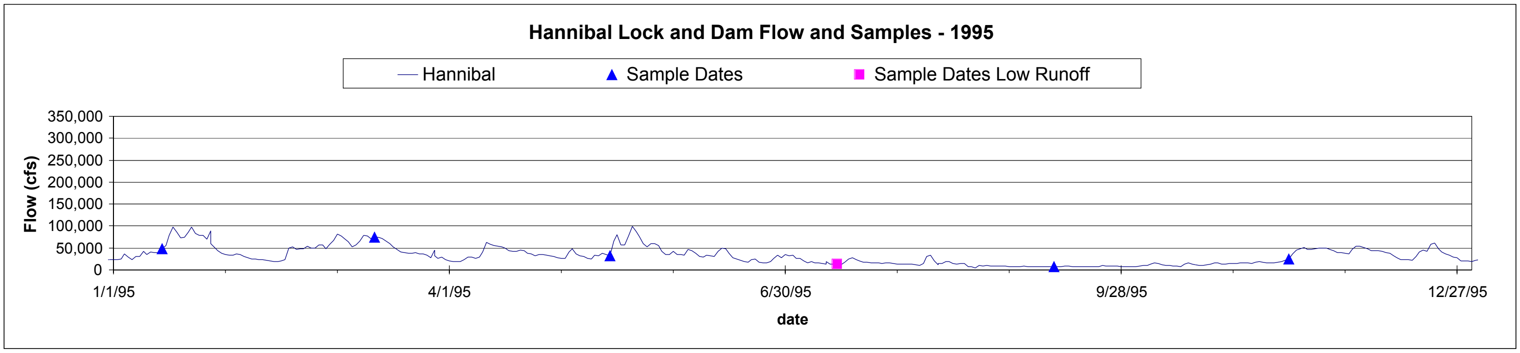


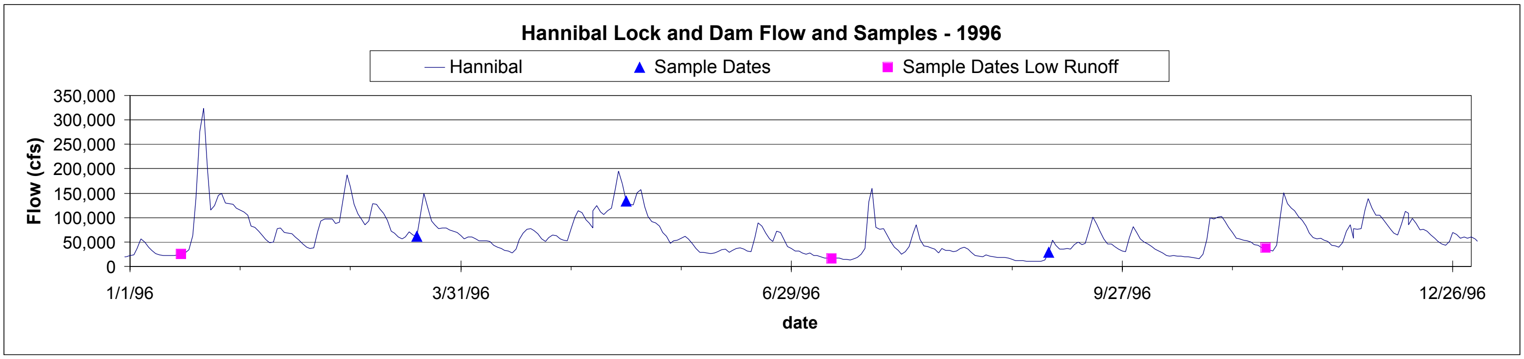
Pike Island Lock and Dam Flow and Samples - 2001
Pike Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date


Hannibal Lock and Dam Flow and Samples - 1992
Hannibal
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date


Hannibal Lock and Dam Flow and Samples - 1993
Hannibal
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date


Hannibal Lock and Dam Flow and Samples - 1994
Hannibal
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date


Hannibal Lock and Dam Flow and Samples - 1995
Hannibal
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date


Hannibal Lock and Dam Flow and Samples - 1996
Hannibal
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
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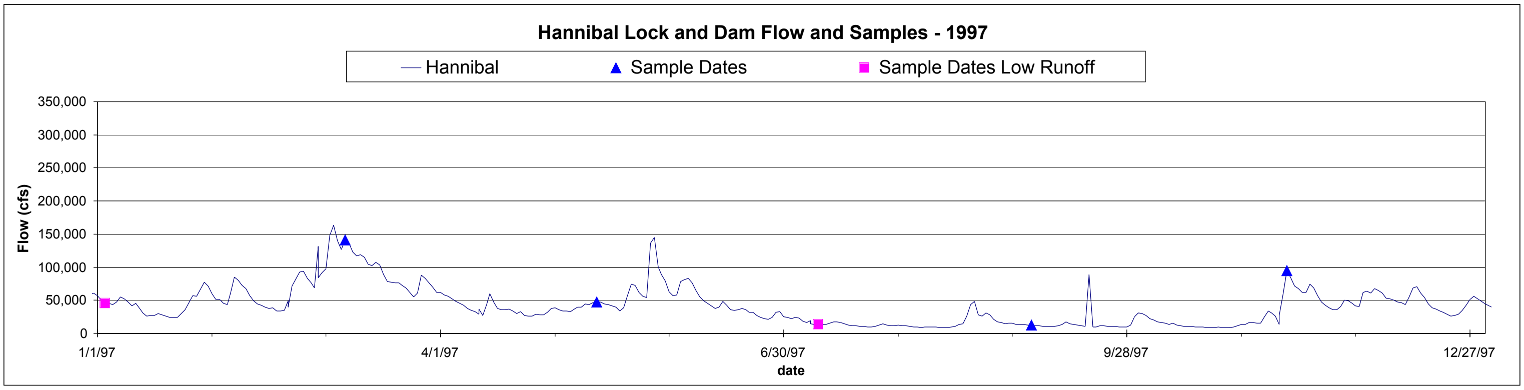
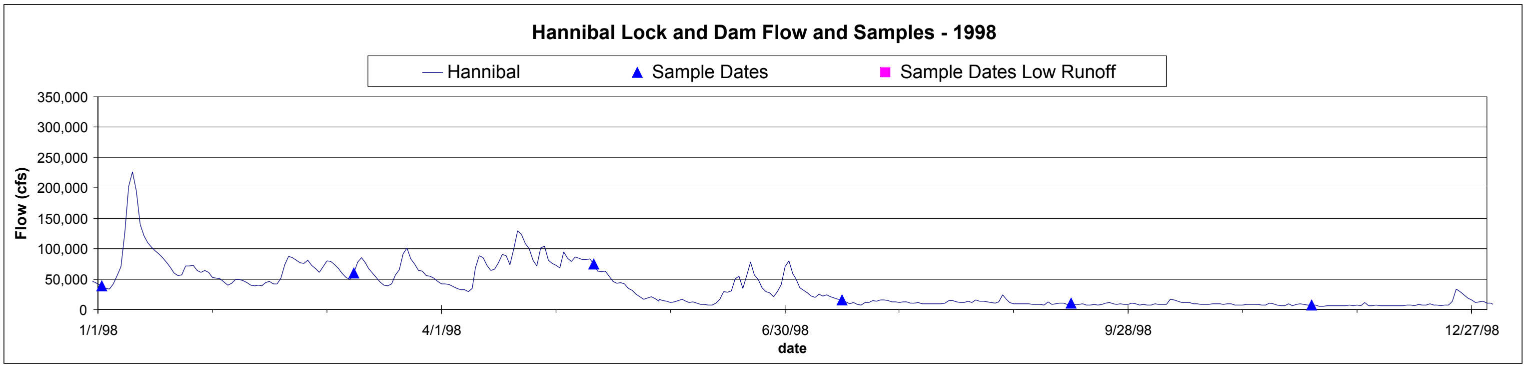
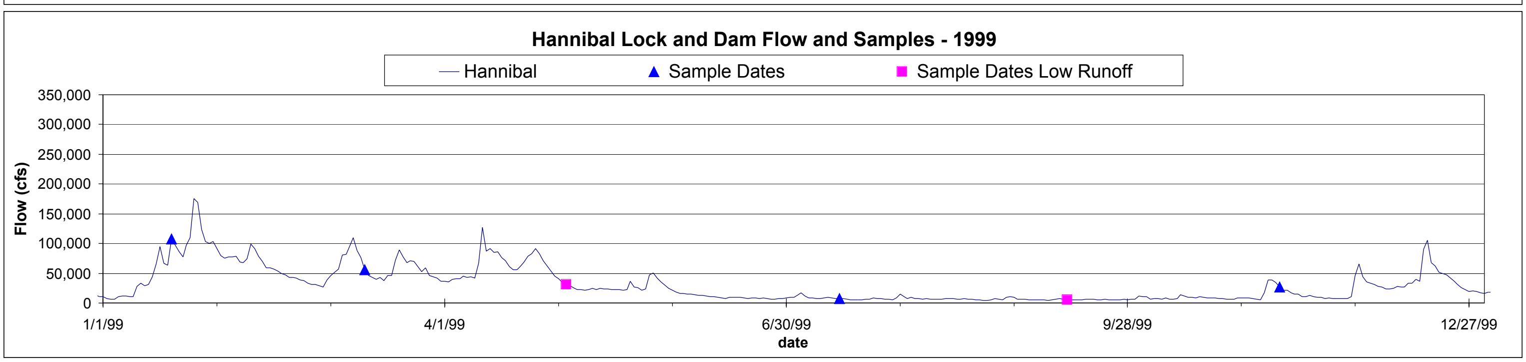
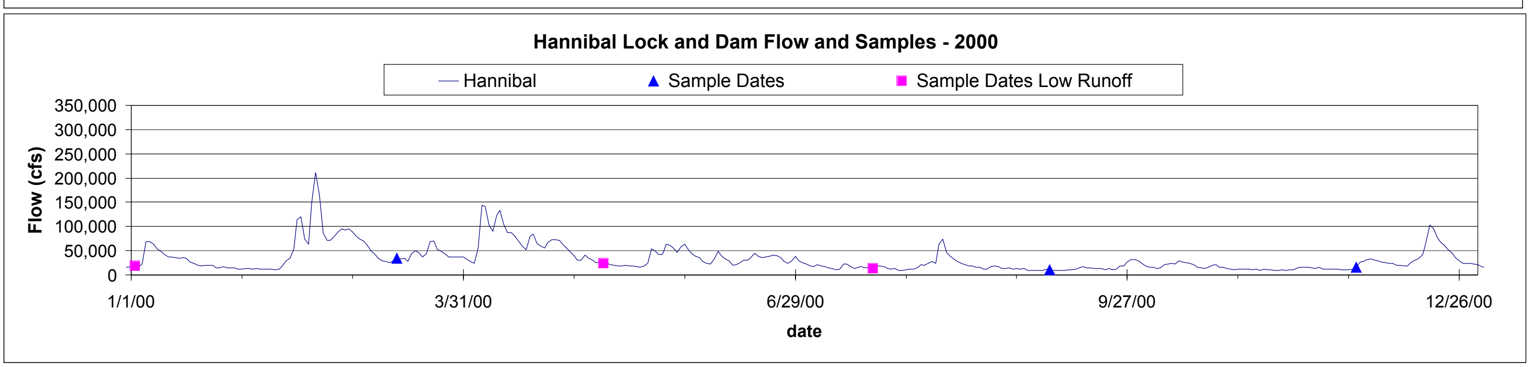
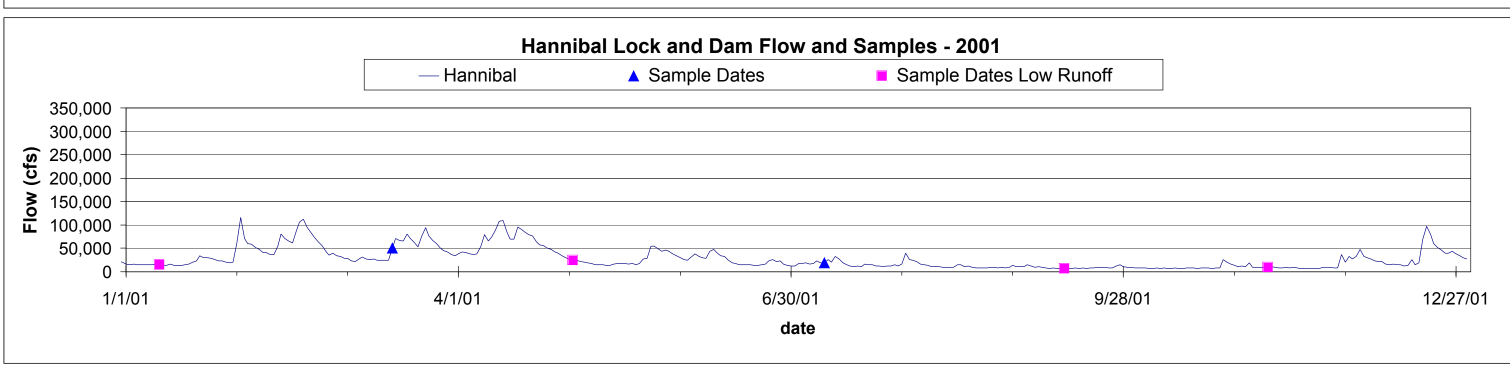
150,000
100,000
50,000
0
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date

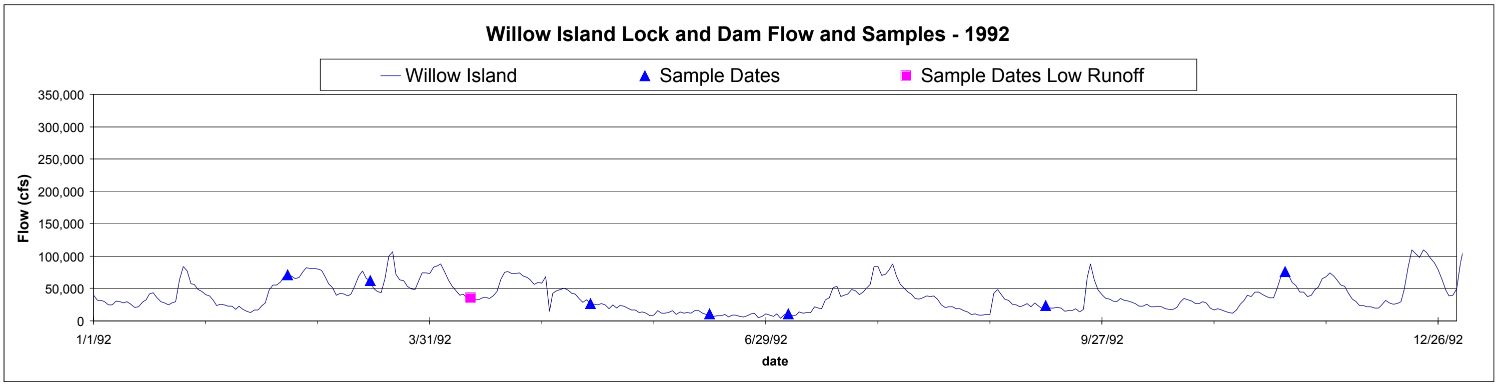

Hannibal Lock and Dam Flow and Samples - 1997
Hannibal
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date

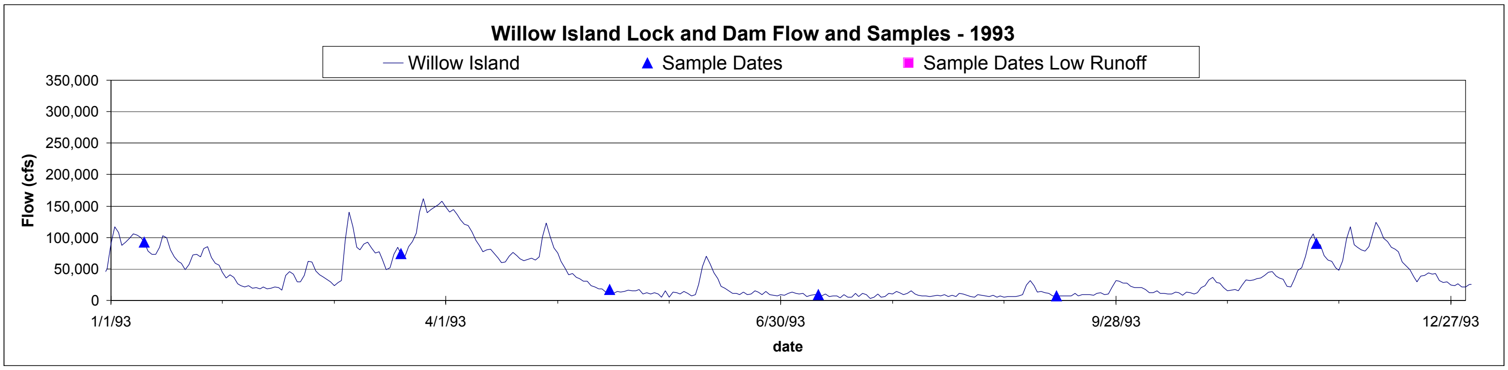

Hannibal Lock and Dam Flow and Samples - 1998
Hannibal
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date

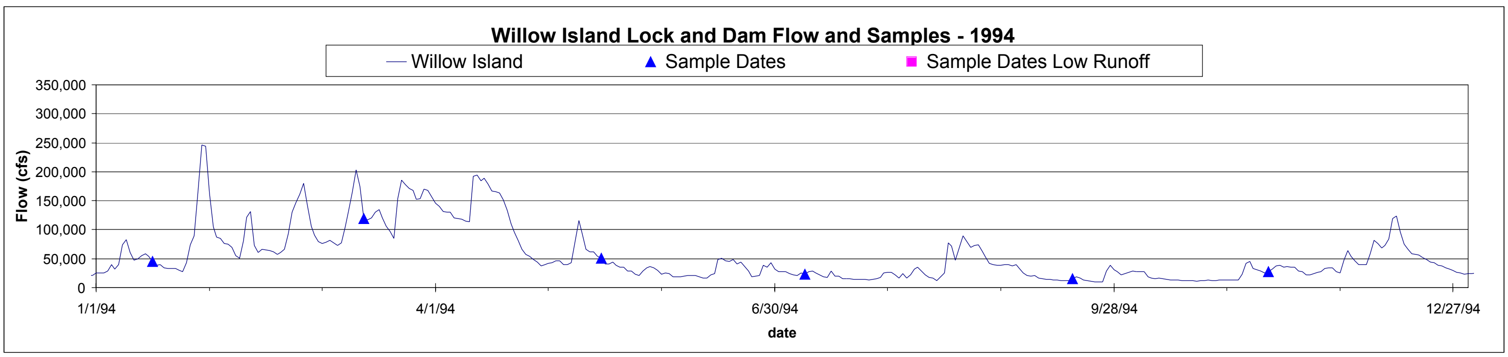

Hannibal Lock and Dam Flow and Samples - 1999
Hannibal
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date

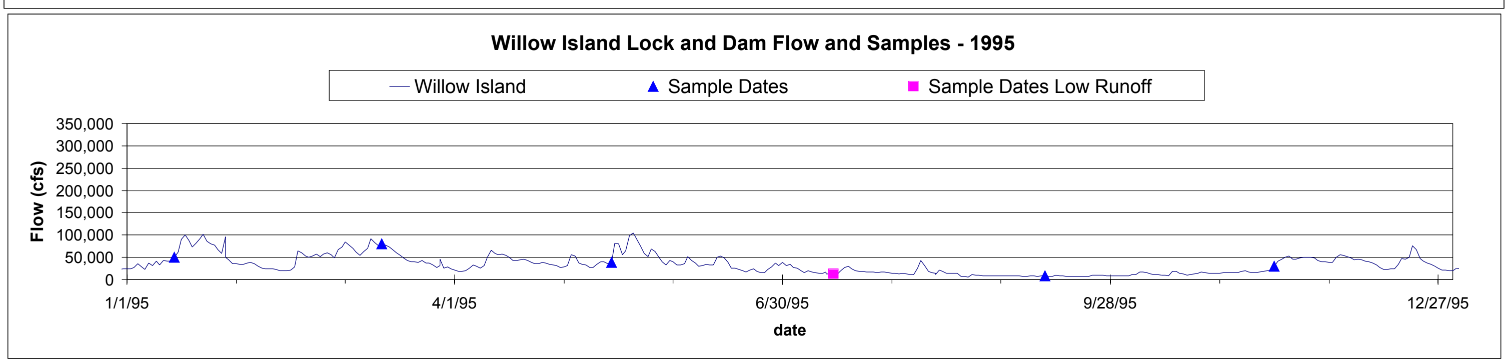

Hannibal Lock and Dam Flow and Samples - 2000
Hannibal
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

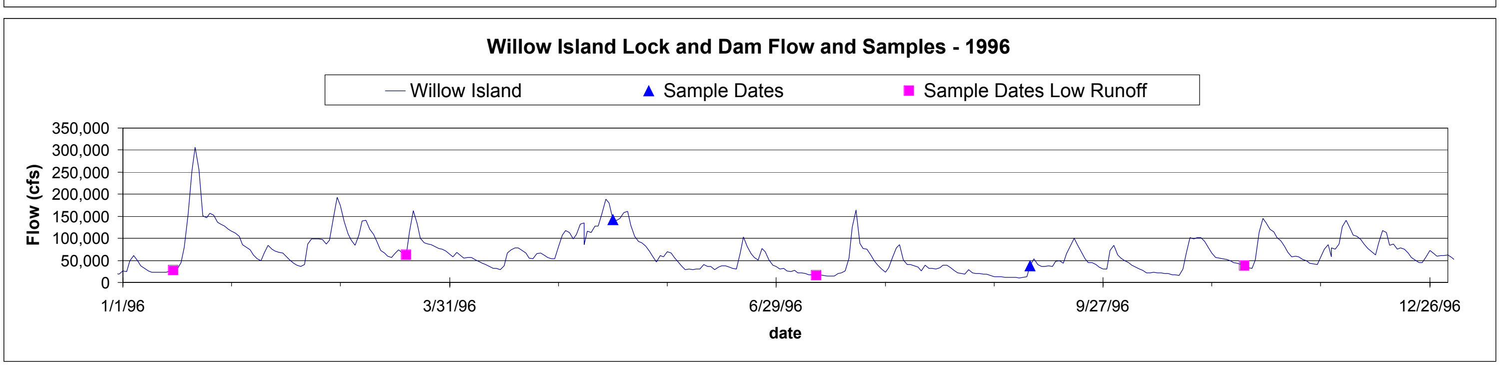

Hannibal Lock and Dam Flow and Samples - 2001
Hannibal
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date

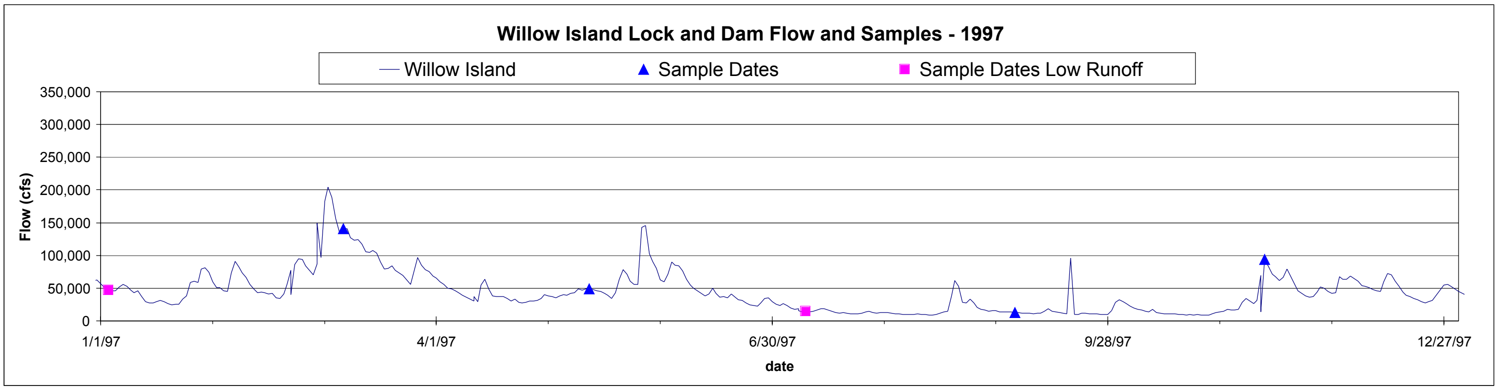

Willow Island Lock and Dam Flow and Samples - 1992
Willow Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date

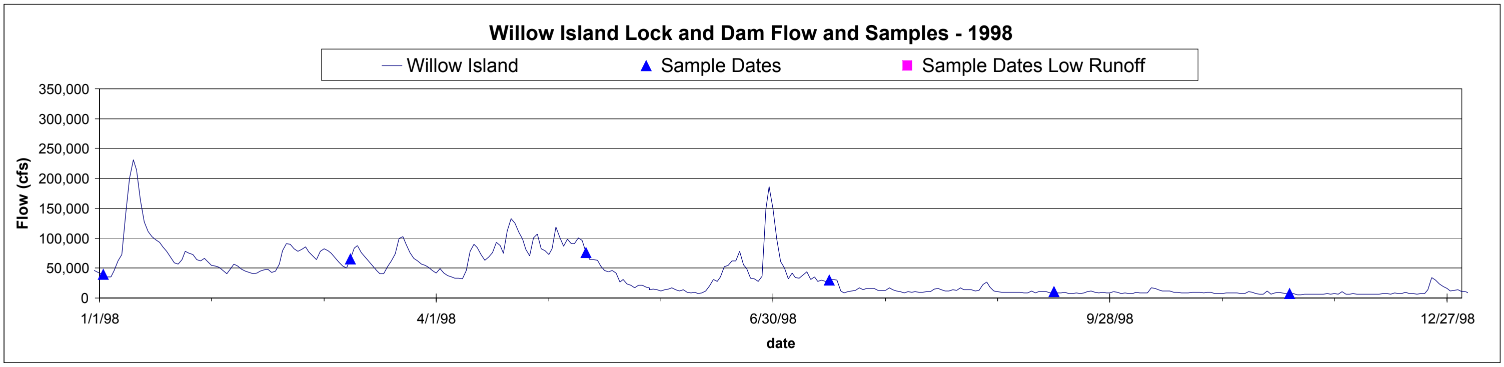

Willow Island Lock and Dam Flow and Samples - 1993
Willow Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date

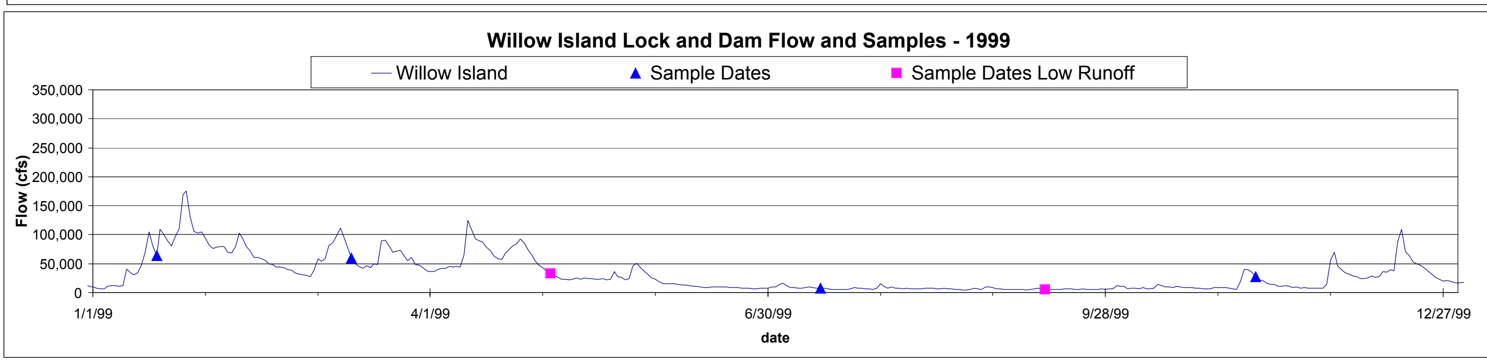

Willow Island Lock and Dam Flow and Samples - 1994
Willow Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date

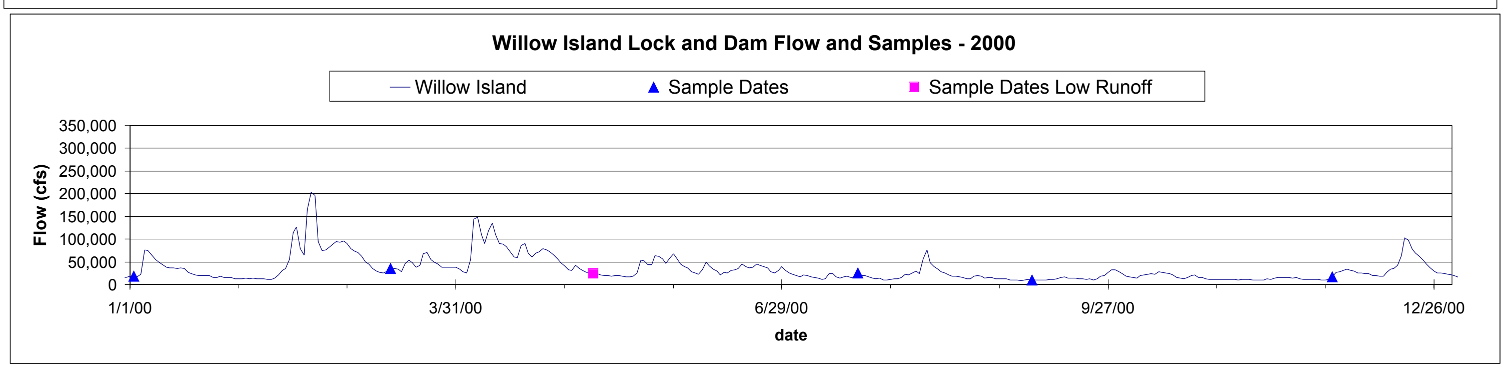

Willow Island Lock and Dam Flow and Samples - 1995
Willow Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date

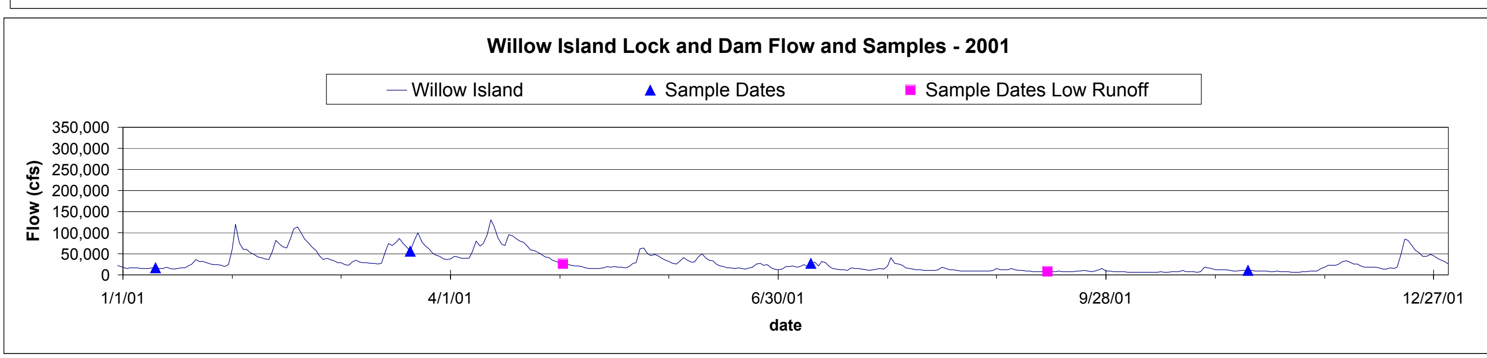

Willow Island Lock and Dam Flow and Samples - 1996
Willow Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date

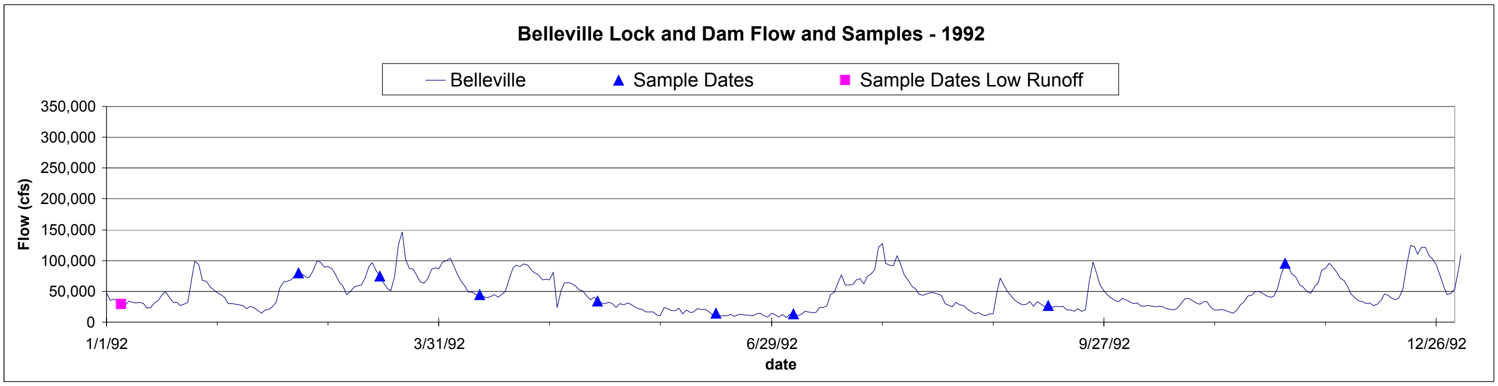

Willow Island Lock and Dam Flow and Samples - 1997
Willow Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date


Willow Island Lock and Dam Flow and Samples - 1998
Willow Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date

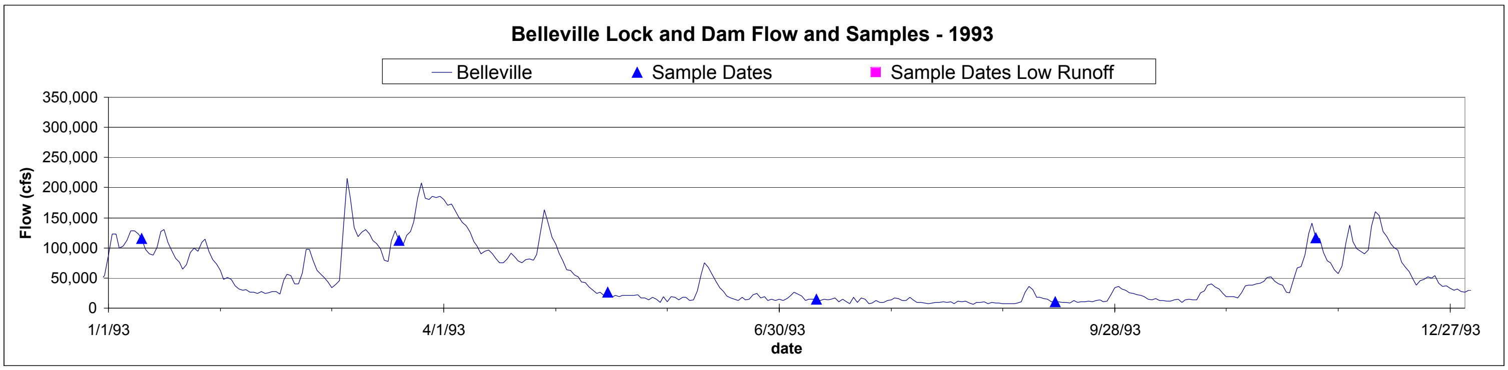

Willow Island Lock and Dam Flow and Samples - 1999
Willow Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date


Willow Island Lock and Dam Flow and Samples - 2000
Willow Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

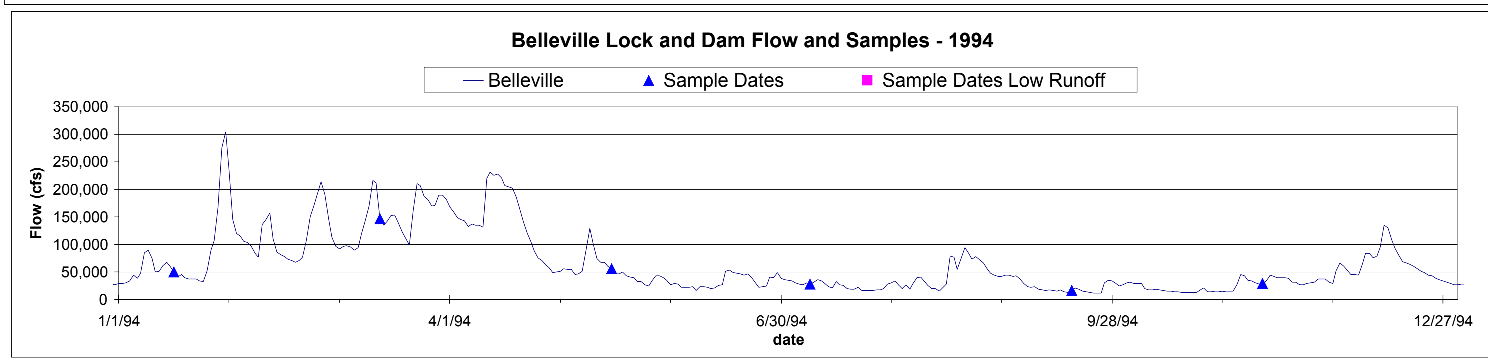

Willow Island Lock and Dam Flow and Samples - 2001
Willow Island
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date



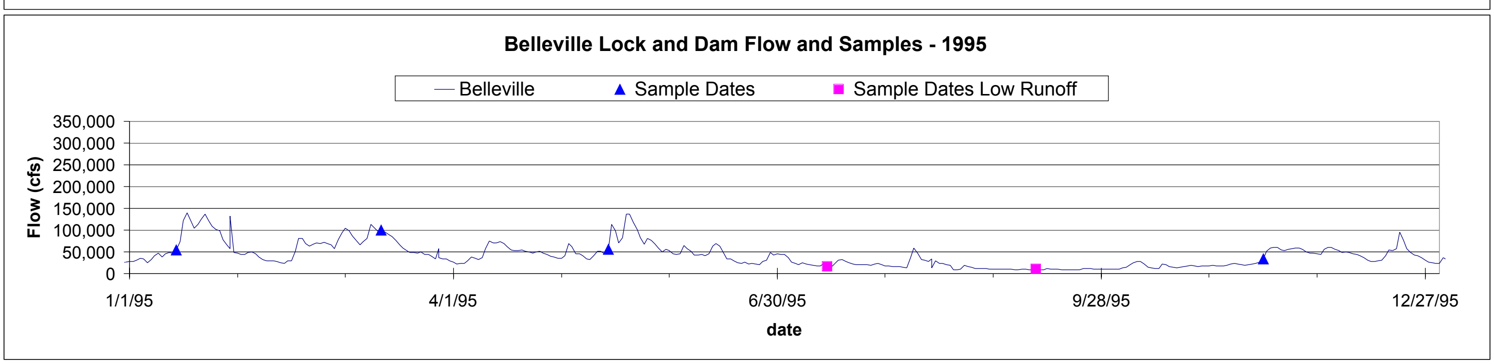
Belleville Lock and Dam Flow and Samples - 1992
Belleville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date



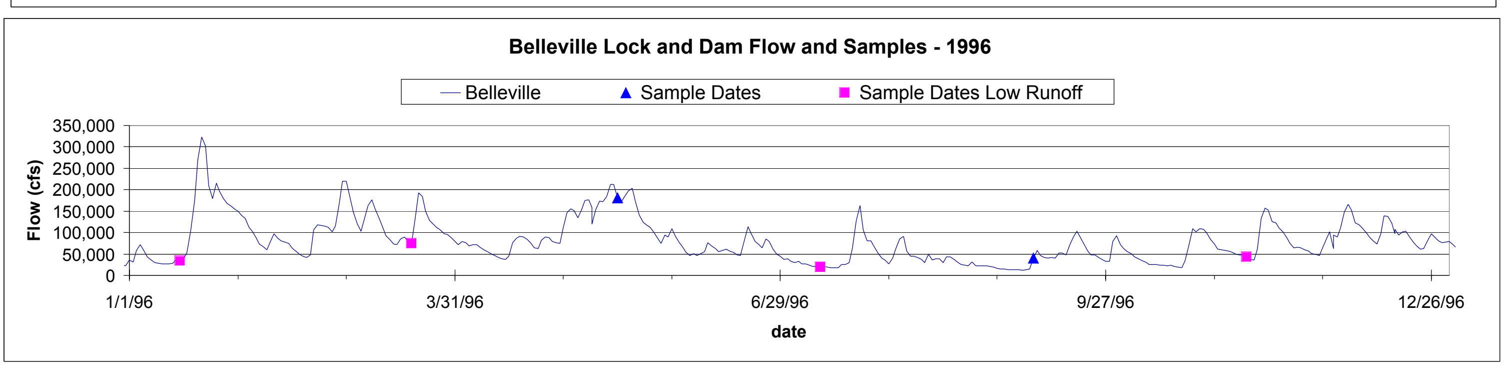
Belleville Lock and Dam Flow and Samples - 1993
Belleville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date



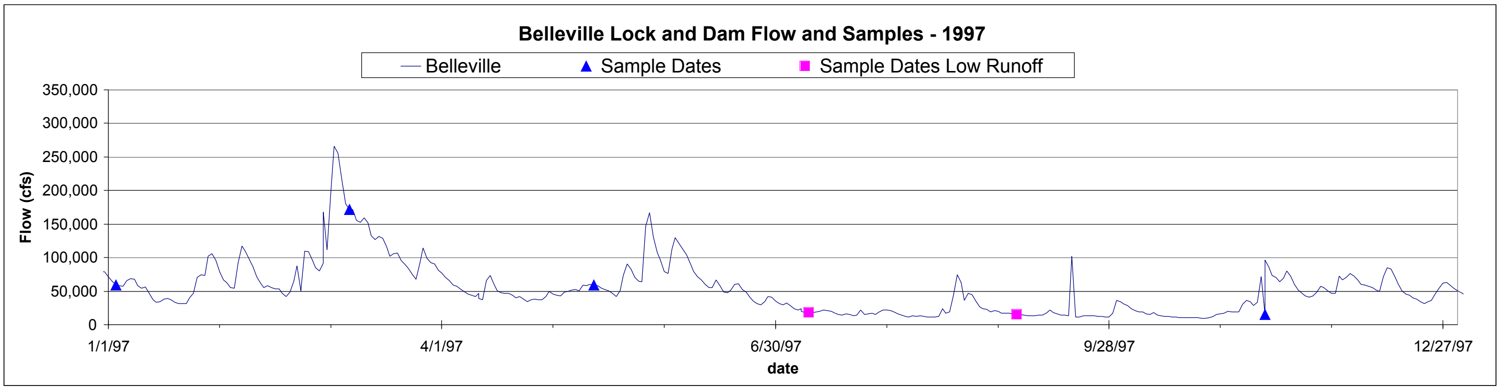
Belleville Lock and Dam Flow and Samples - 1994
Belleville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date



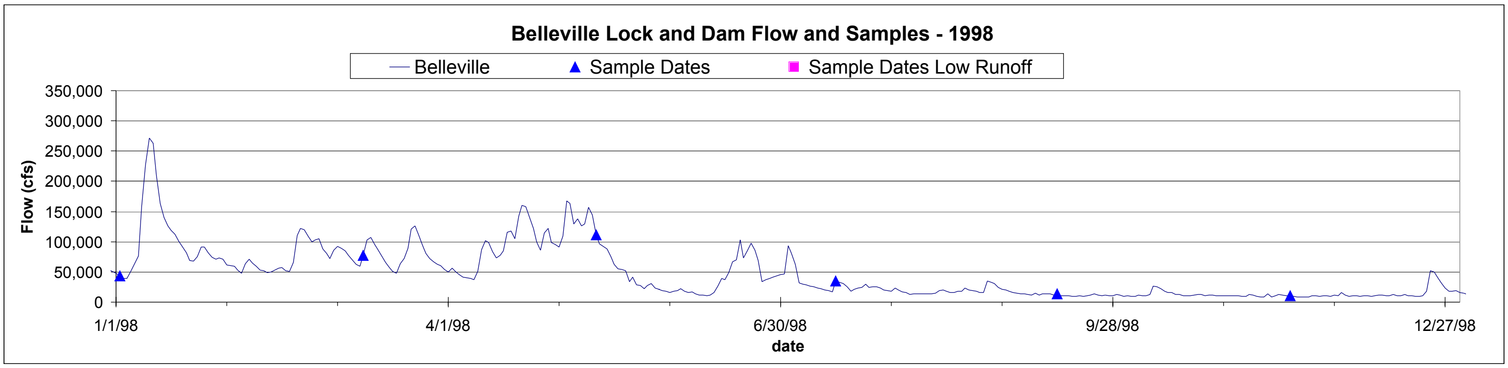
Belleville Lock and Dam Flow and Samples - 1995
Belleville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date



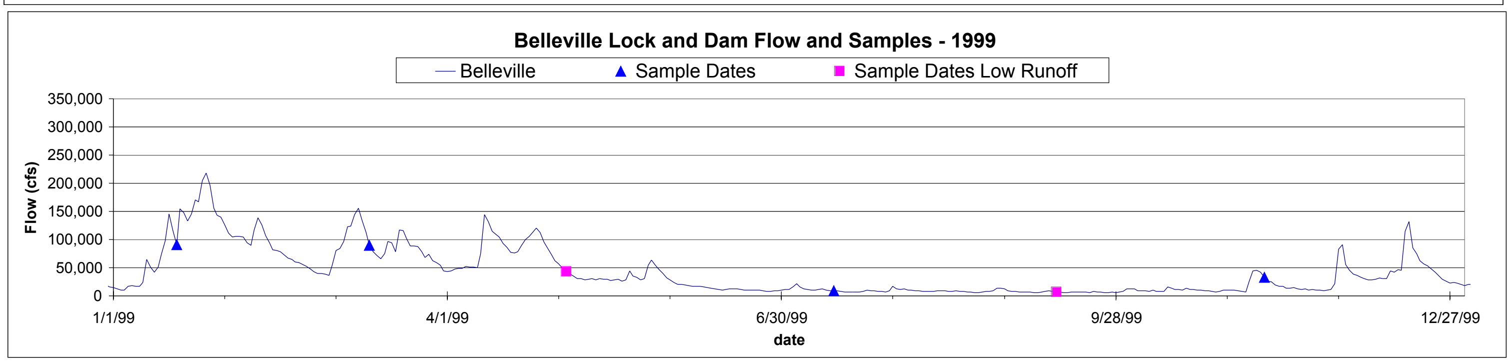
Belleville Lock and Dam Flow and Samples - 1996
Belleville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date



Belleville Lock and Dam Flow and Samples - 1997
Belleville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date



Belleville Lock and Dam Flow and Samples - 1998
Belleville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date



Belleville Lock and Dam Flow and Samples - 1999
Belleville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
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50,000
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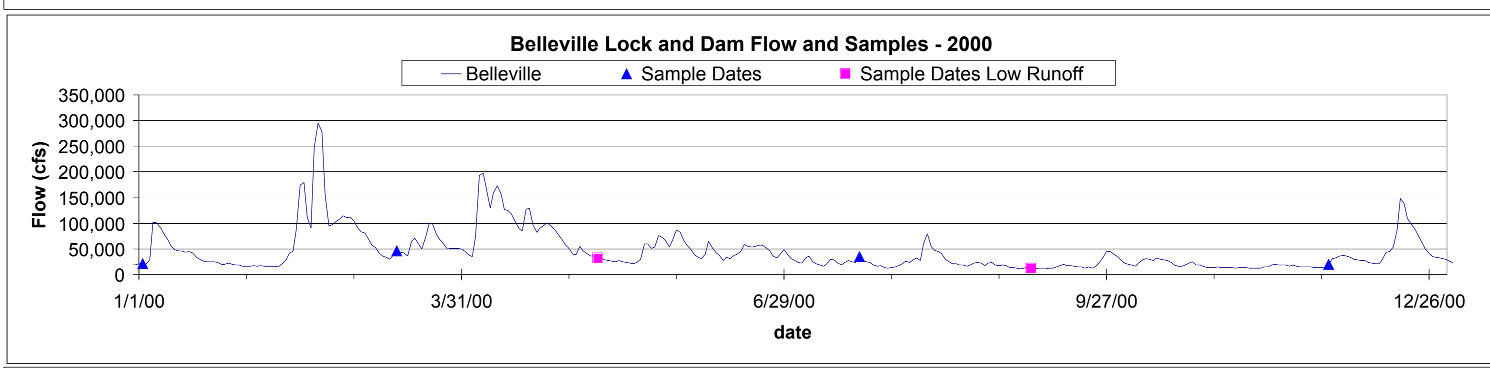
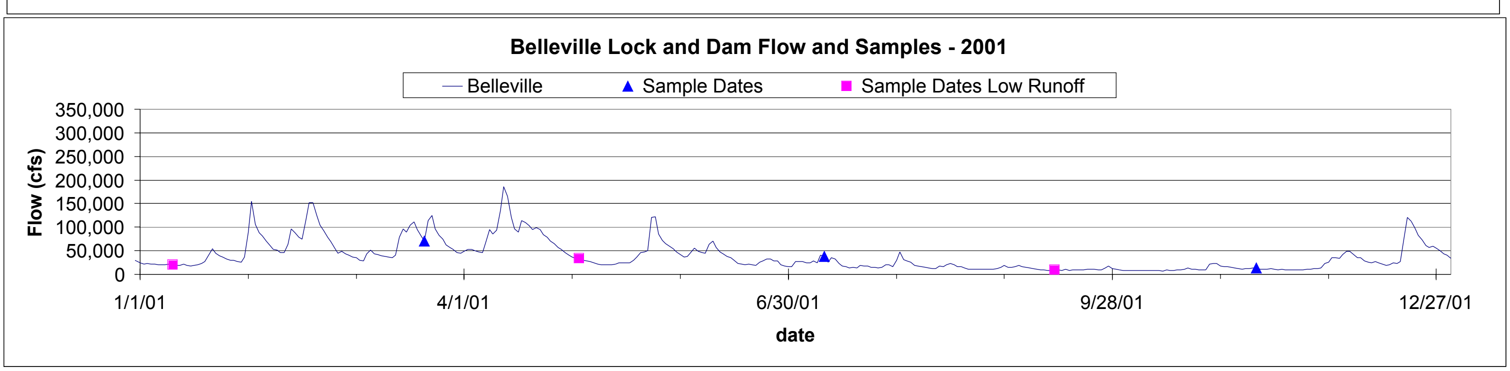
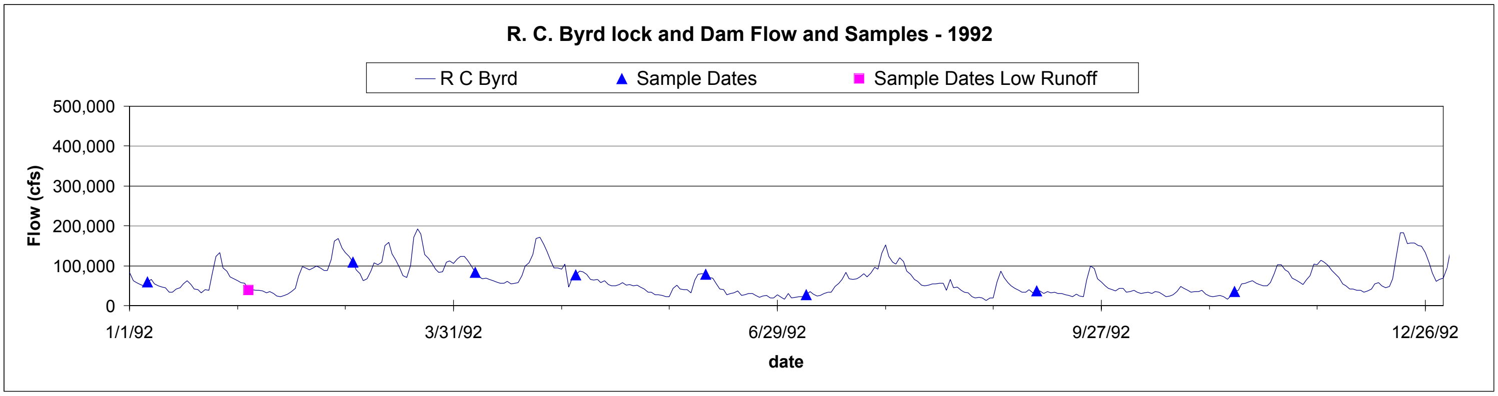
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date

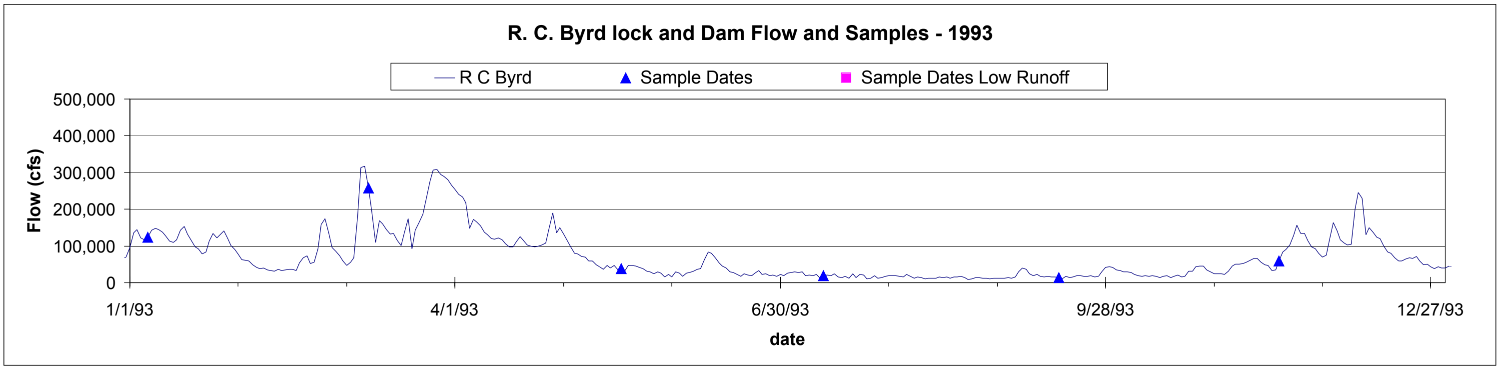


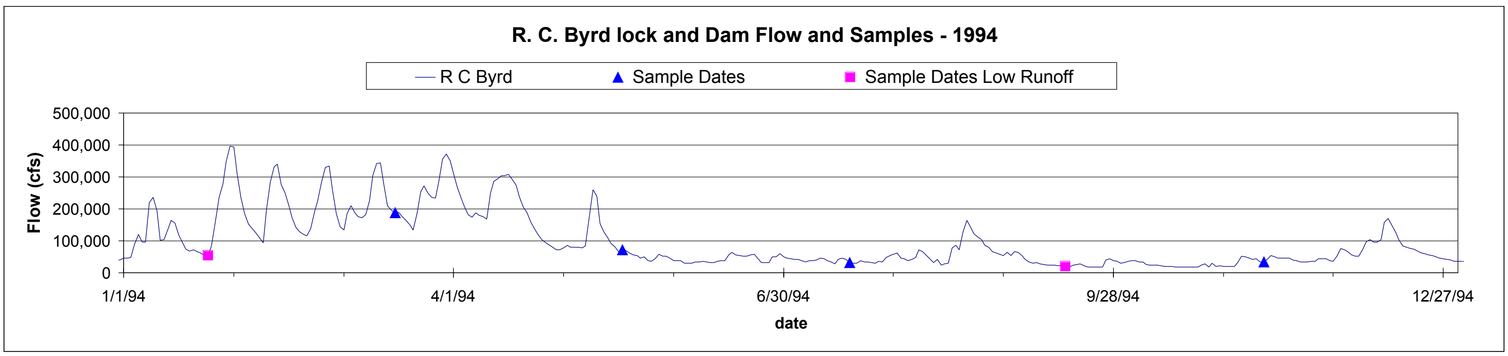
Belleville Lock and Dam Flow and Samples - 2000
Belleville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

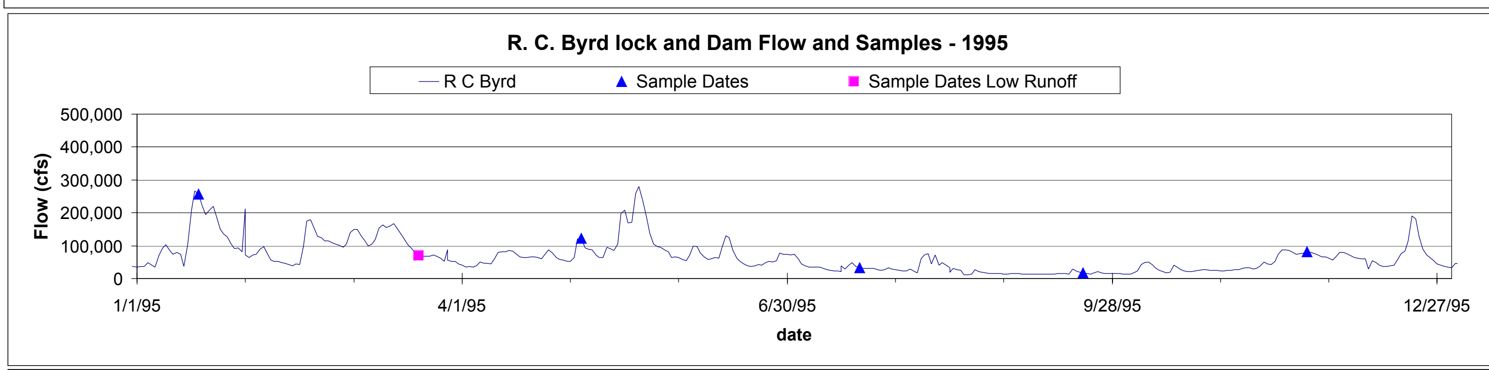


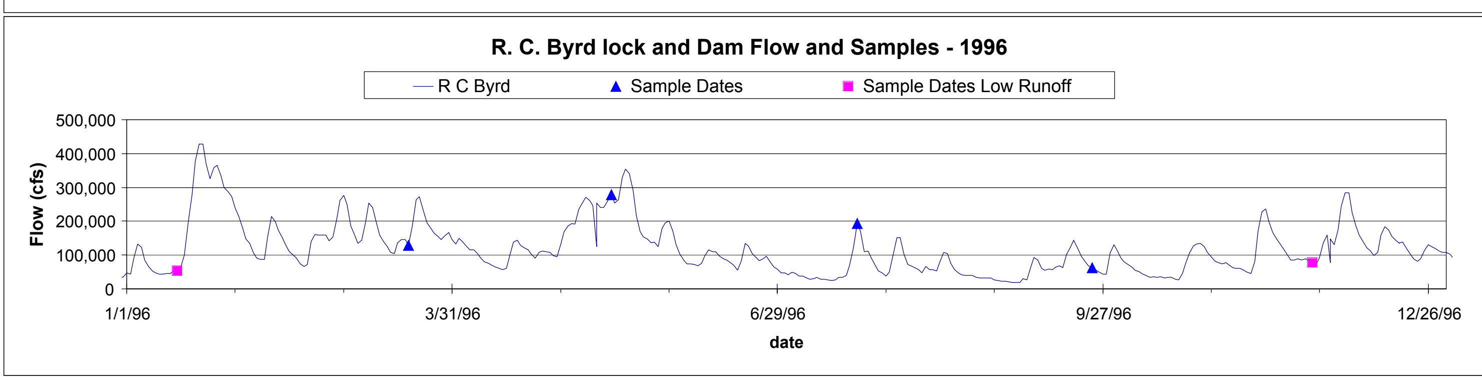
Belleville Lock and Dam Flow and Samples - 2001
Belleville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date

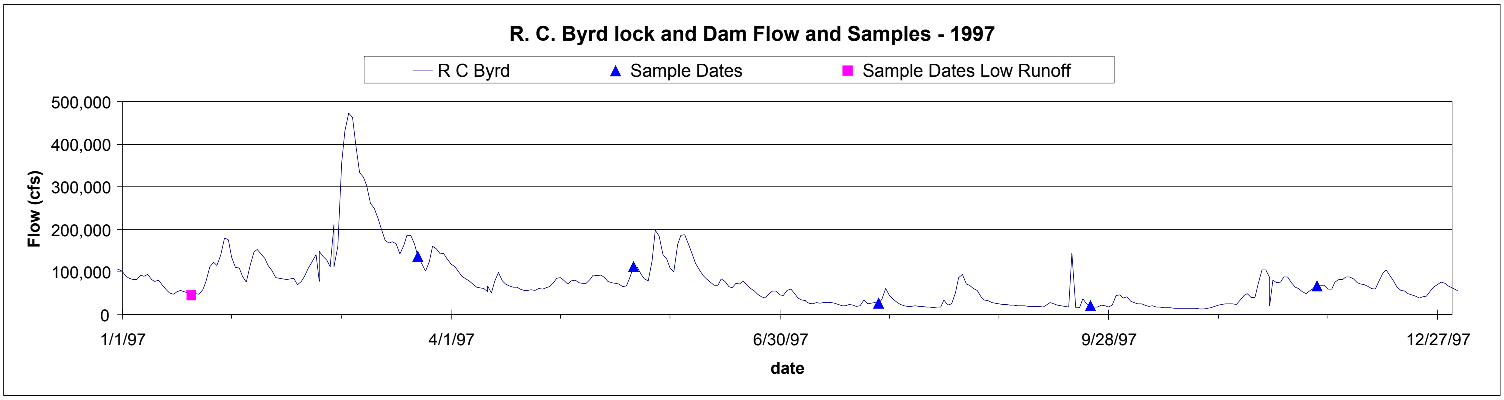

R. C. Byrd lock and Dam Flow and Samples - 1992
R C Byrd
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
500,000
400,000
300,000
200,000
100,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date

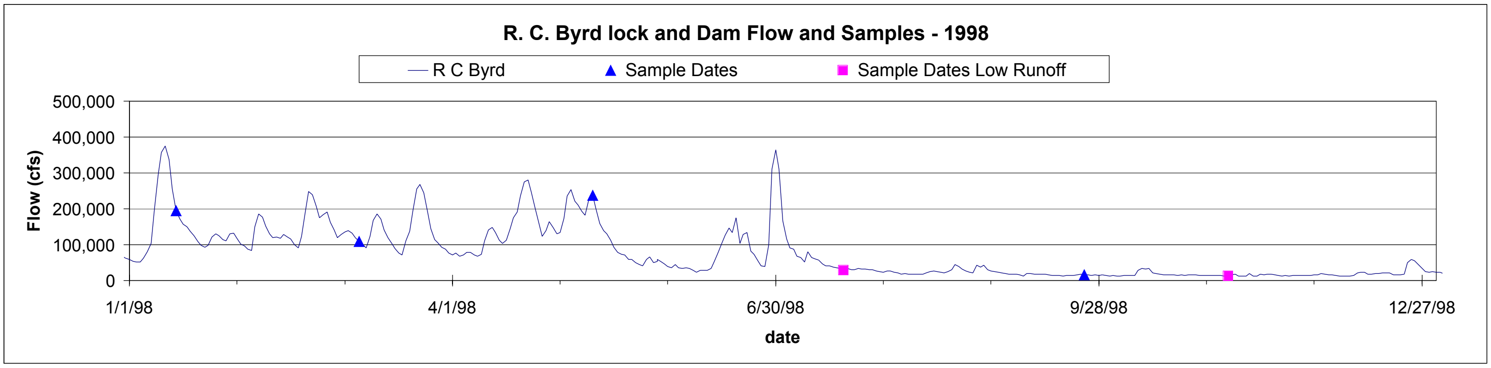

R. C. Byrd lock and Dam Flow and Samples - 1993
R C Byrd
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
500,000
400,000
300,000
200,000
100,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date

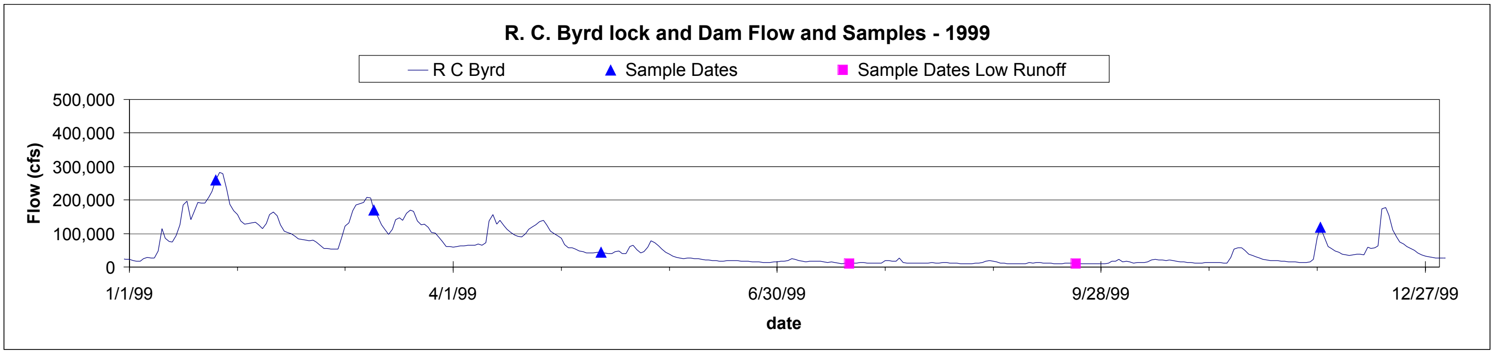

R. C. Byrd lock and Dam Flow and Samples - 1994
R C Byrd
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
500,000
400,000
300,000
200,000
100,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date

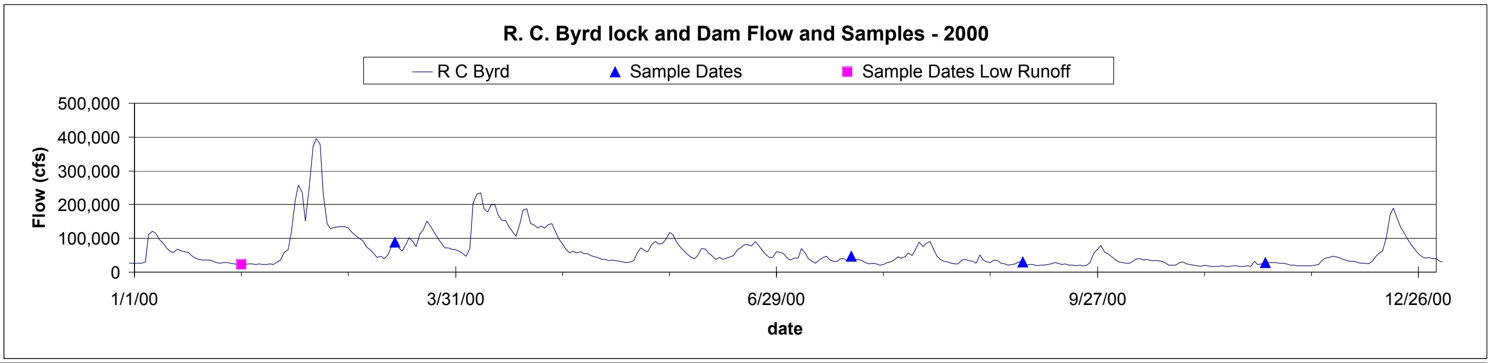

R. C. Byrd lock and Dam Flow and Samples - 1995
R C Byrd
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
500,000
400,000
300,000
200,000
100,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date

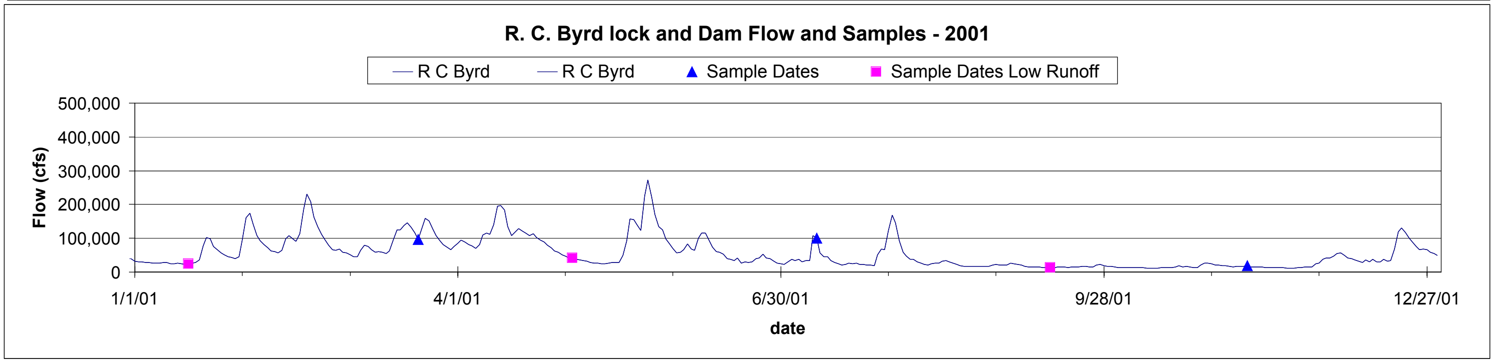

R. C. Byrd lock and Dam Flow and Samples - 1996
R C Byrd
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
500,000
400,000
300,000
200,000
100,000
0
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date

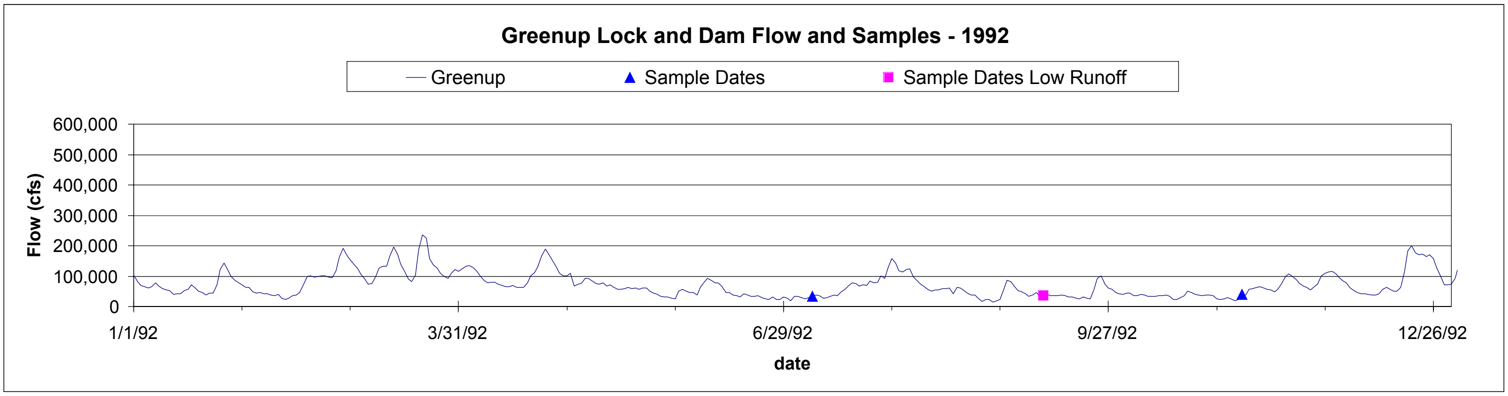

R. C. Byrd lock and Dam Flow and Samples - 1997
R C Byrd
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
500,000
400,000
300,000
200,000
100,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date


R. C. Byrd lock and Dam Flow and Samples - 1998
R C Byrd
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
500,000
400,000
300,000
200,000
100,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date

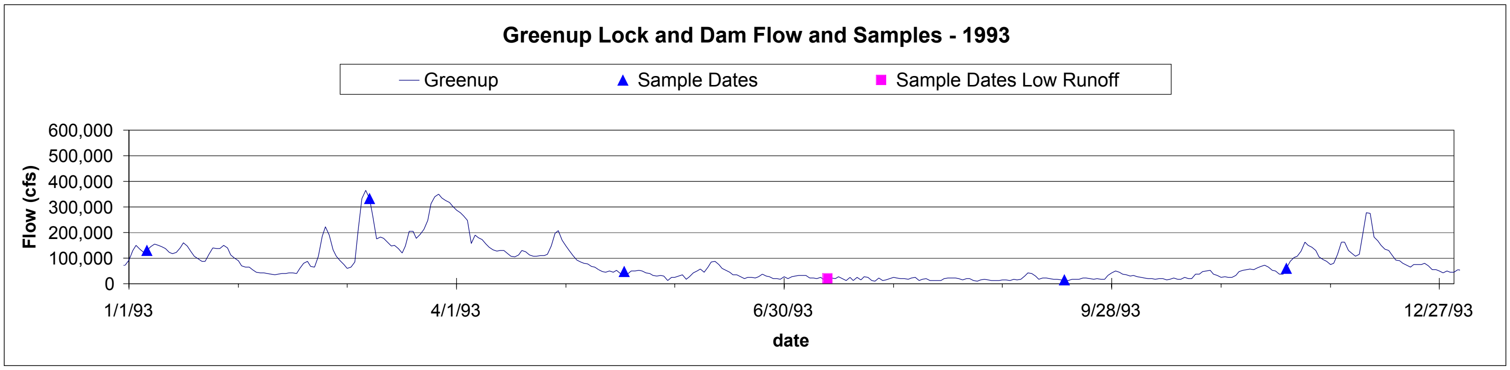

R. C. Byrd lock and Dam Flow and Samples - 1999
R C Byrd
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
500,000
400,000
300,000
200,000
100,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date


R. C. Byrd lock and Dam Flow and Samples - 2000
R C Byrd
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
500,000
400,000
300,000
200,000
100,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

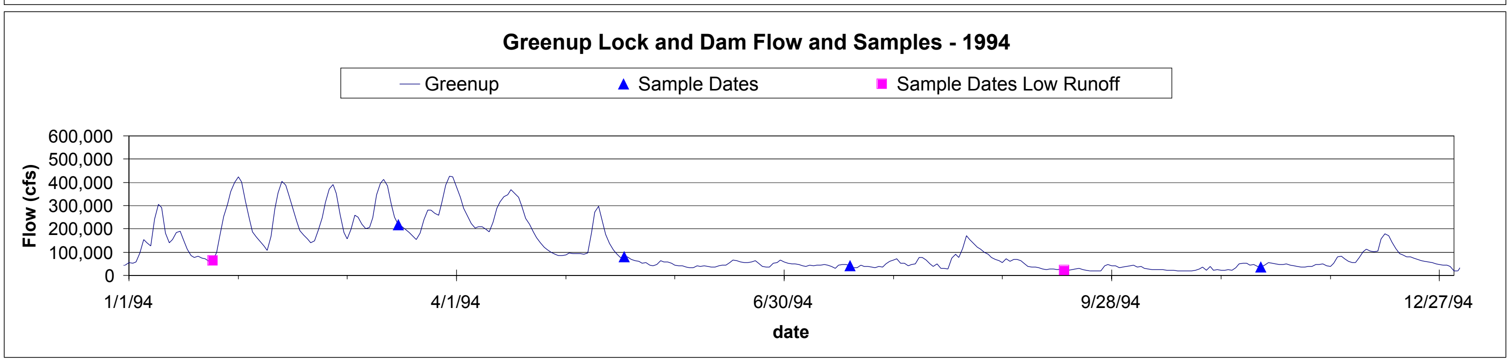

R. C. Byrd lock and Dam Flow and Samples - 2001
R C Byrd
R C Byrd
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
500,000
400,000
300,000
200,000
100,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date



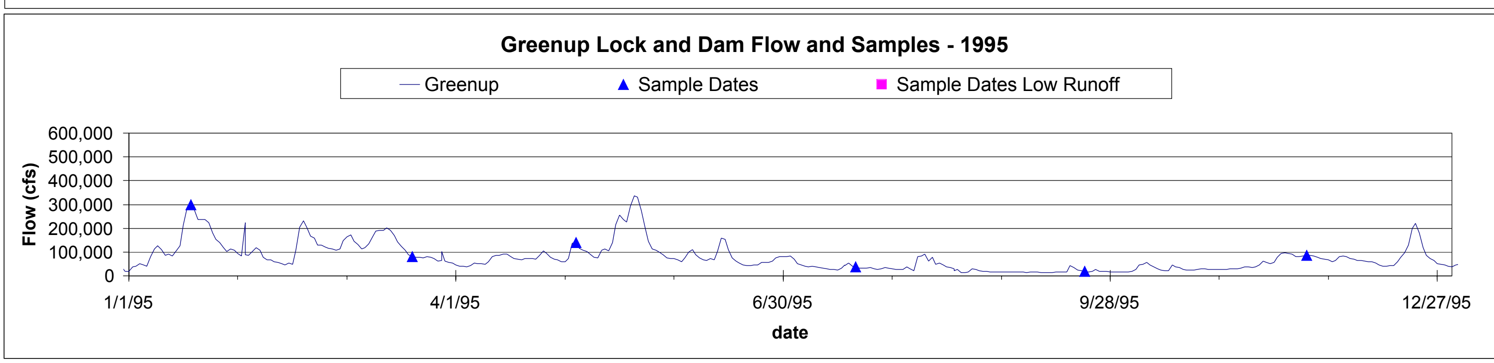
Greenup Lock and Dam Flow and Samples - 1992
Greenup
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date



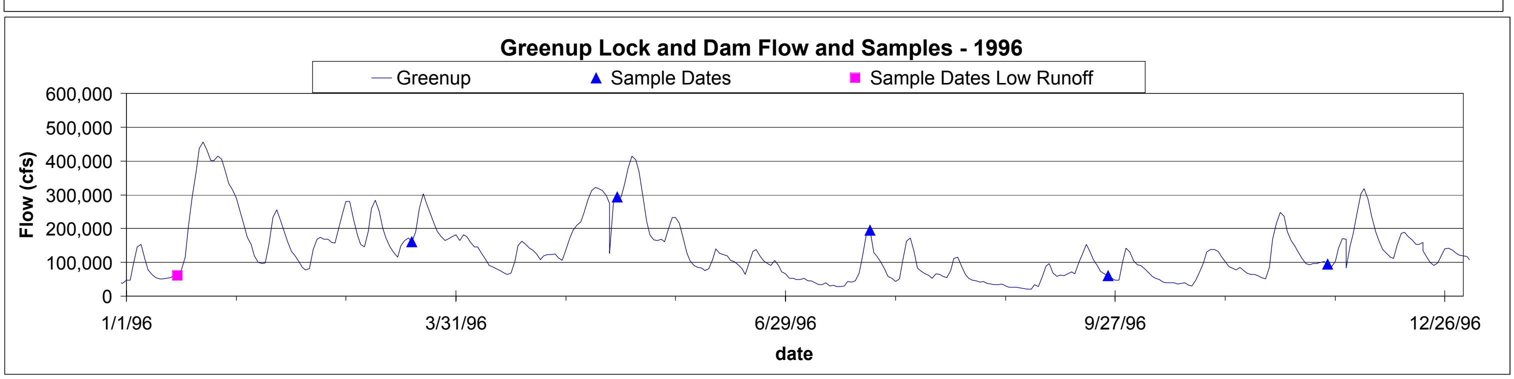
Greenup Lock and Dam Flow and Samples - 1993
Greenup
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date



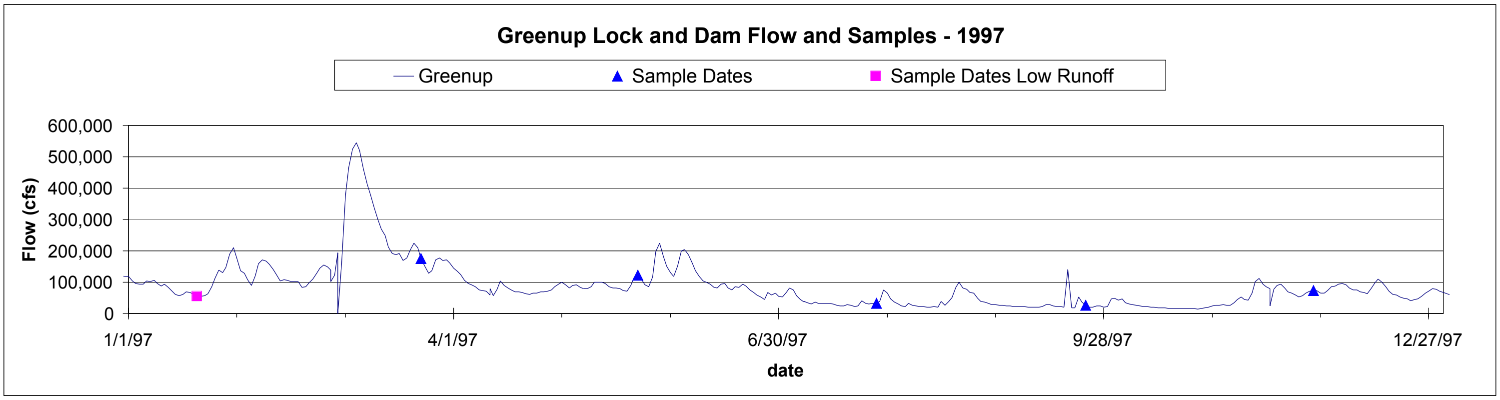
Greenup Lock and Dam Flow and Samples - 1994
Greenup
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date

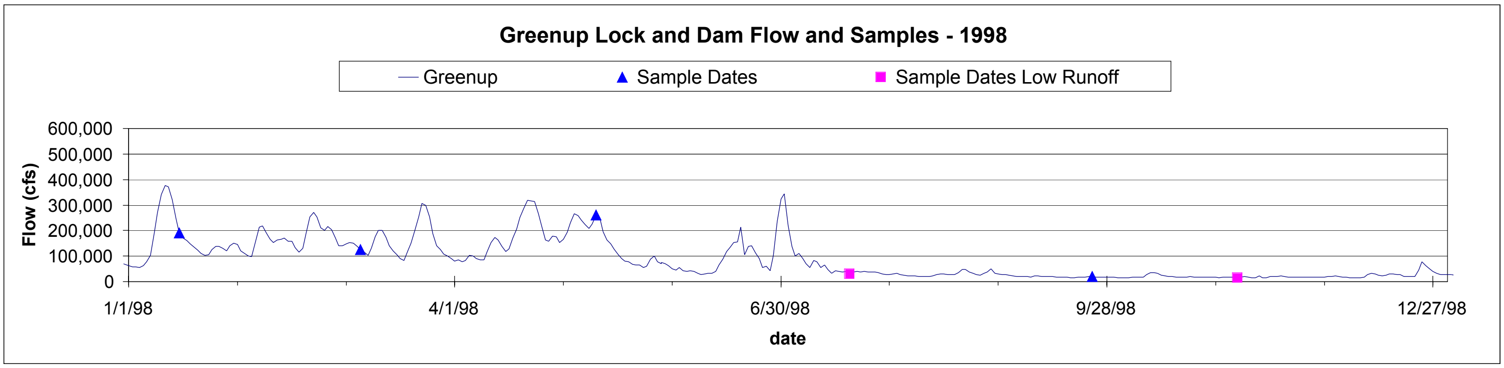


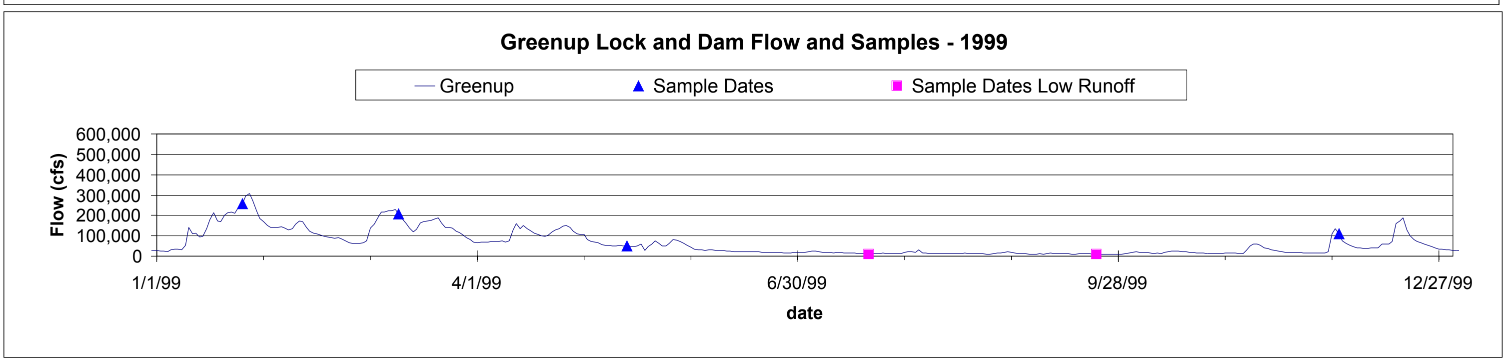
Greenup Lock and Dam Flow and Samples - 1995
Greenup
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date

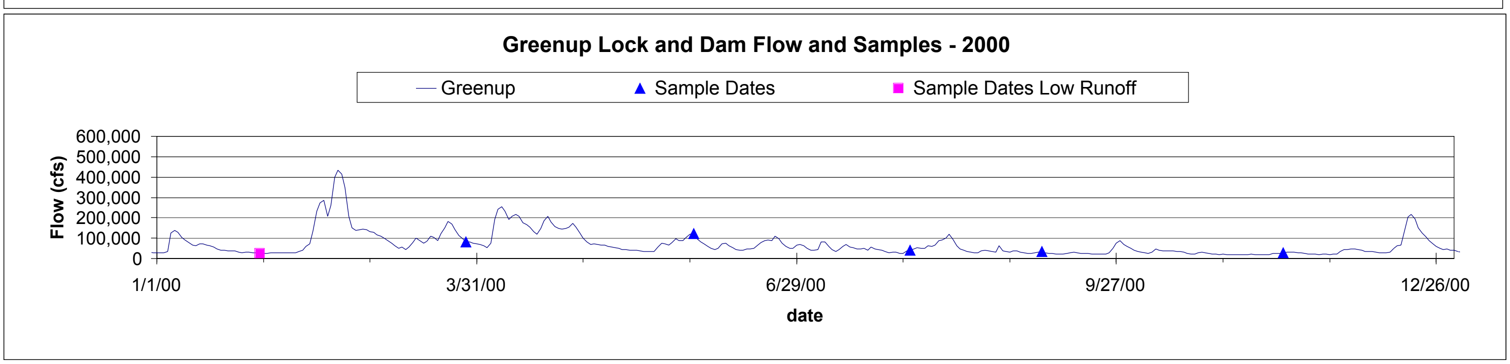


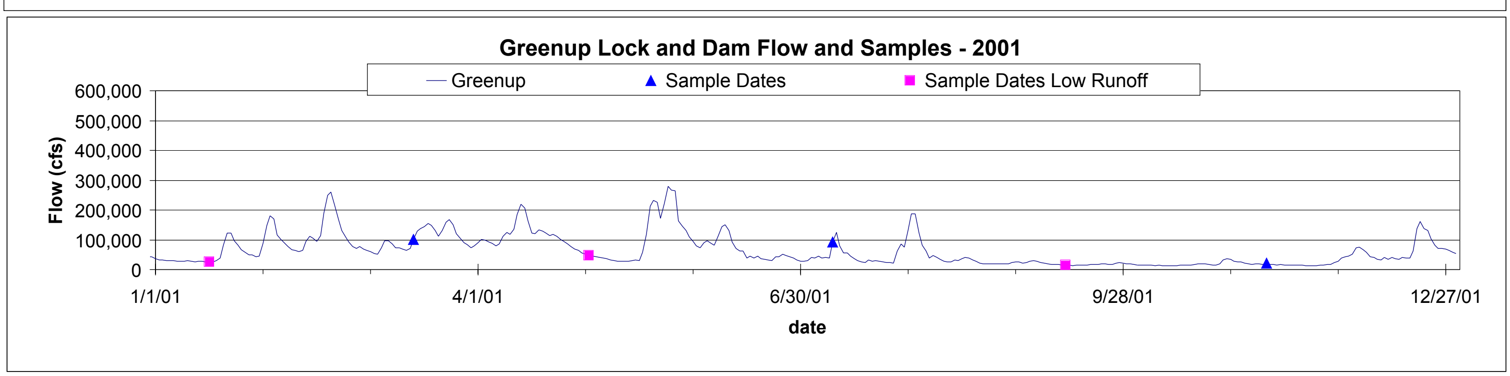
Greenup Lock and Dam Flow and Samples - 1996
Greenup
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date

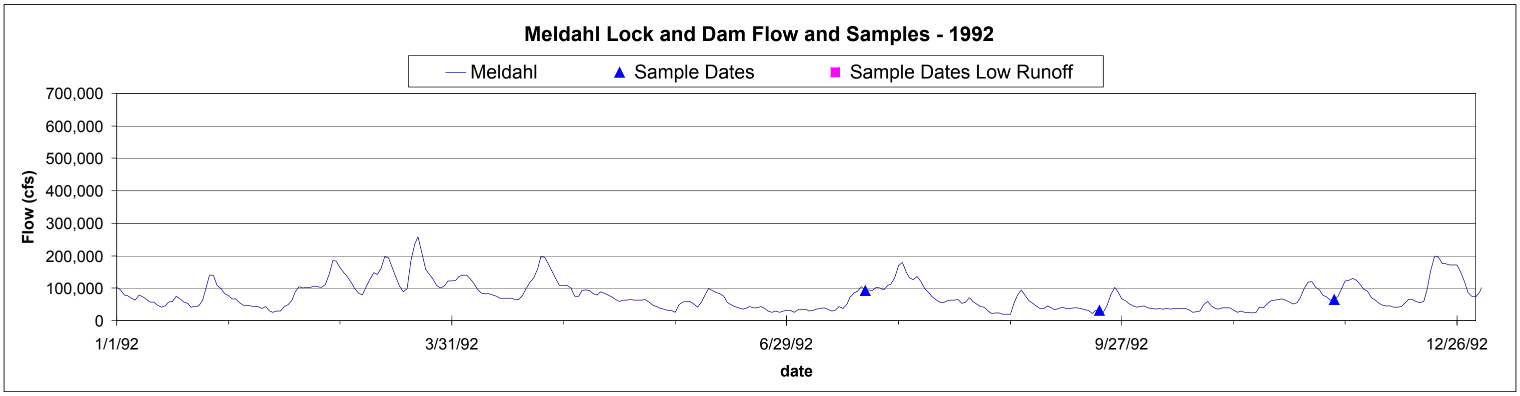

Greenup Lock and Dam Flow and Samples - 1997
Greenup
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date


Greenup Lock and Dam Flow and Samples - 1998
Greenup
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date

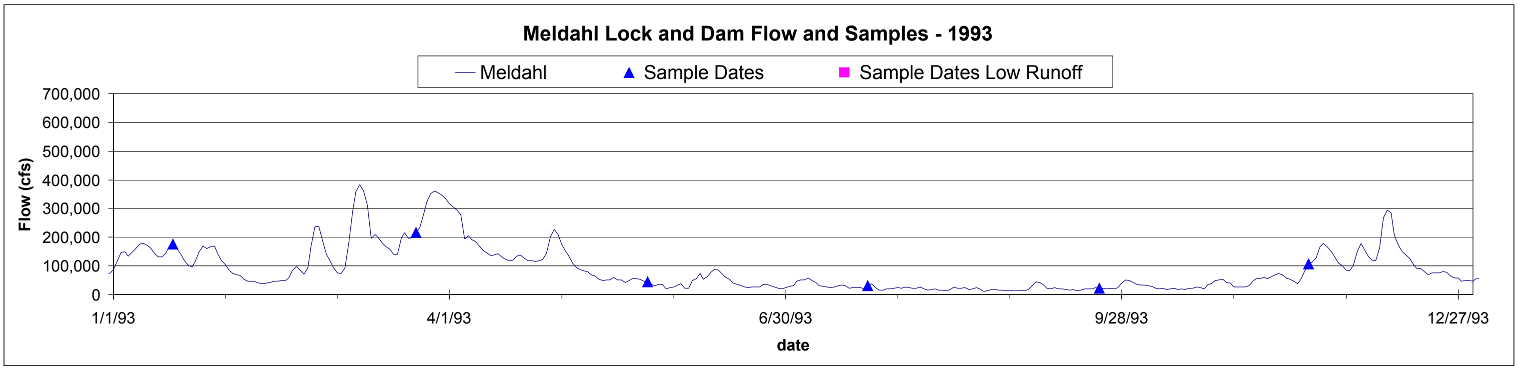

Greenup Lock and Dam Flow and Samples - 1999
Greenup
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date


Greenup Lock and Dam Flow and Samples - 2000
Greenup
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

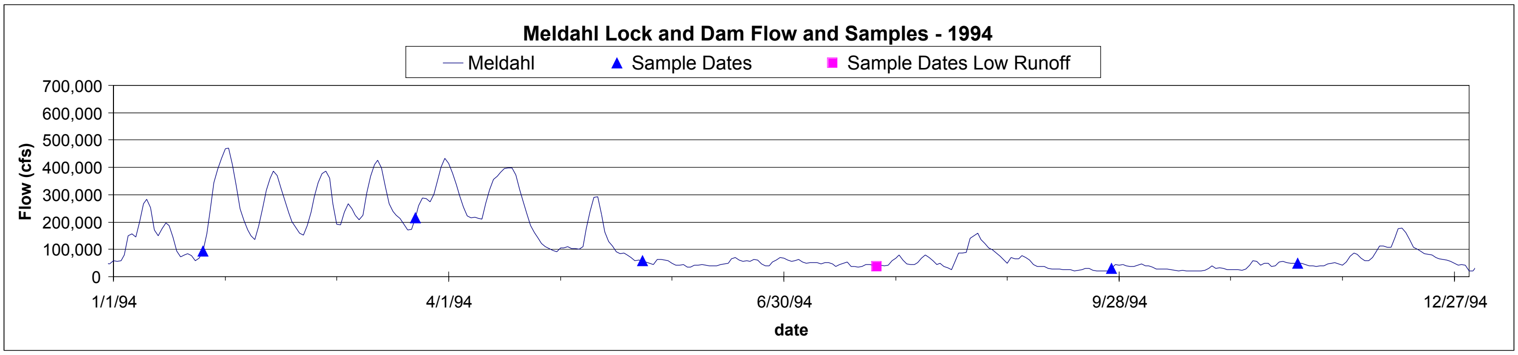

Greenup Lock and Dam Flow and Samples - 2001
Greenup
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date



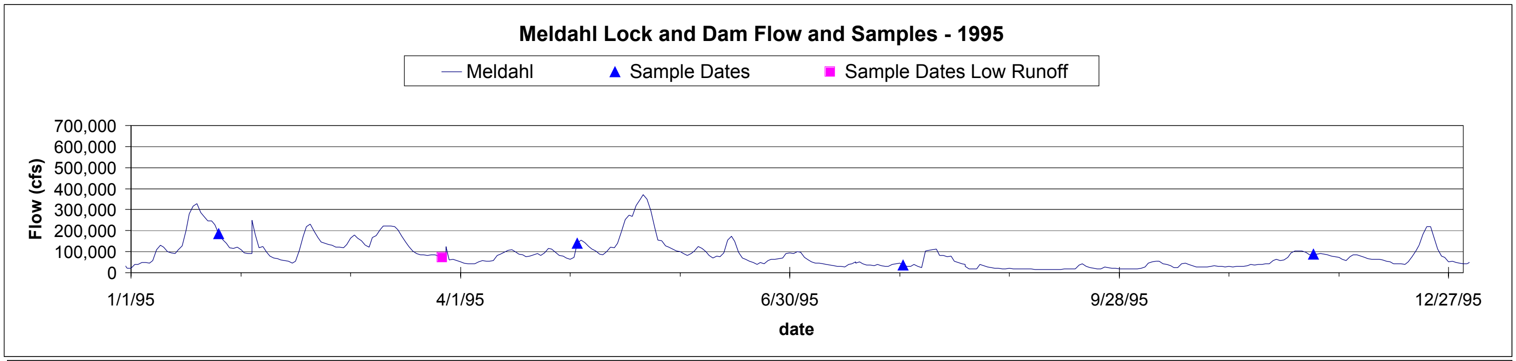
Meldahl Lock and Dam Flow and Samples - 1992
Meldahl
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date



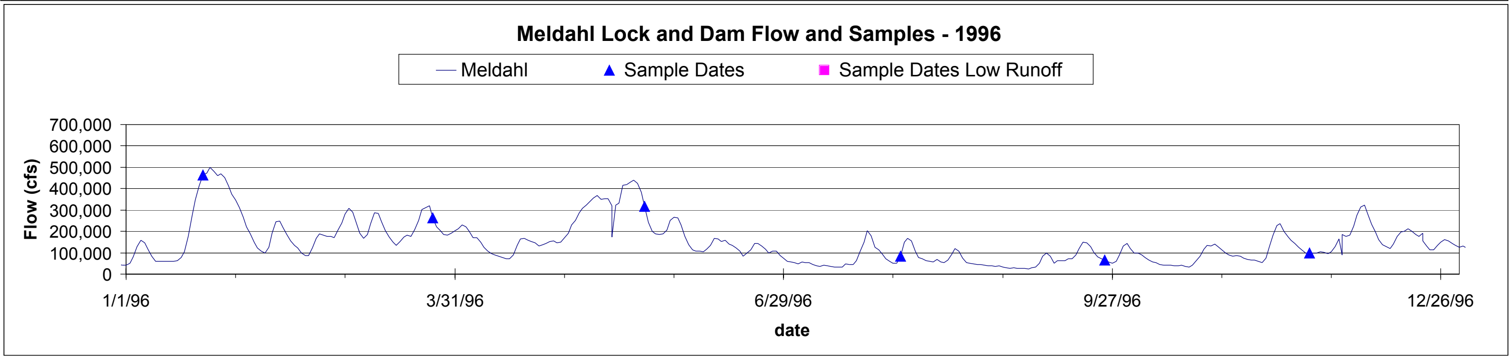
Meldahl Lock and Dam Flow and Samples - 1993
Meldahl
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date



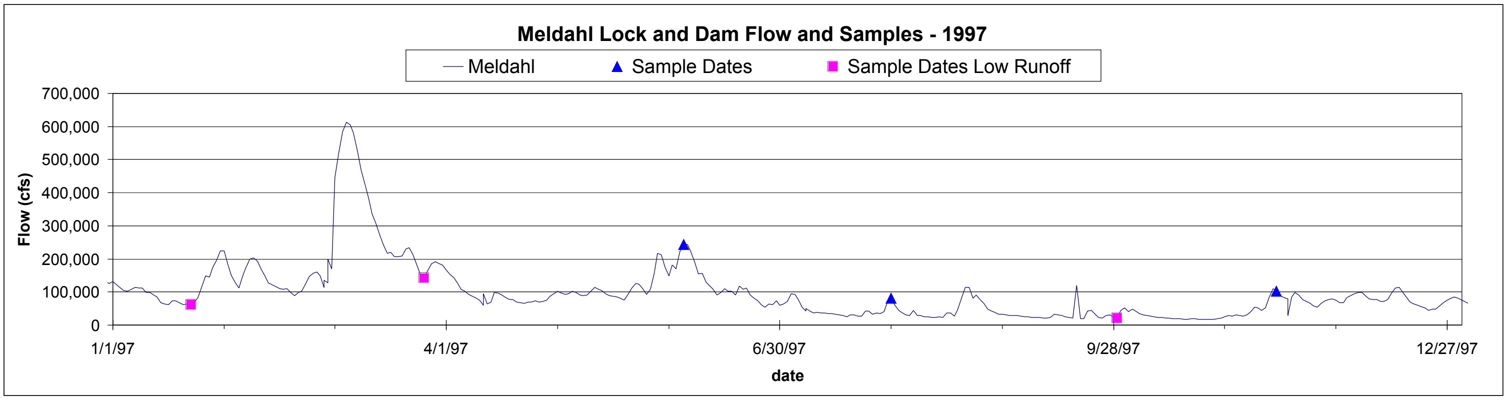
Meldahl Lock and Dam Flow and Samples - 1994
Meldahl
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date



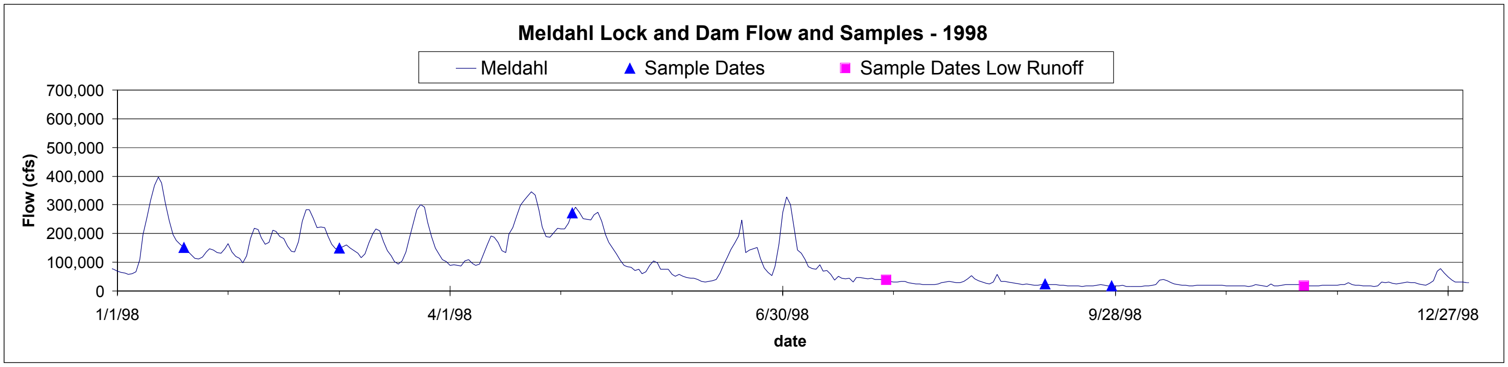
Meldahl Lock and Dam Flow and Samples - 1995
Meldahl
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date



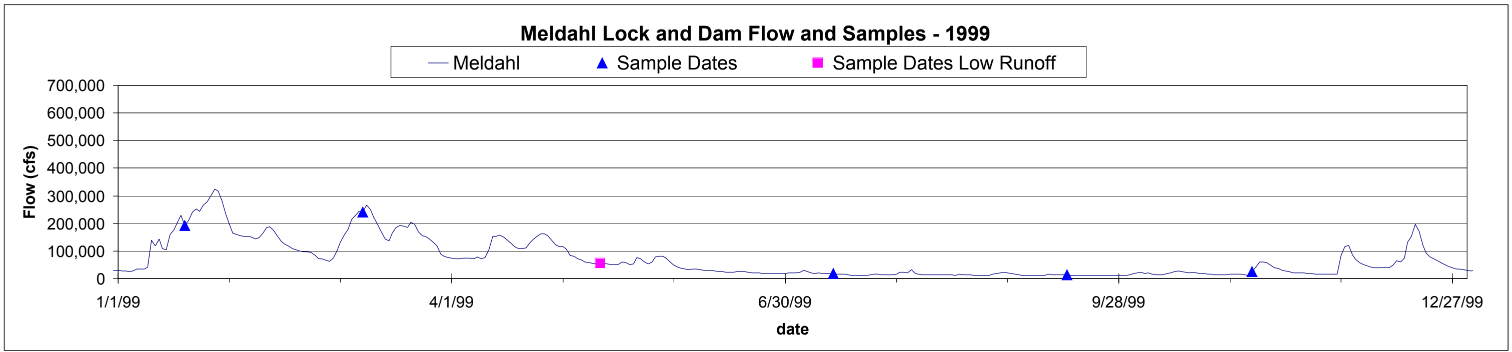
Meldahl Lock and Dam Flow and Samples - 1996
Meldahl
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date



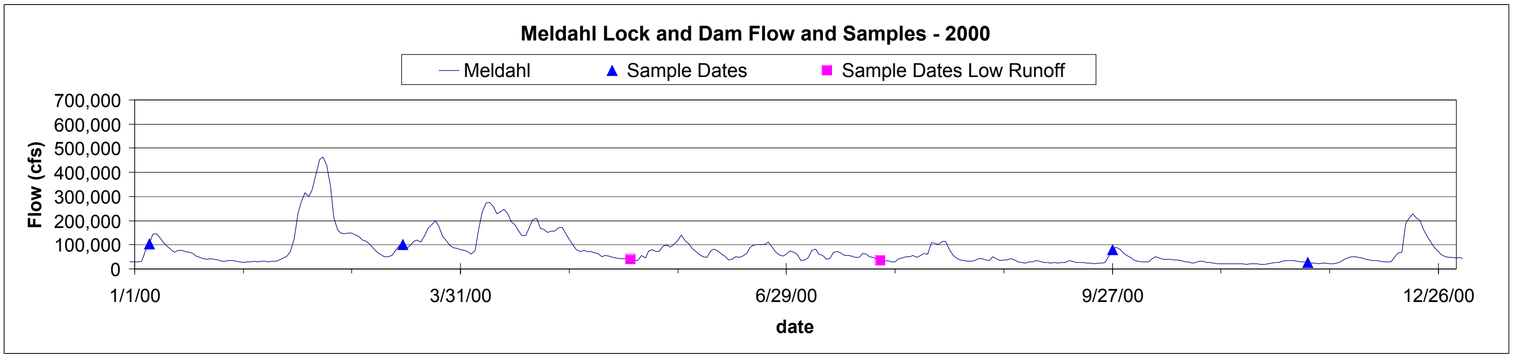
Meldahl Lock and Dam Flow and Samples - 1997
Meldahl
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date



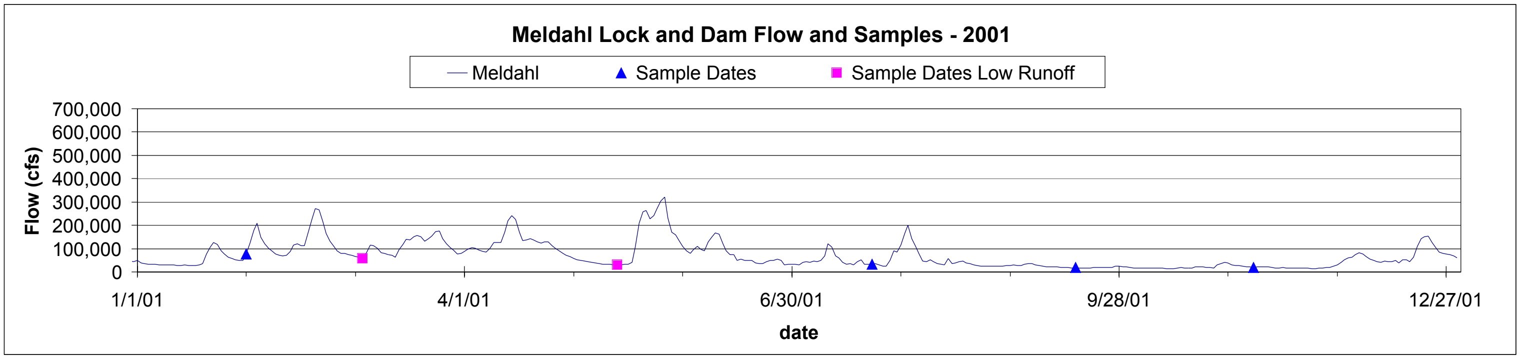
Meldahl Lock and Dam Flow and Samples - 1998
Meldahl
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date



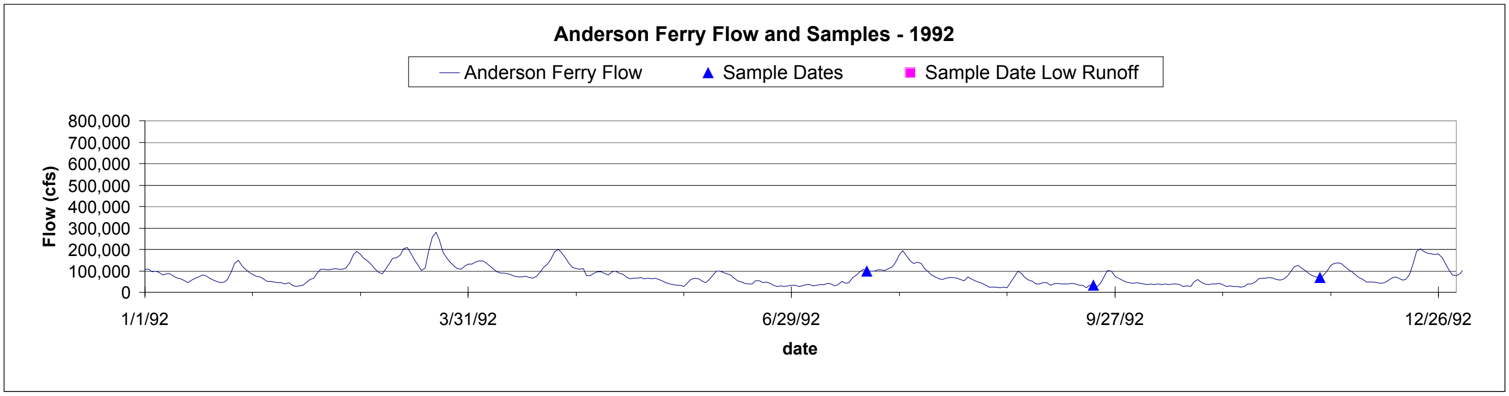
Meldahl Lock and Dam Flow and Samples - 1999
Meldahl
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date

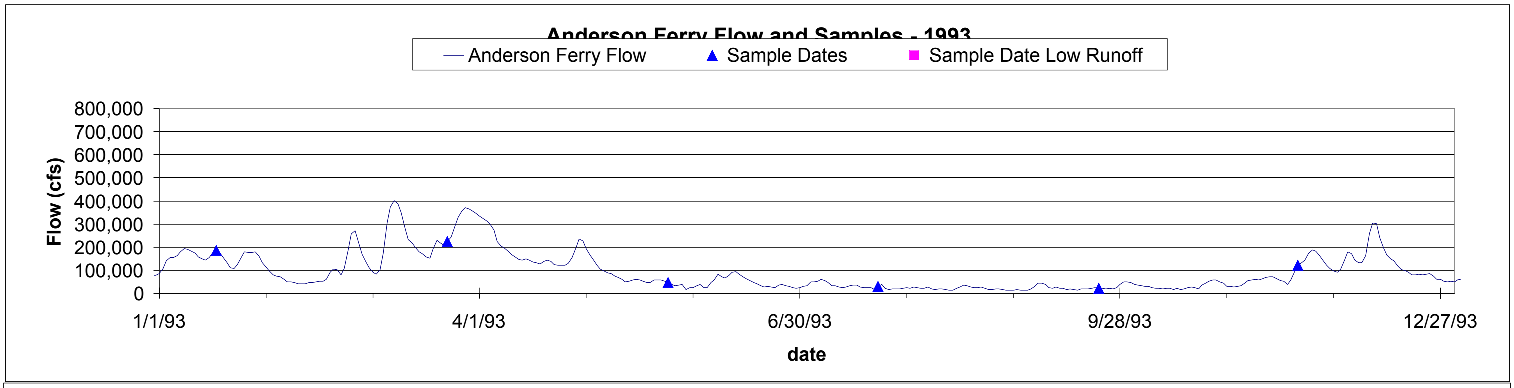


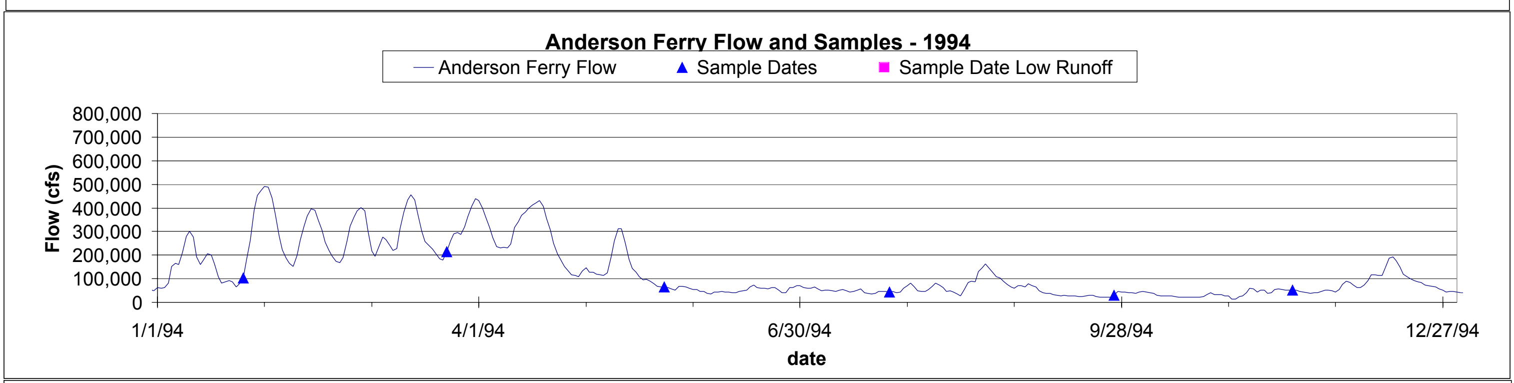
Meldahl Lock and Dam Flow and Samples - 2000
Meldahl
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

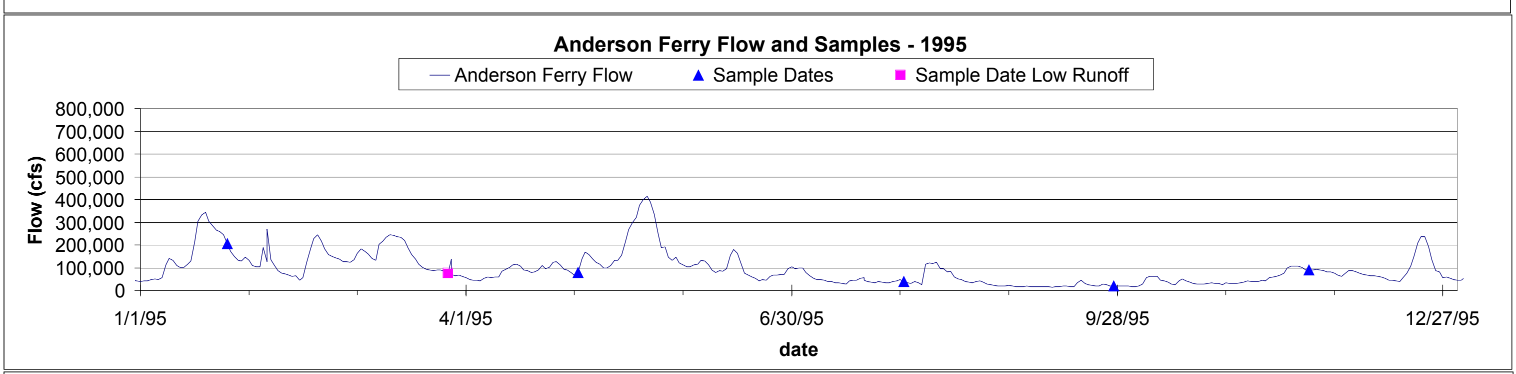


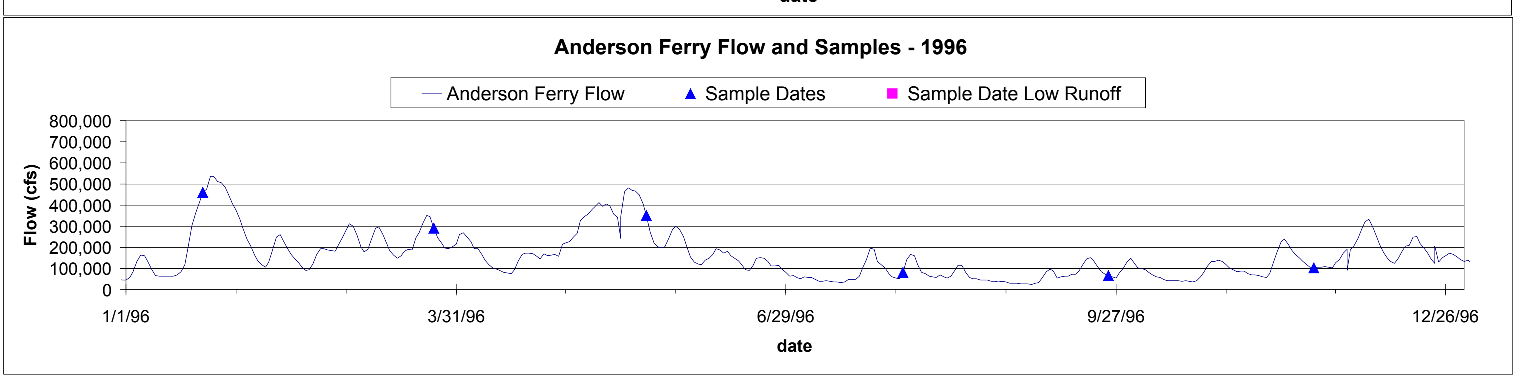
Meldahl Lock and Dam Flow and Samples - 2001
Meldahl
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date

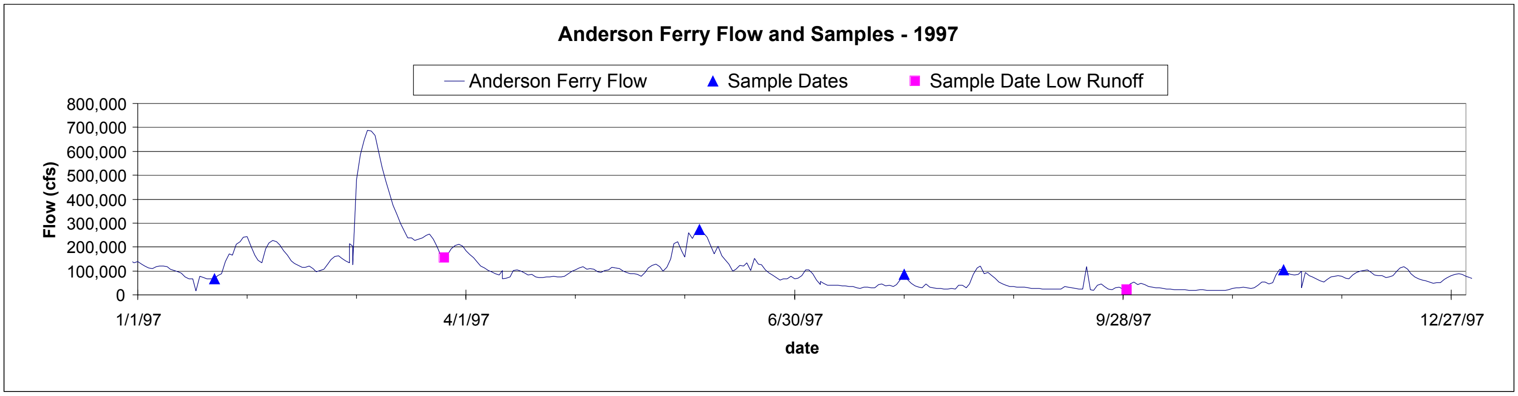

Anderson Ferry Flow and Samples - 1992
Anderson Ferry Flow
Sample Dates
Sample Date Low Runoff
Flow (cfs)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date

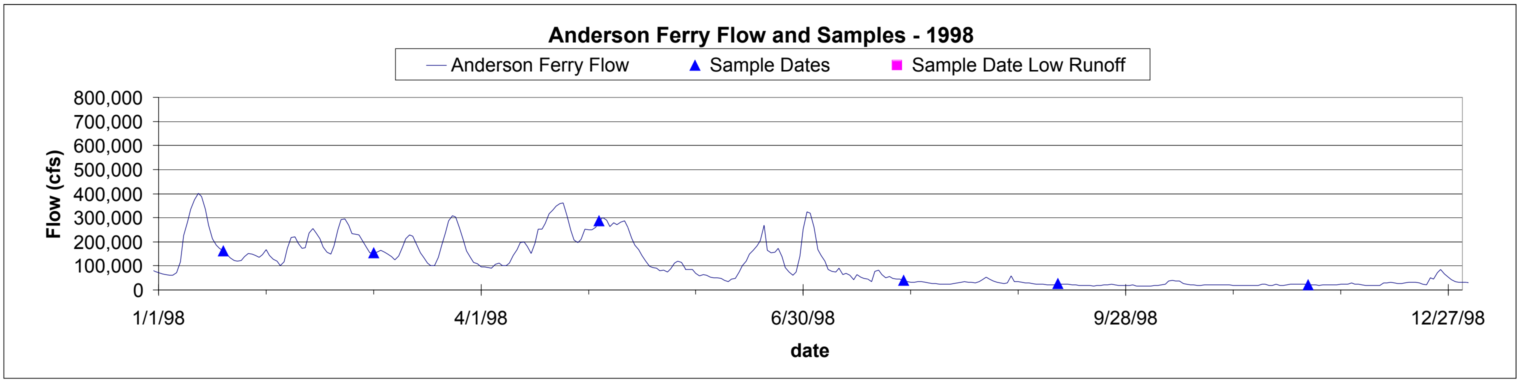

Anderson Ferry Flow and Samples - 1993
Anderson Ferry Flow
Sample Dates
Sample Date Low Runoff
Flow (cfs)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date

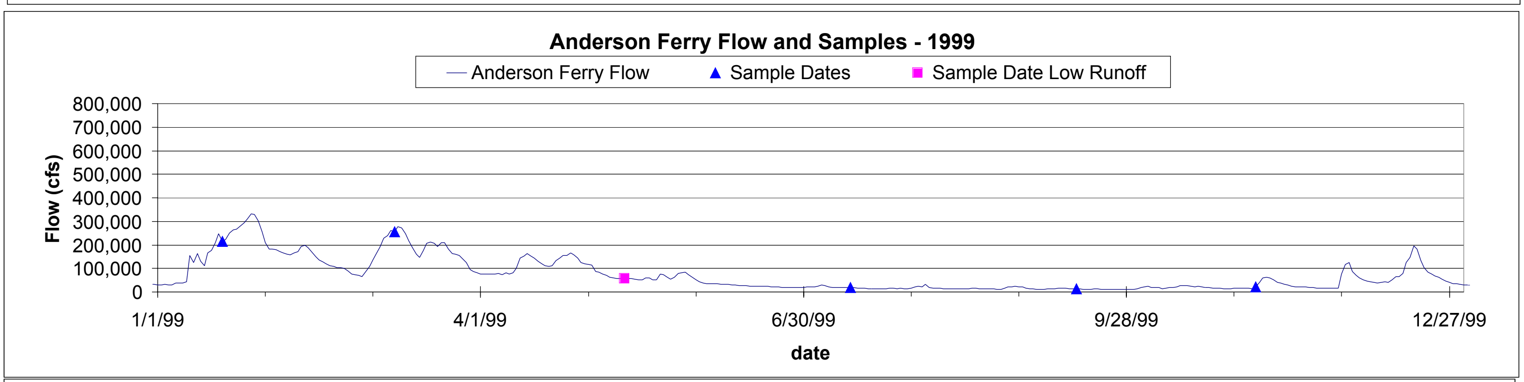

Anderson Ferry Flow and Samples - 1994
Anderson Ferry Flow
Sample Dates
Sample Date Low Runoff
Flow (cfs)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date

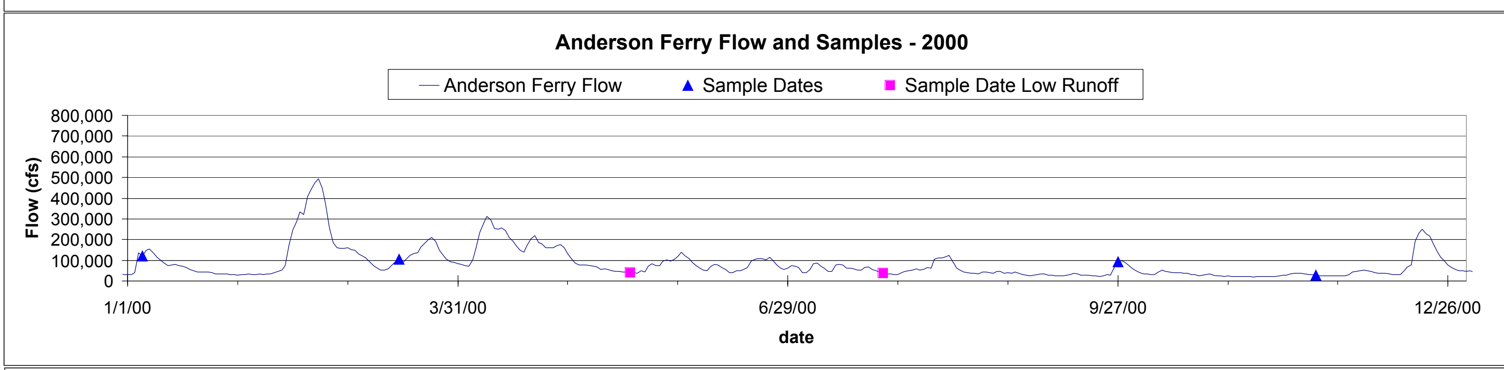

Anderson Ferry Flow and Samples - 1995
Anderson Ferry Flow
Sample Dates
Sample Date Low Runoff
Flow (cfs)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date

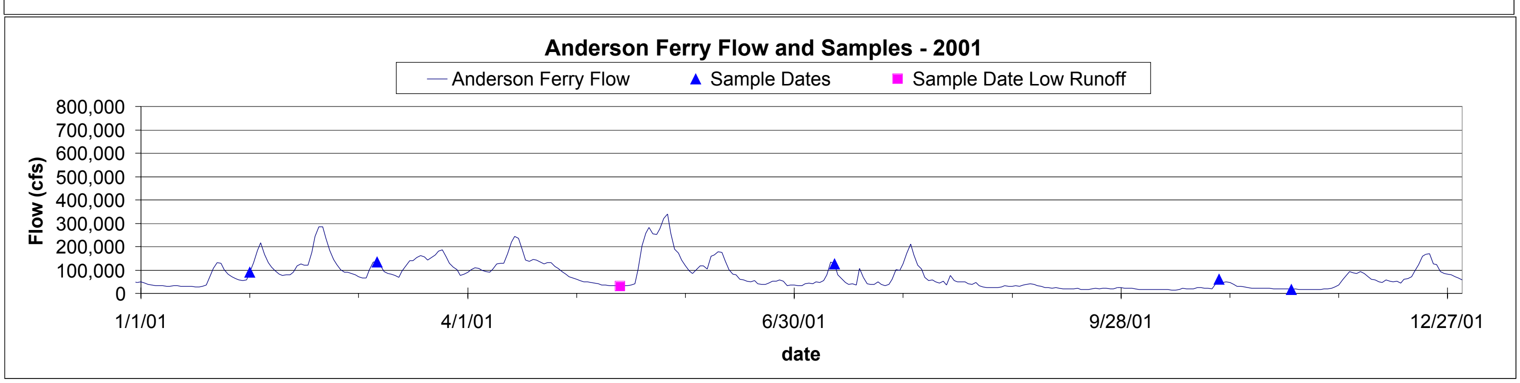

Anderson Ferry Flow and Samples - 1996
Anderson Ferry Flow
Sample Dates
Sample Date Low Runoff
Flow (cfs)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date

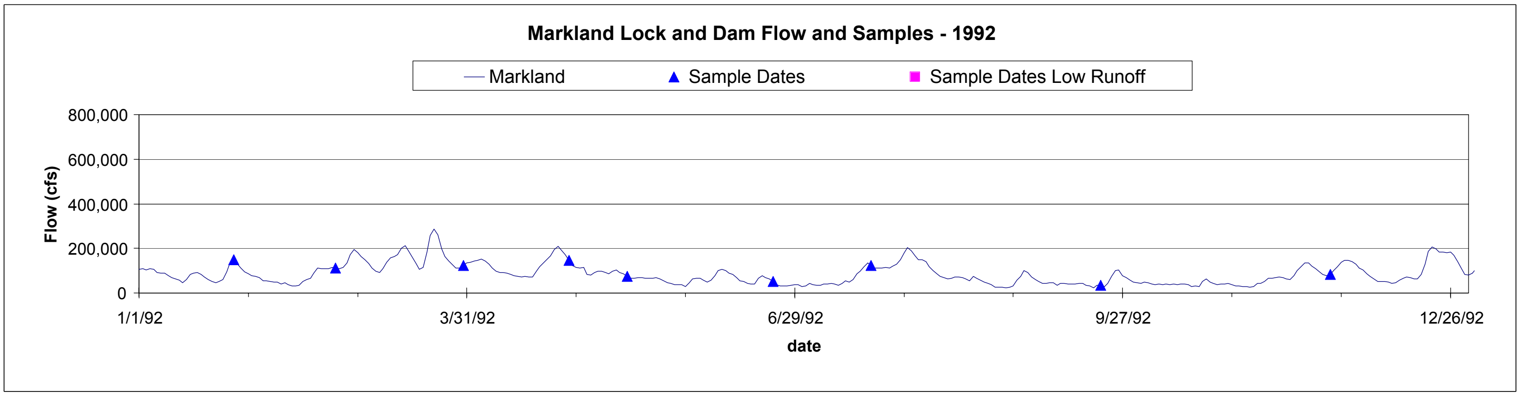

Anderson Ferry Flow and Samples - 1997
Anderson Ferry Flow
Sample Dates
Sample Date Low Runoff
Flow (cfs)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date

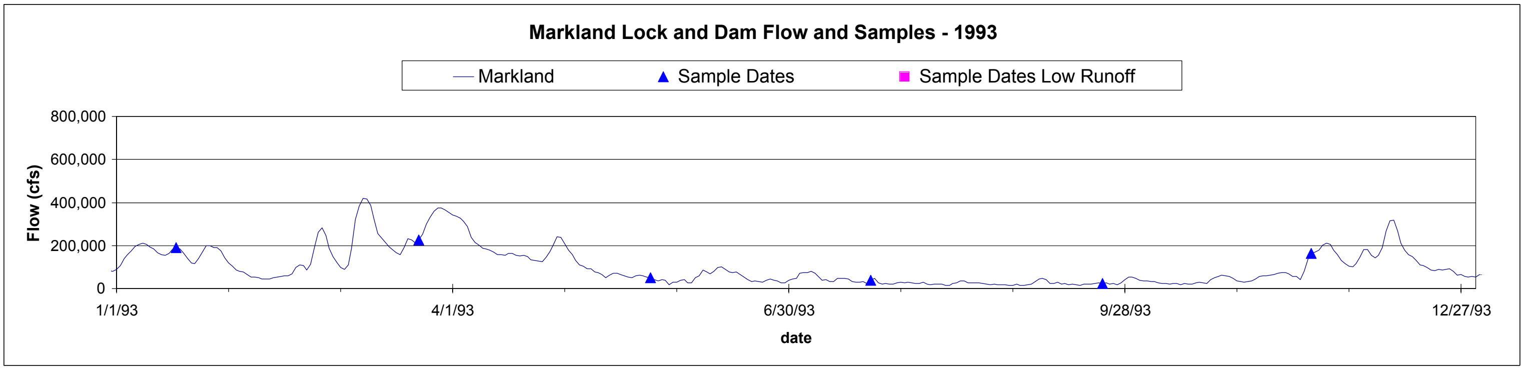

Anderson Ferry Flow and Samples - 1998
Anderson Ferry Flow
Sample Dates
Sample Date Low Runoff
Flow (cfs)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date

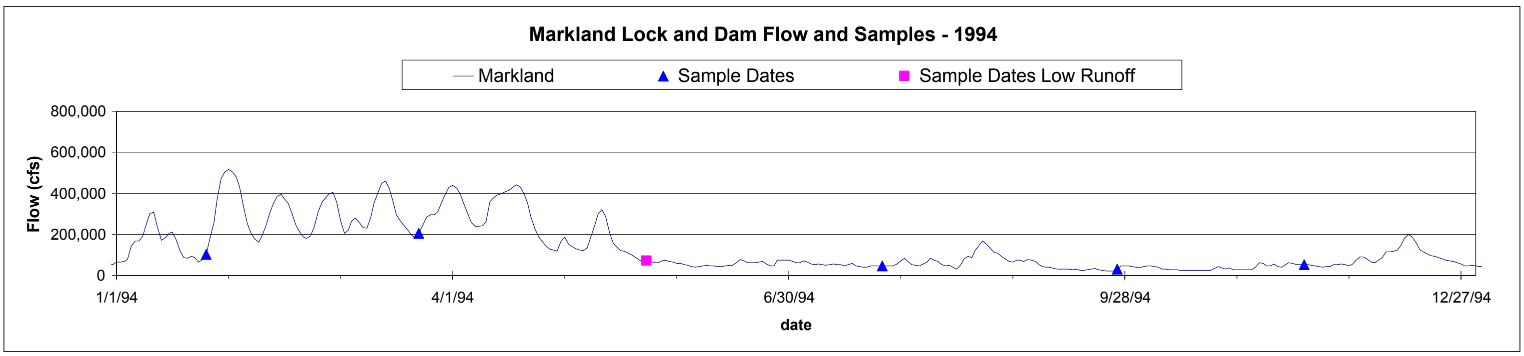

Anderson Ferry Flow and Samples - 1999
Anderson Ferry Flow
Sample Dates
Sample Date Low Runoff
Flow (cfs)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date

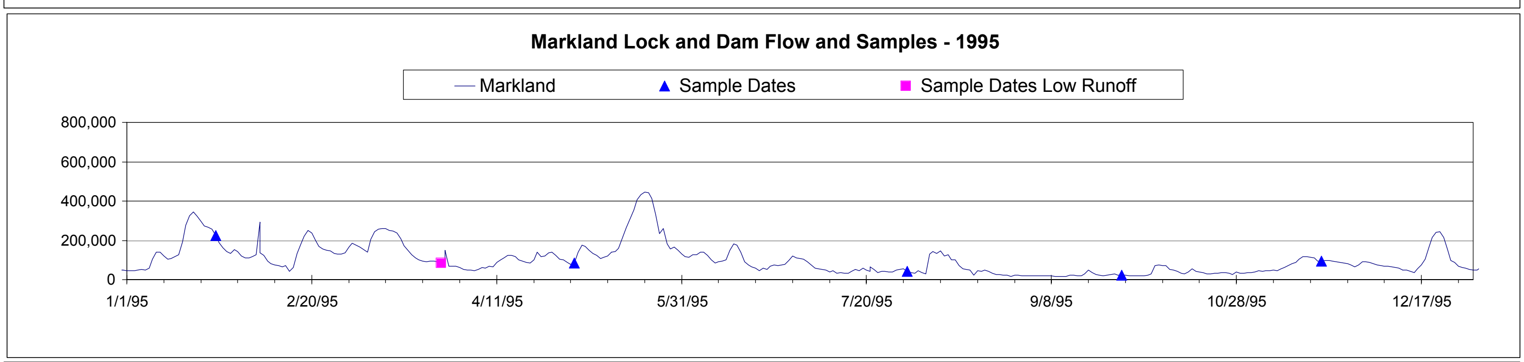

Anderson Ferry Flow and Samples - 2000
Anderson Ferry Flow
Sample Dates
Sample Date Low Runoff
Flow (cfs)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

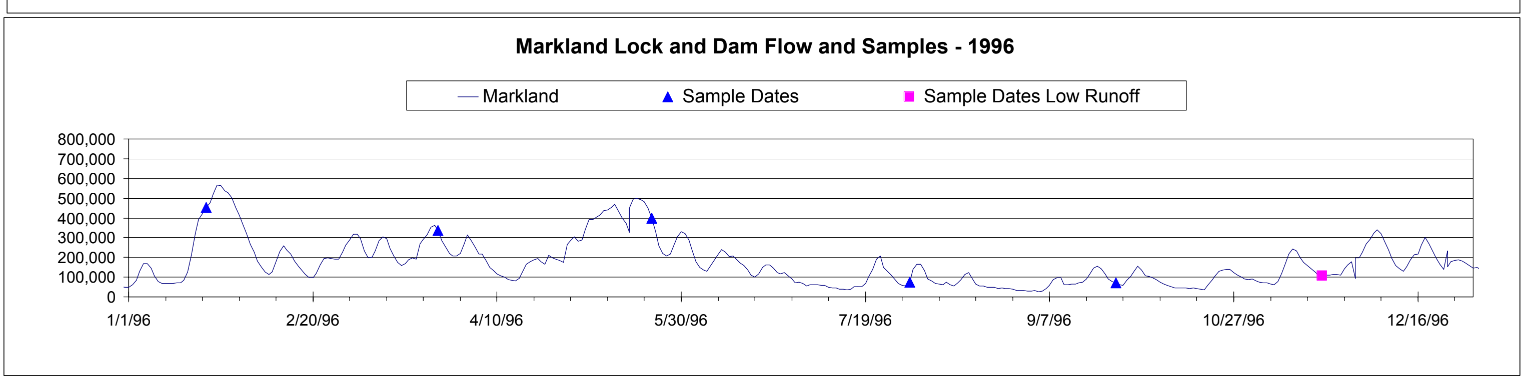

Anderson Ferry Flow and Samples - 2001
Anderson Ferry Flow
Sample Dates
Sample Date Low Runoff
Flow (cfs)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date

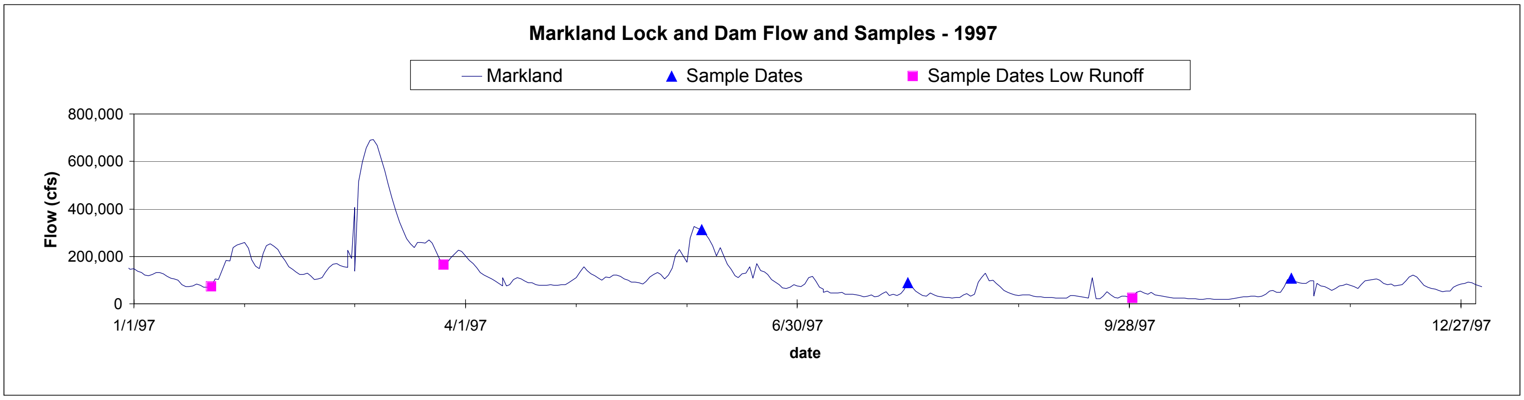

Markland Lock and Dam Flow and Samples - 1992
Markland
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
800,000
600,000
400,000
200,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date


Markland Lock and Dam Flow and Samples - 1993
Markland
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
800,000
600,000
400,000
200,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date

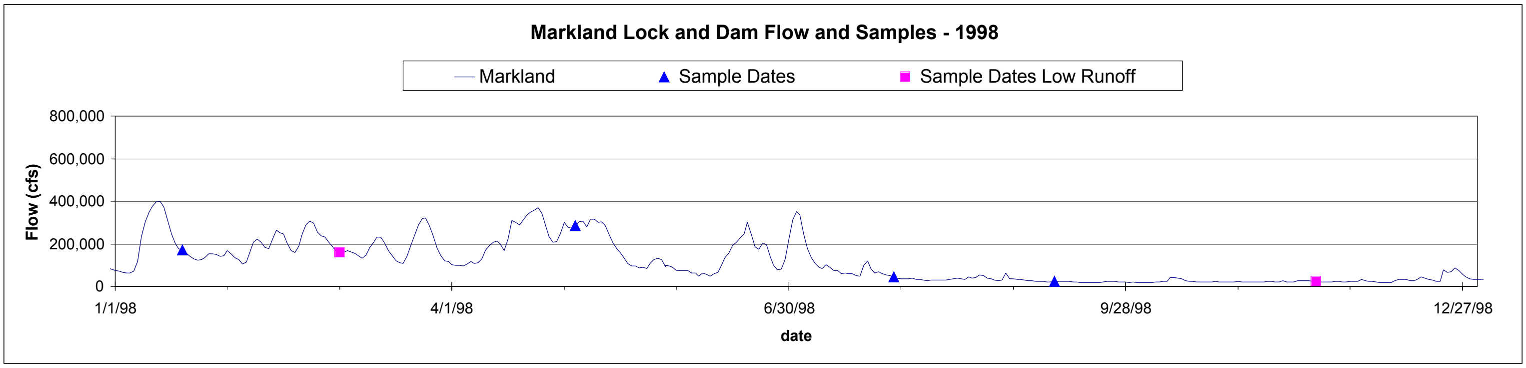

Markland Lock and Dam Flow and Samples - 1994
Markland
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
800,000
600,000
400,000
200,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date


Markland Lock and Dam Flow and Samples - 1995
Markland
Sample Dates
Sample Dates Low Runoff
800,000
600,000
400,000
200,000
0
1/1/95
2/20/95
4/11/95
5/31/95
7/20/95
9/8/95
10/28/95
12/17/95

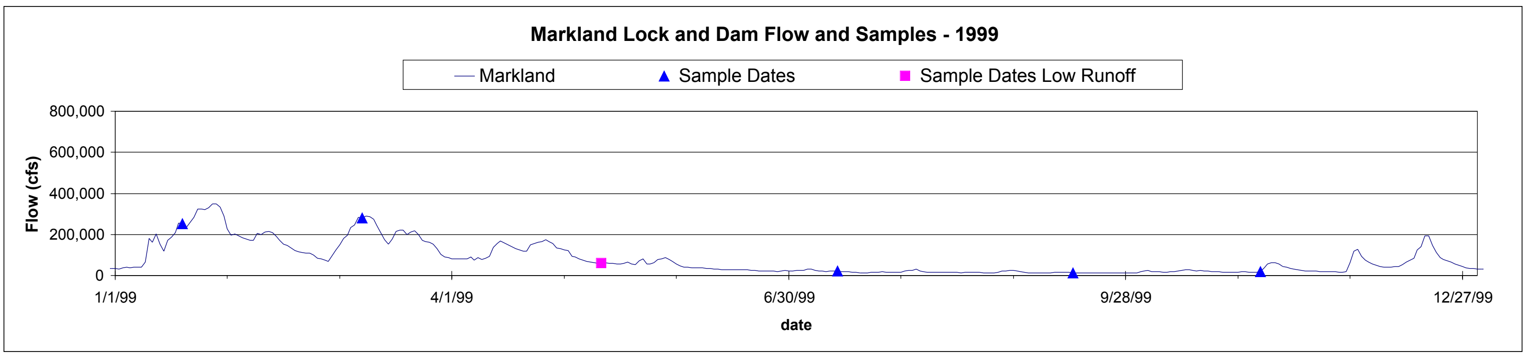

Markland Lock and Dam Flow and Samples - 1996
Markland
Sample Dates
Sample Dates Low Runoff
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/96
2/20/96
4/10/96
5/30/96
7/19/96
9/7/96
10/27/96
12/16/96



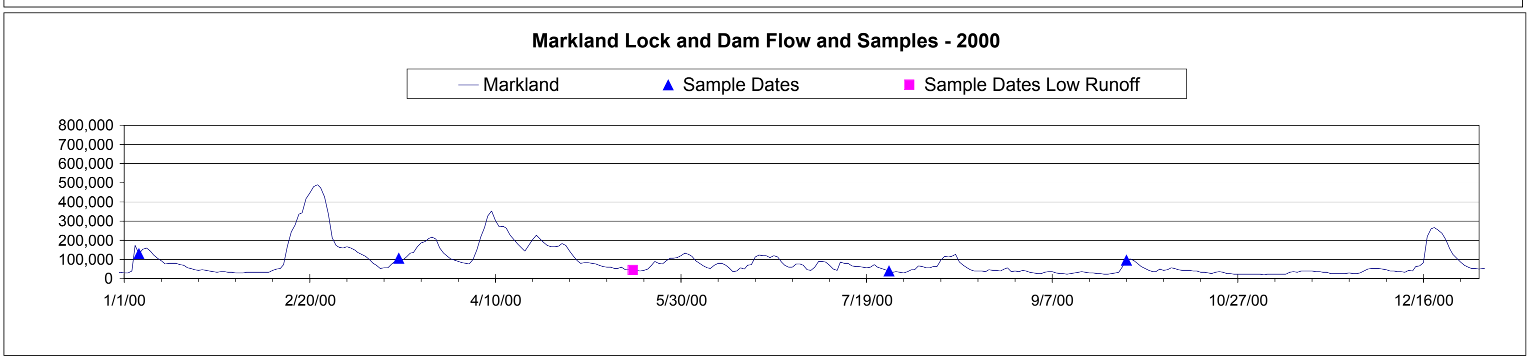
Markland Lock and Dam Flow and Samples - 1997
Markland
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
800,000
600,000
400,000
200,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date



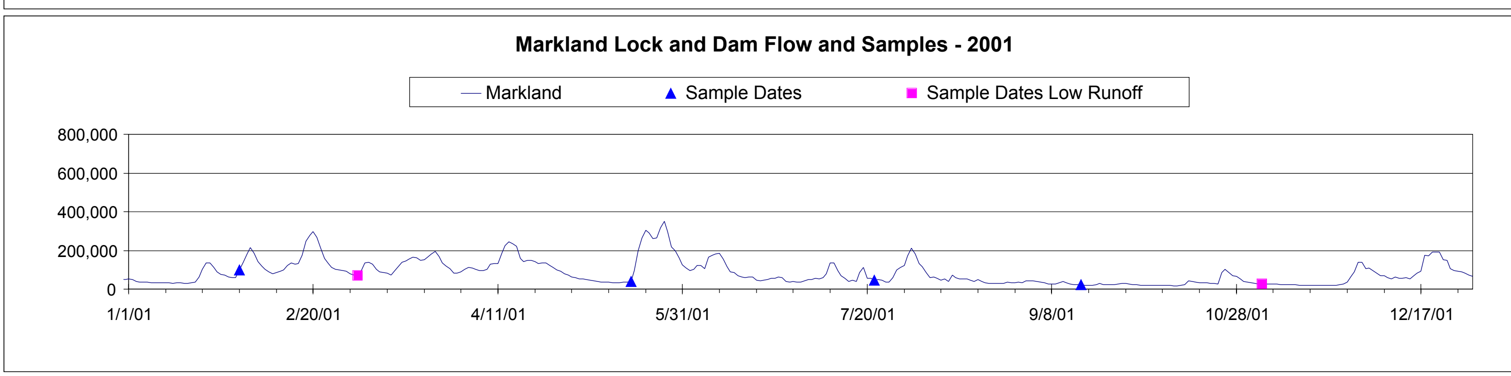
Markland Lock and Dam Flow and Samples - 1998
Markland
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
800,000
600,000
400,000
200,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date



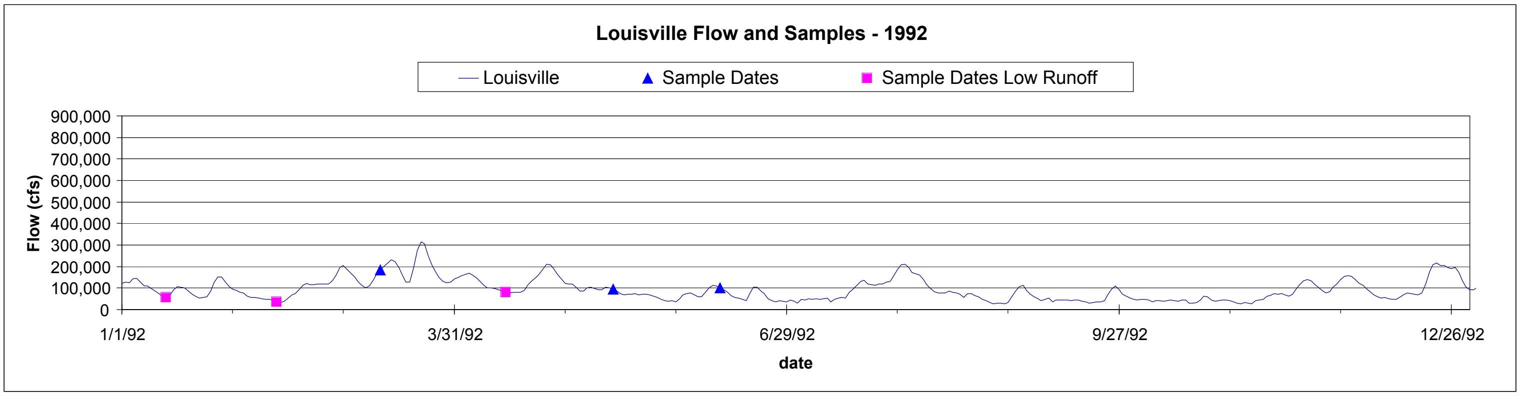
Markland Lock and Dam Flow and Samples - 1999
Markland
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
800,000
600,000
400,000
200,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date

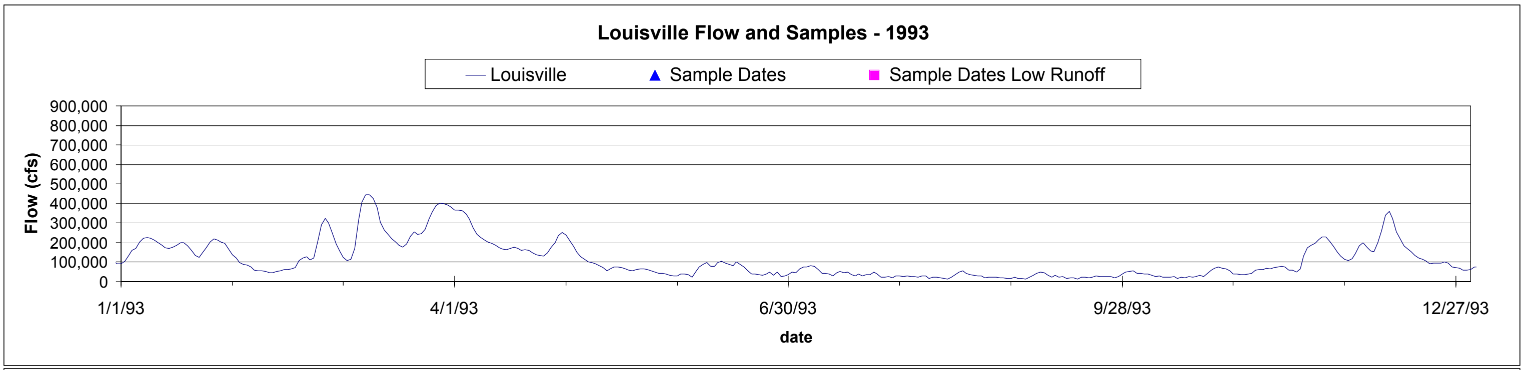


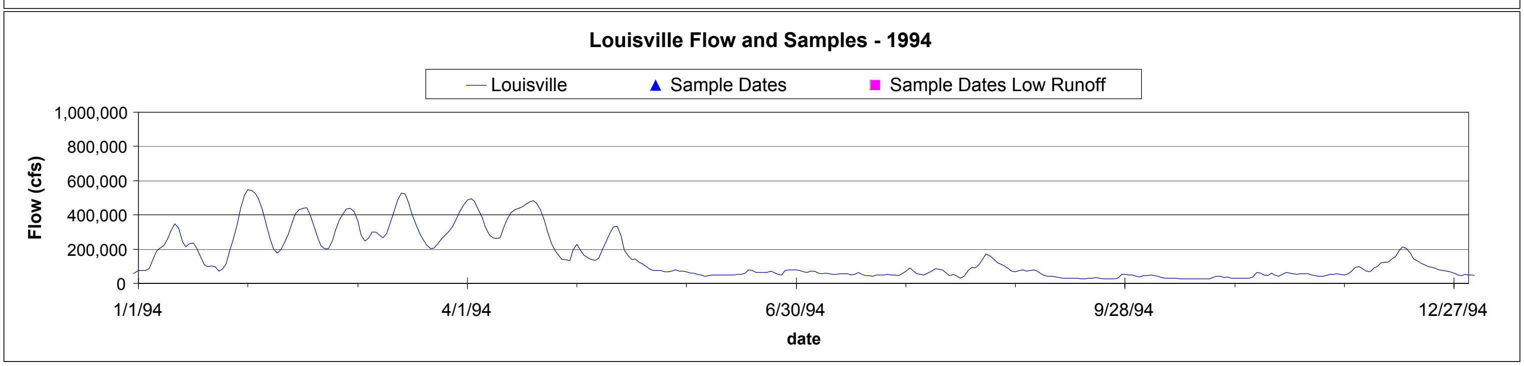
Markland Lock and Dam Flow and Samples - 2000
Markland
Sample Dates
Sample Dates Low Runoff
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/00
2/20/00
4/10/00
5/30/00
7/19/00
9/7/00
10/27/00
12/16/00

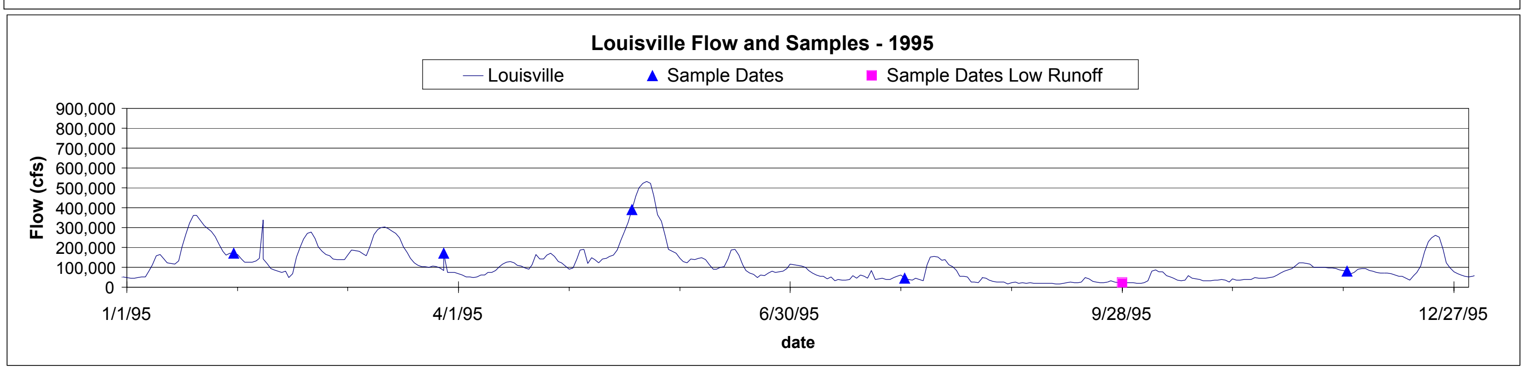


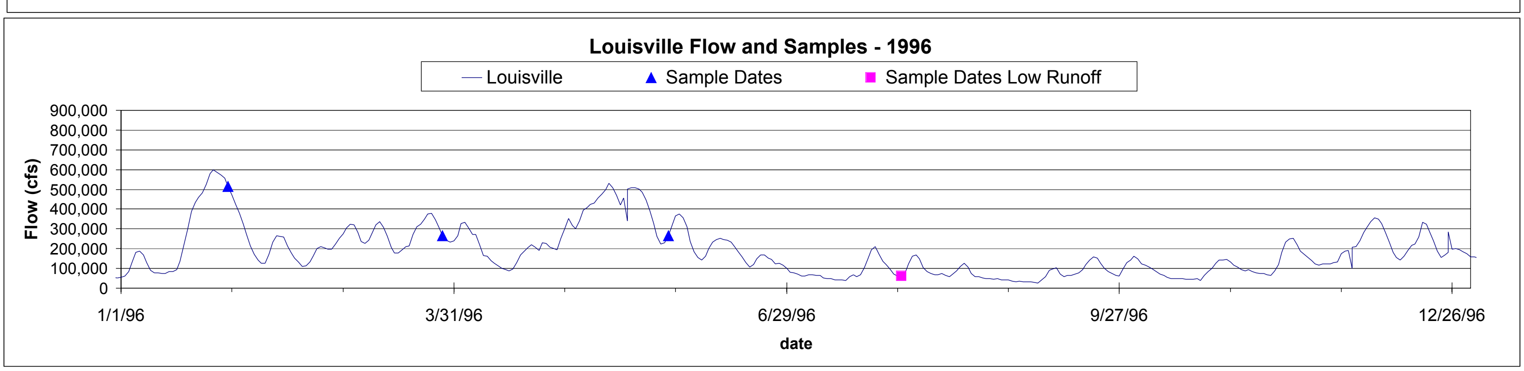
Markland Lock and Dam Flow and Samples - 2001
Markland
Sample Dates
Sample Dates Low Runoff
800,000
600,000
400,000
200,000
0
1/1/01
2/20/01
4/11/01
5/31/01
7/20/01
9/8/01
10/28/01
12/17/01

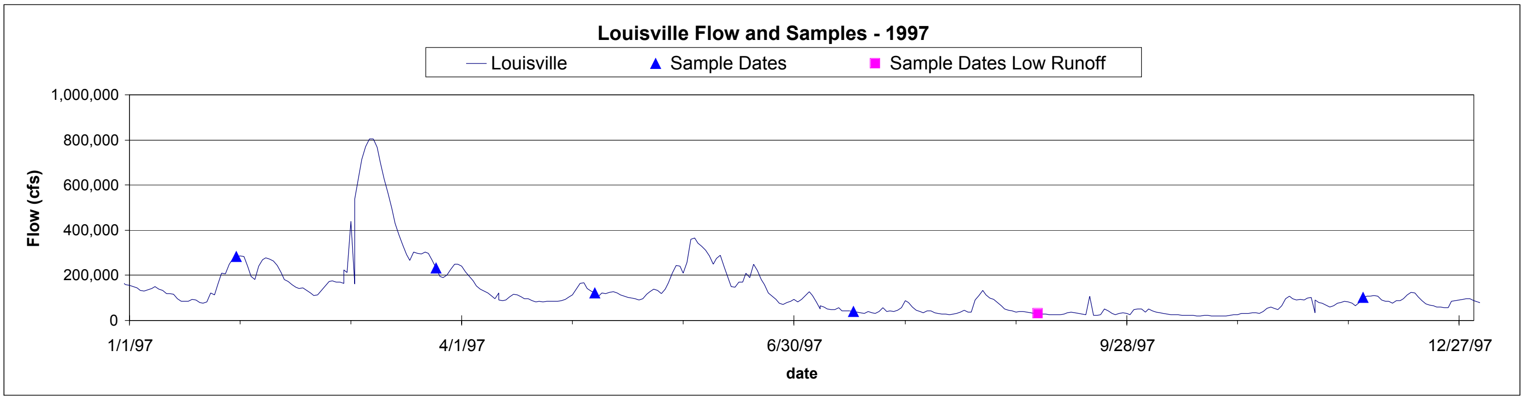

Louisville Flow and Samples - 1992
Louisville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date

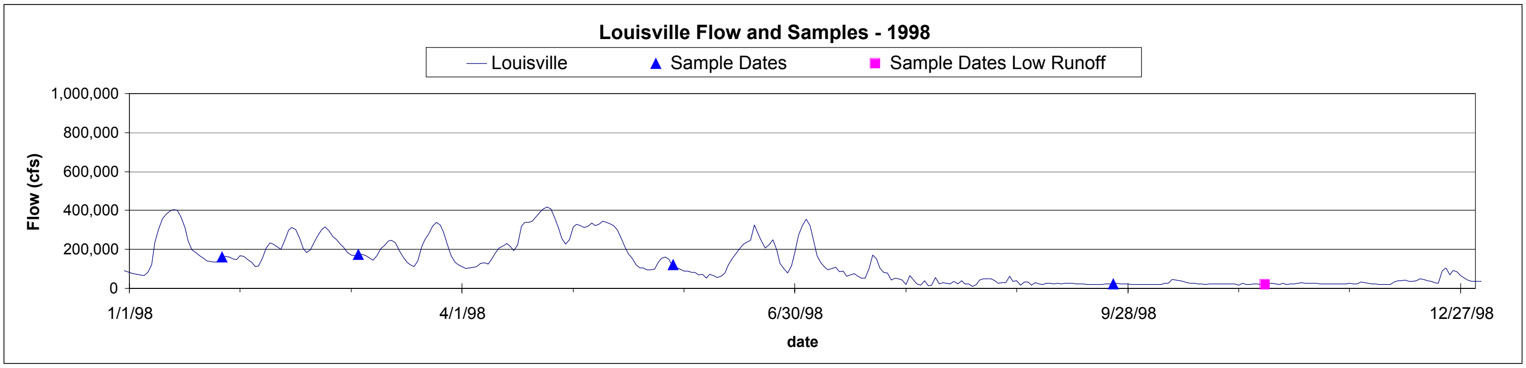

Louisville Flow and Samples - 1993
Louisville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date

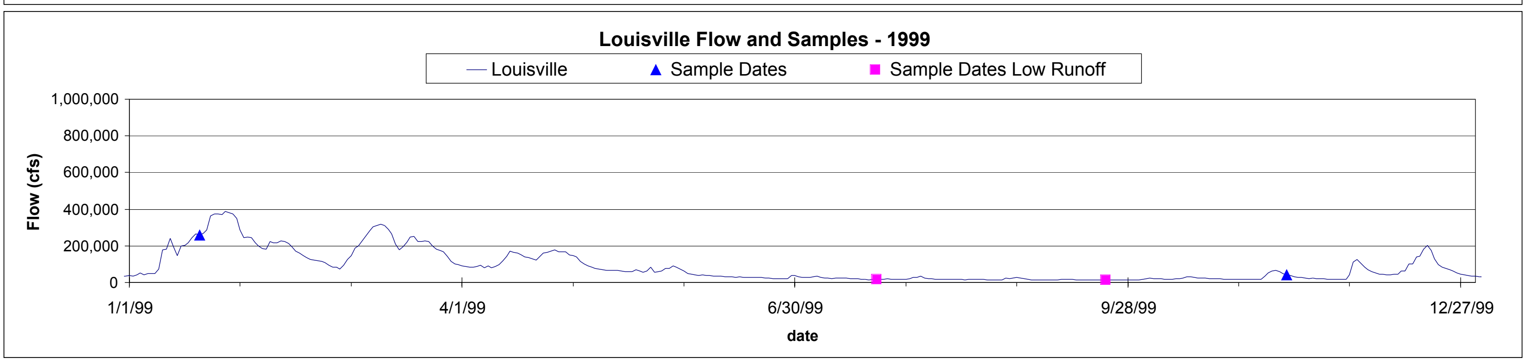

Louisville Flow and Samples - 1994
Louisville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date

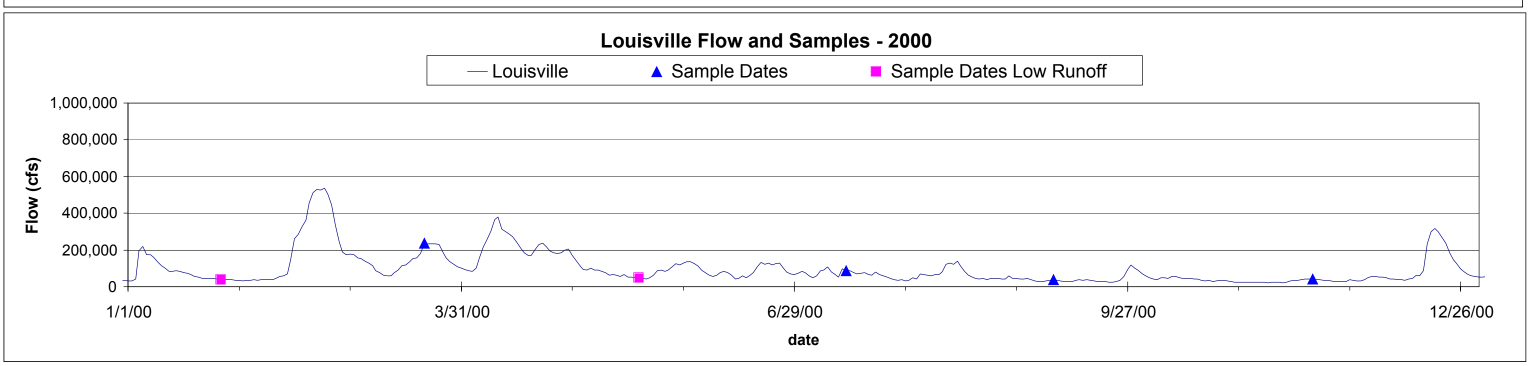

Louisville Flow and Samples - 1995
Louisville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date

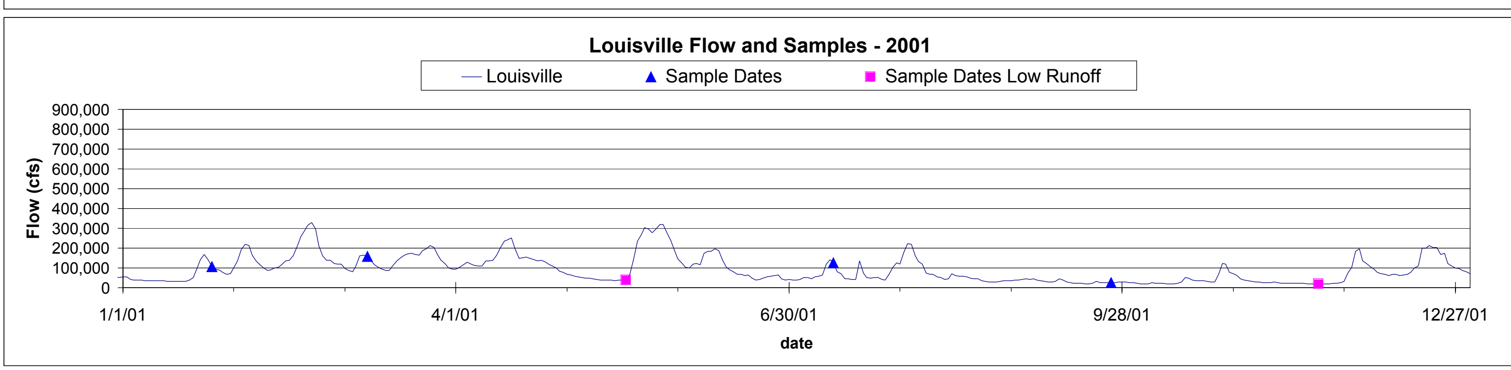

Louisville Flow and Samples - 1996
Louisville
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date

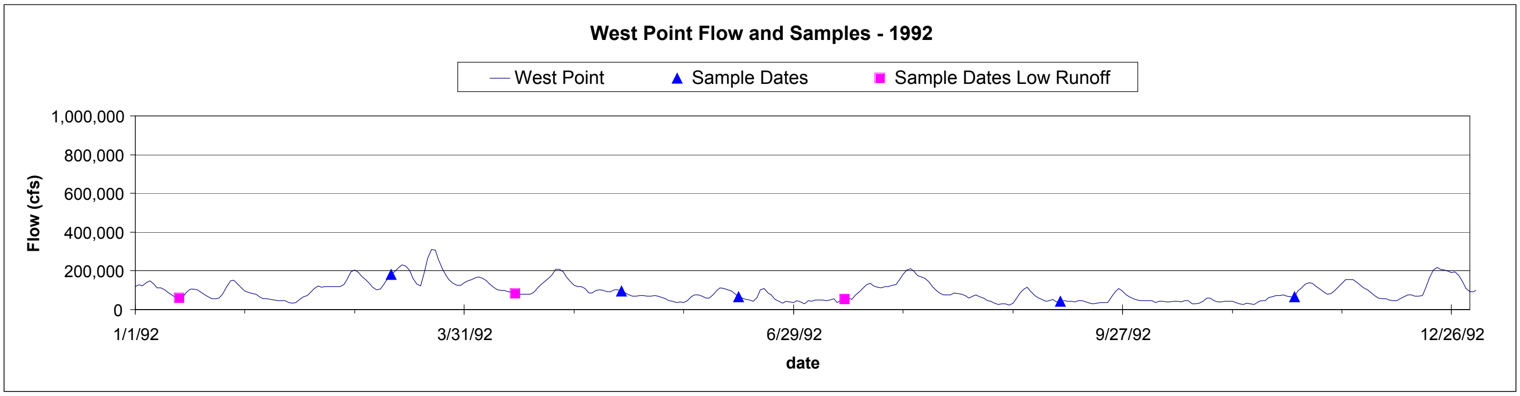

Louisville Flow and Samples - 1997
Louisville
Sample Dates
Sample Dates Low Runoff
1,000,000
800,000
600,000
400,000
200,000
0
Flow (cfs)
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date

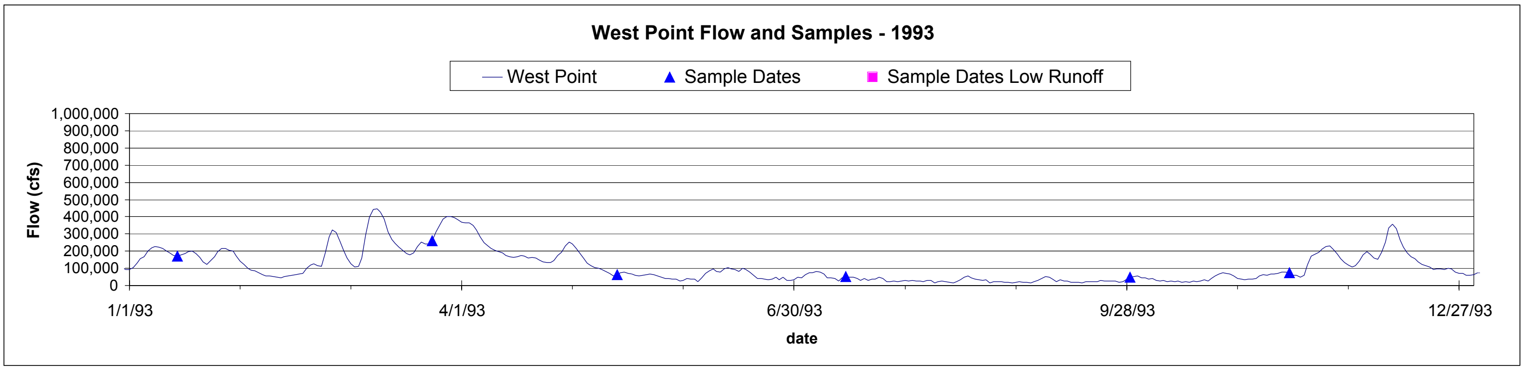

Louisville Flow and Samples - 1998
Louisville
Sample Dates
Sample Dates Low Runoff
1,000,000
800,000
600,000
400,000
200,000
0
Flow (cfs)
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date

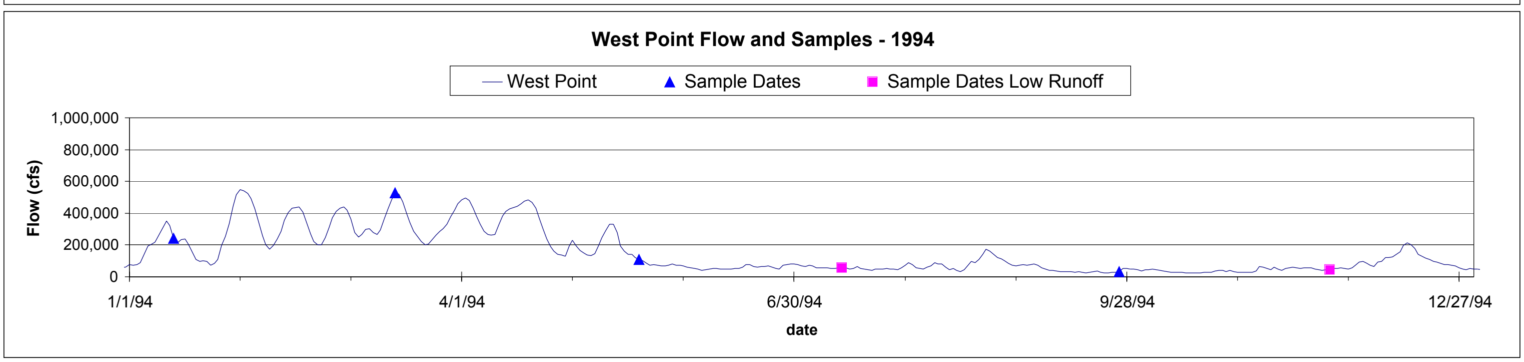

Louisville Flow and Samples - 1999
Louisville
Sample Dates
Sample Dates Low Runoff
1,000,000
800,000
600,000
400,000
200,000
0
Flow (cfs)
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date

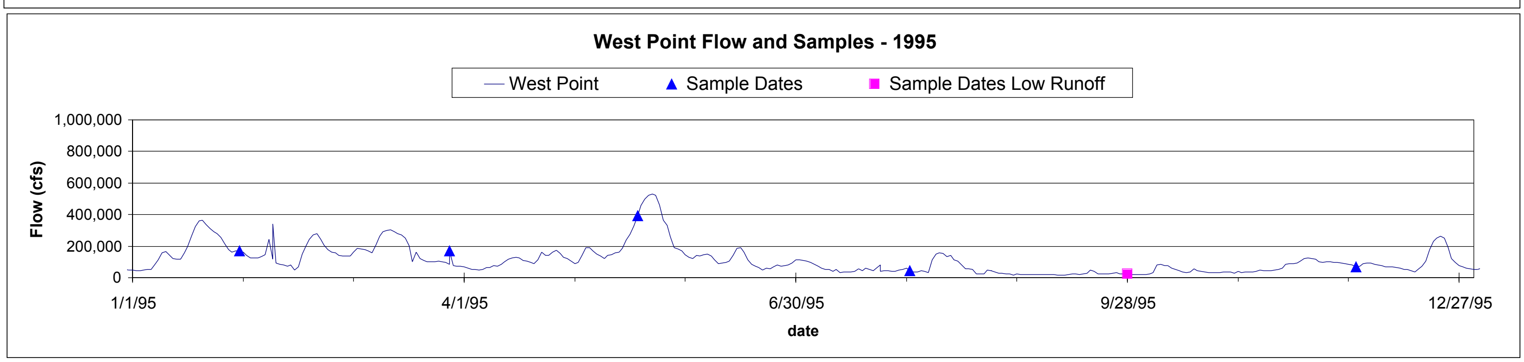

Louisville Flow and Samples - 2000
Louisville
Sample Dates
Sample Dates Low Runoff
1,000,000
800,000
600,000
400,000
200,000
0
Flow (cfs)
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

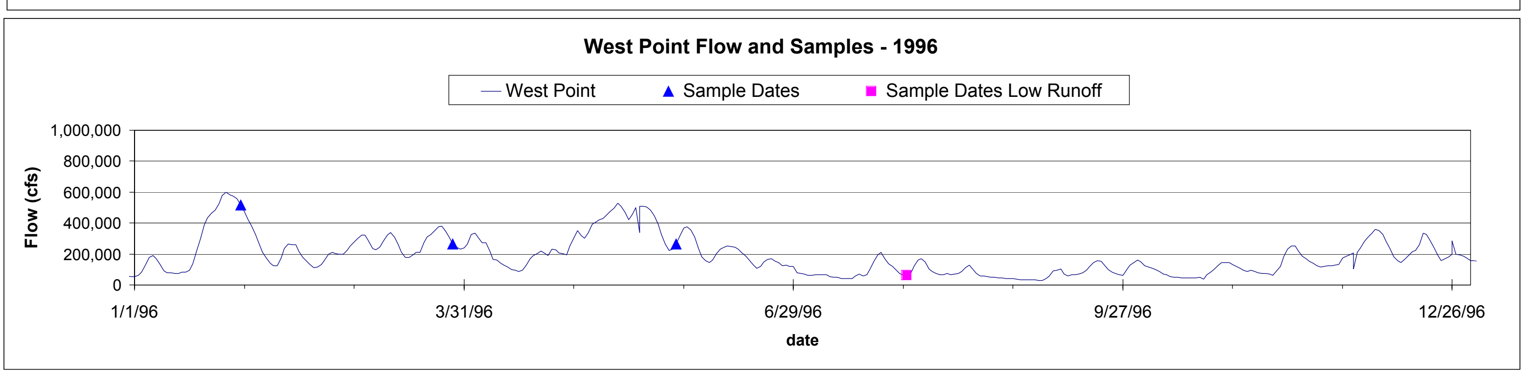

Louisville Flow and Samples - 2001
Louisville
Sample Dates
Sample Dates Low Runoff
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Flow (cfs)
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date

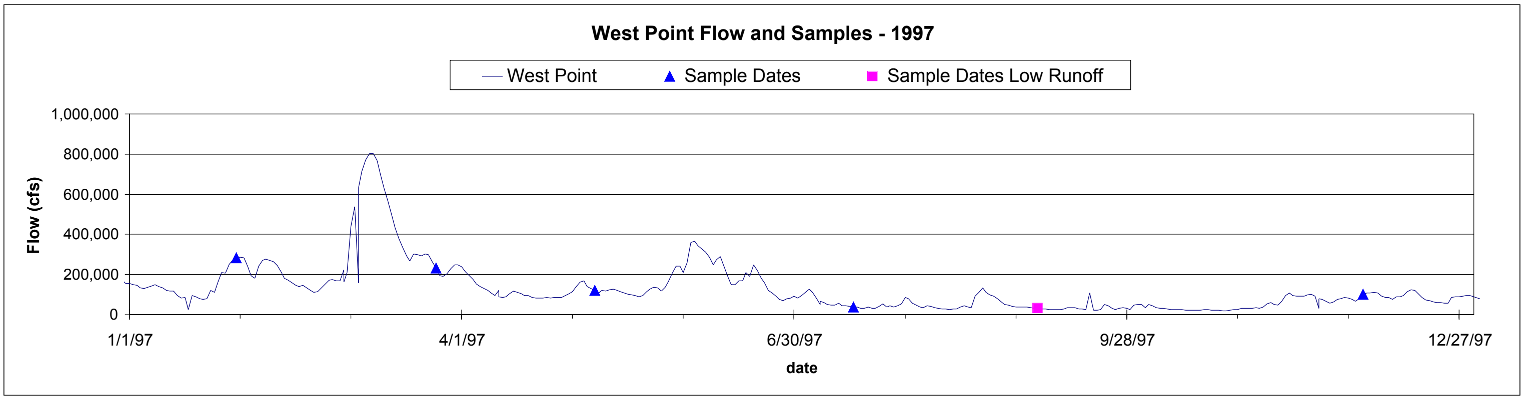

West Point Flow and Samples - 1992
West Point
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date

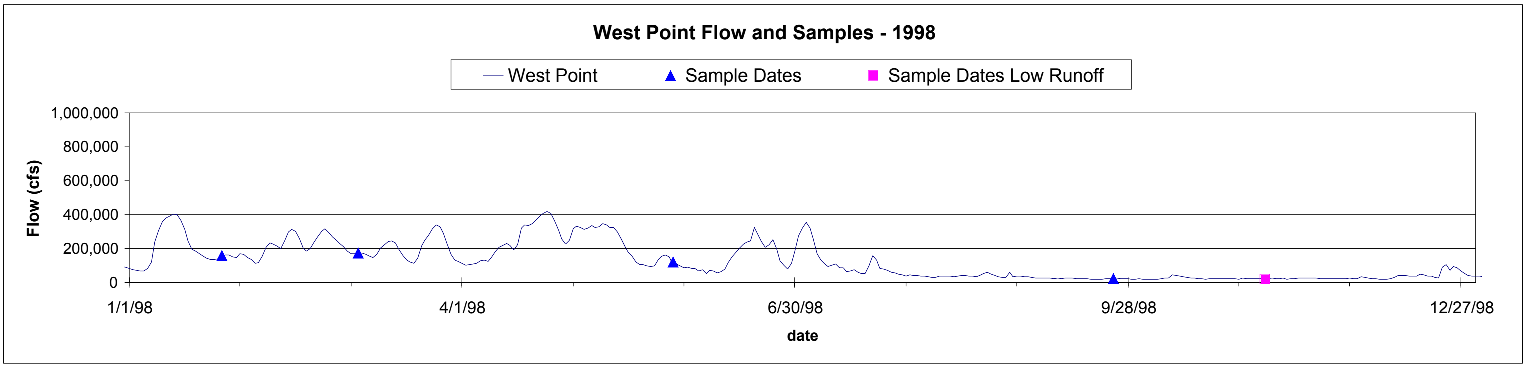

West Point Flow and Samples - 1993
West Point
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date

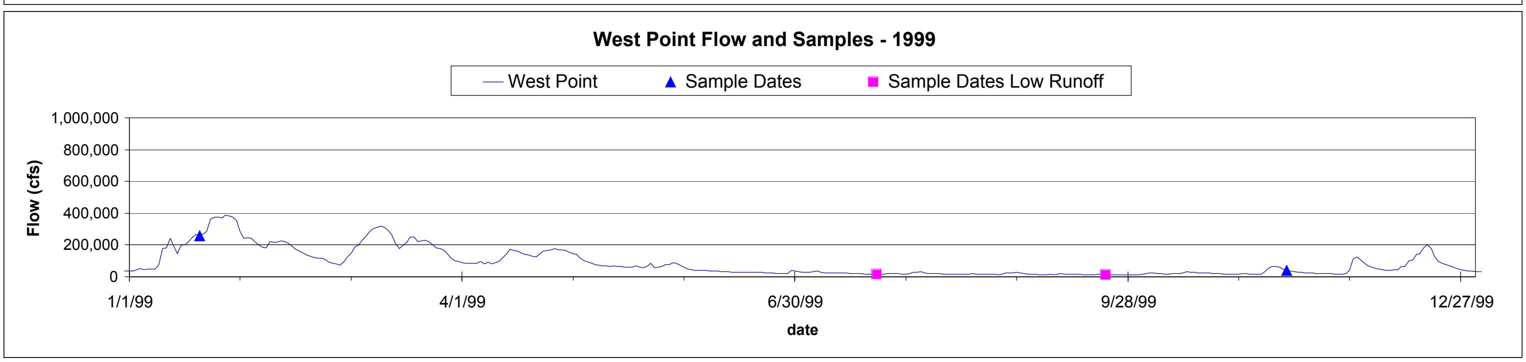

West Point Flow and Samples - 1994
West Point
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date

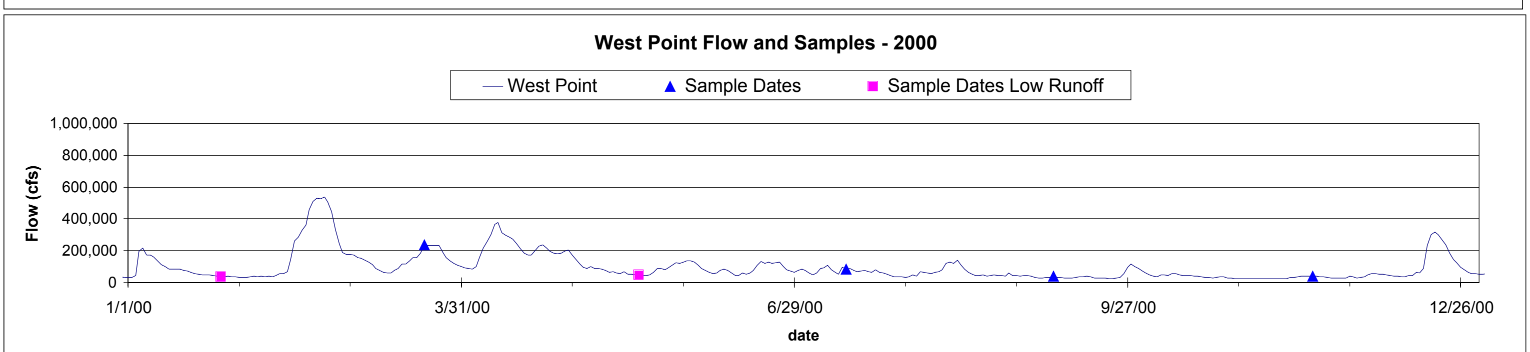

West Point Flow and Samples - 1995
West Point
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date

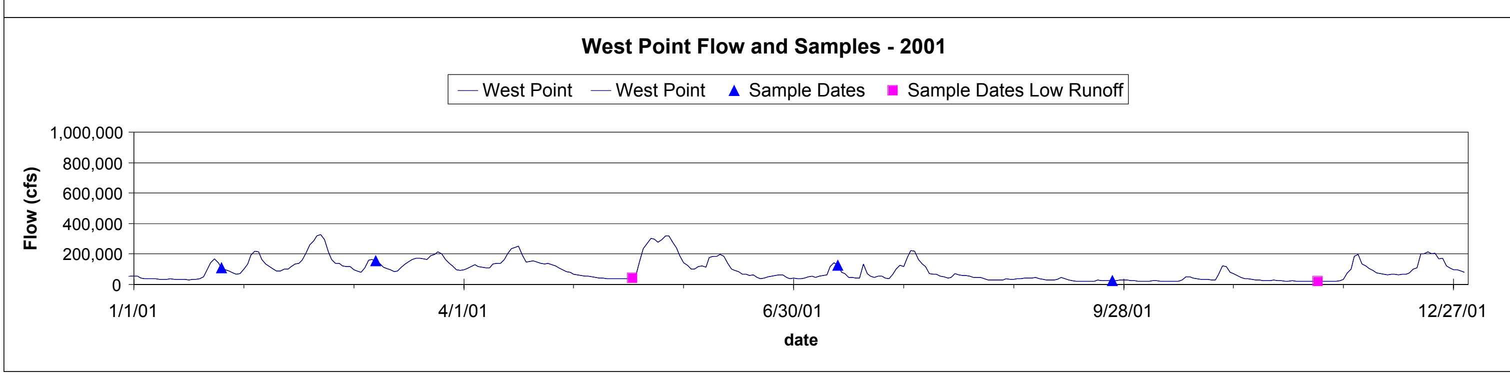

West Point Flow and Samples - 1996
West Point
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date

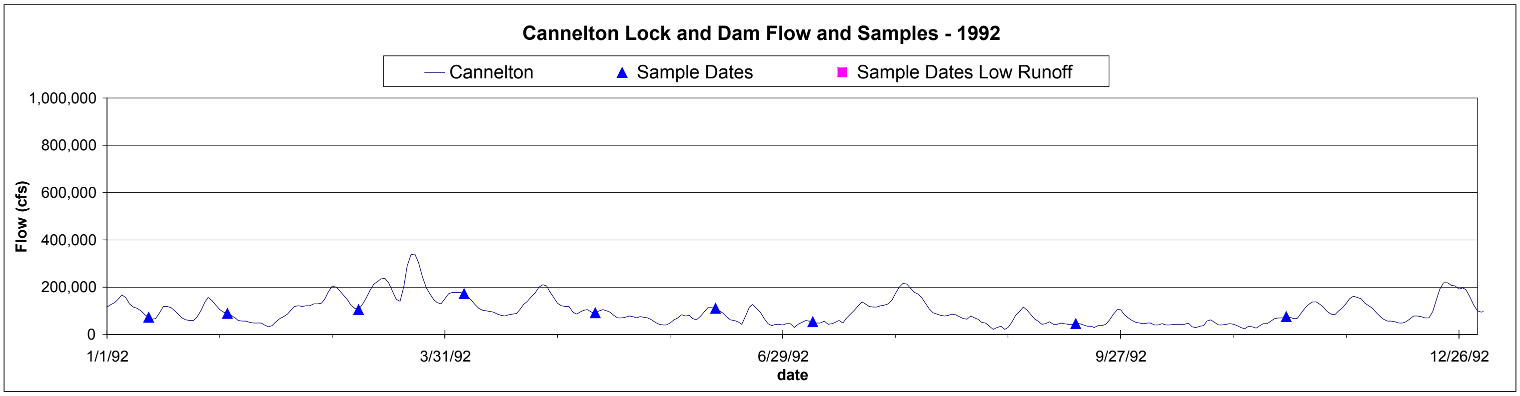

West Point Flow and Samples - 1997
West Point
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date


West Point Flow and Samples - 1998
West Point
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date

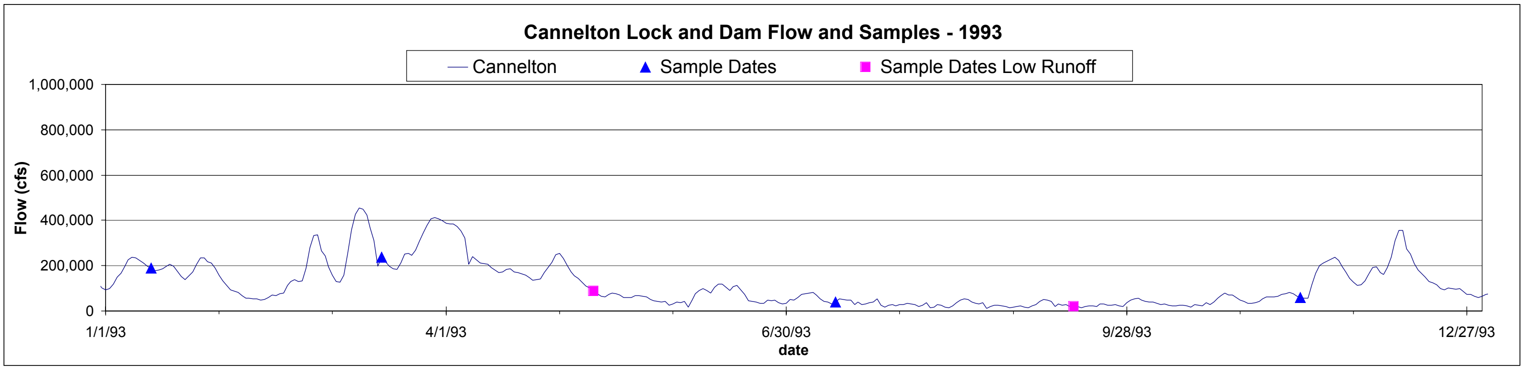

West Point Flow and Samples - 1999
West Point
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date


West Point Flow and Samples - 2000
West Point
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

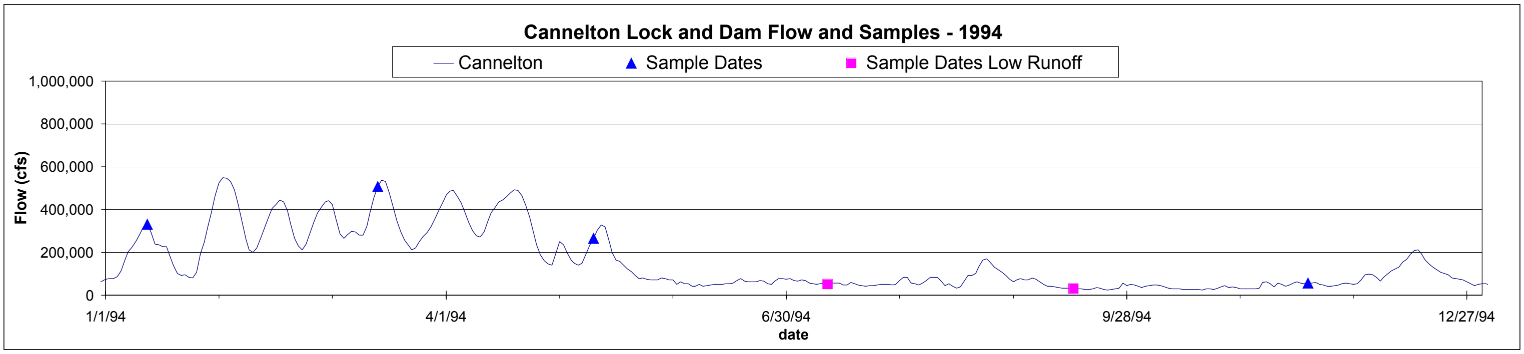

West Point Flow and Samples - 2001
West Point
West Point
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date



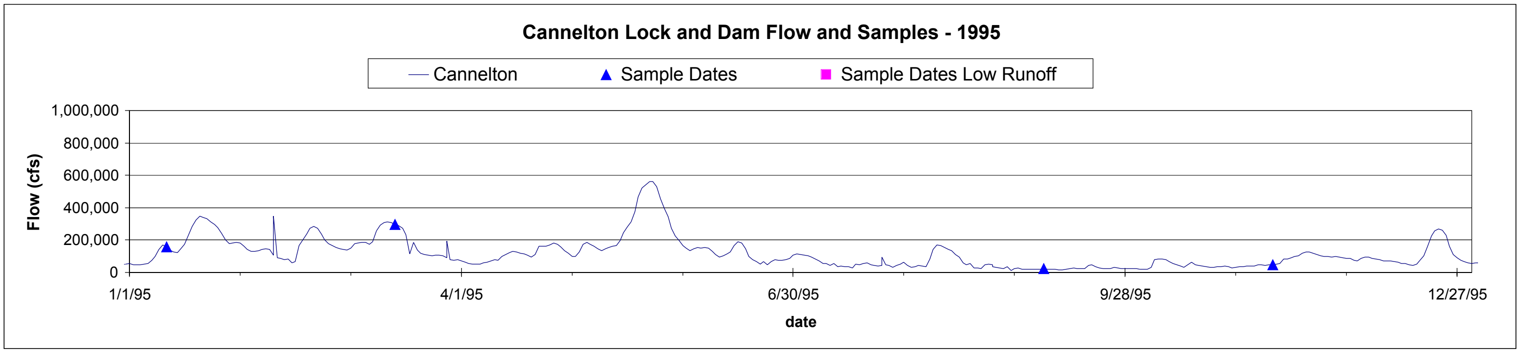
Cannelton Lock and Dam Flow and Samples - 1992
Cannelton
Sample Dates
Sample Dates Low Runoff
1,000,000
800,000
600,000
400,000
200,000
0
Flow (cfs)
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date



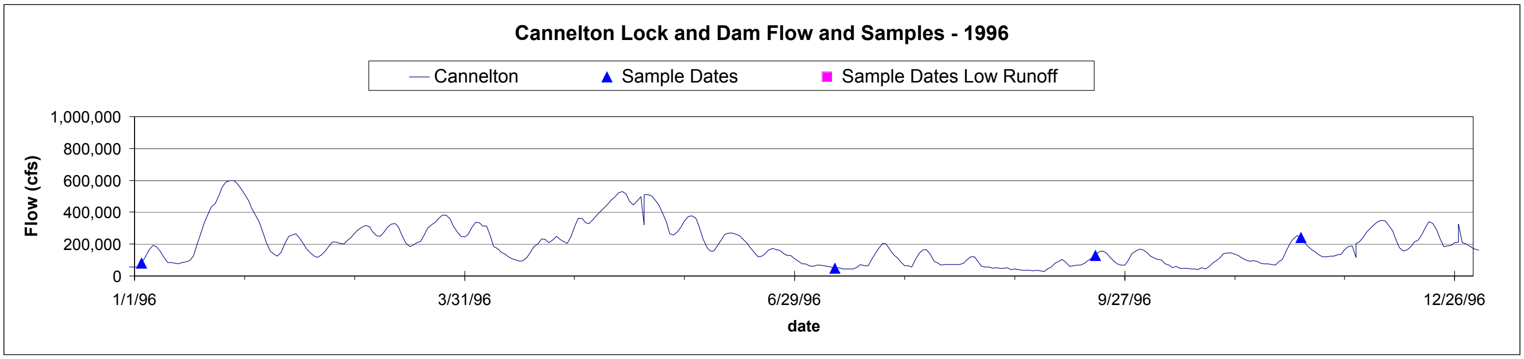
Cannelton Lock and Dam Flow and Samples - 1993
Cannelton
Sample Dates
Sample Dates Low Runoff
1,000,000
800,000
600,000
400,000
200,000
0
Flow (cfs)
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date



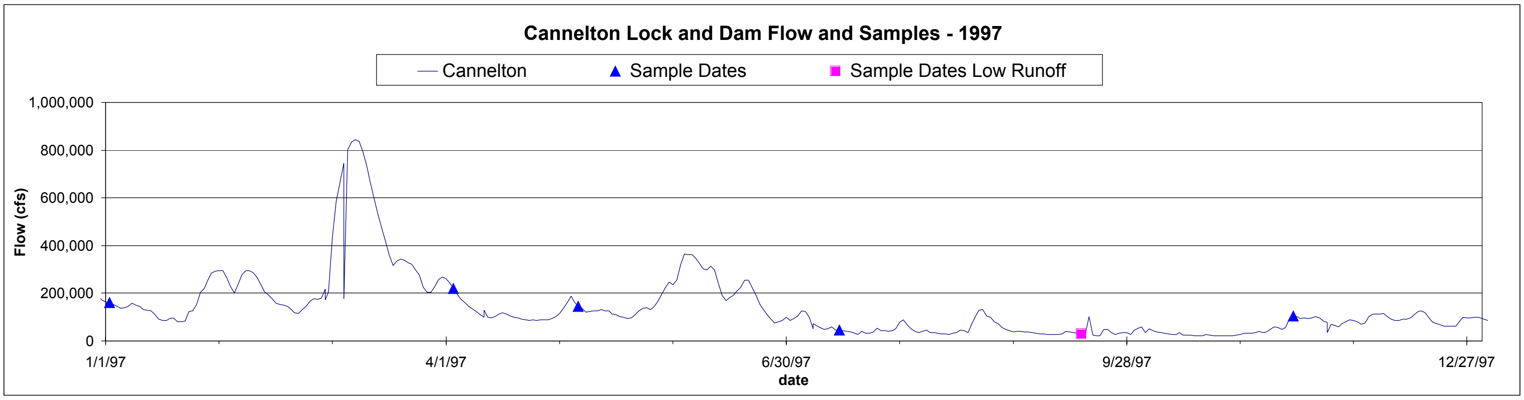
Cannelton Lock and Dam Flow and Samples - 1994
Cannelton
Sample Dates
Sample Dates Low Runoff
1,000,000
800,000
600,000
400,000
200,000
0
Flow (cfs)
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date



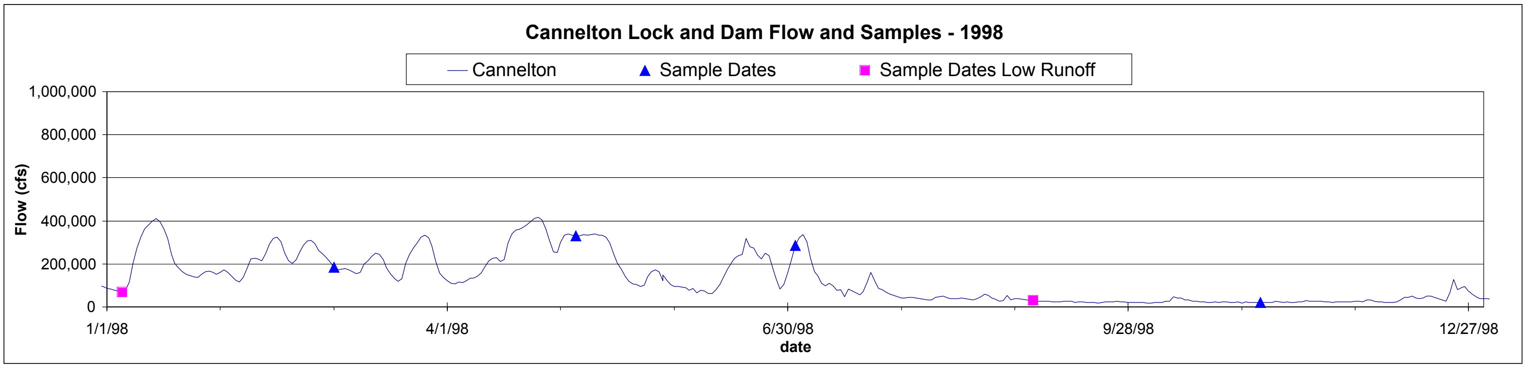
Cannelton Lock and Dam Flow and Samples - 1995
Cannelton
Sample Dates
Sample Dates Low Runoff
1,000,000
800,000
600,000
400,000
200,000
0
Flow (cfs)
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date



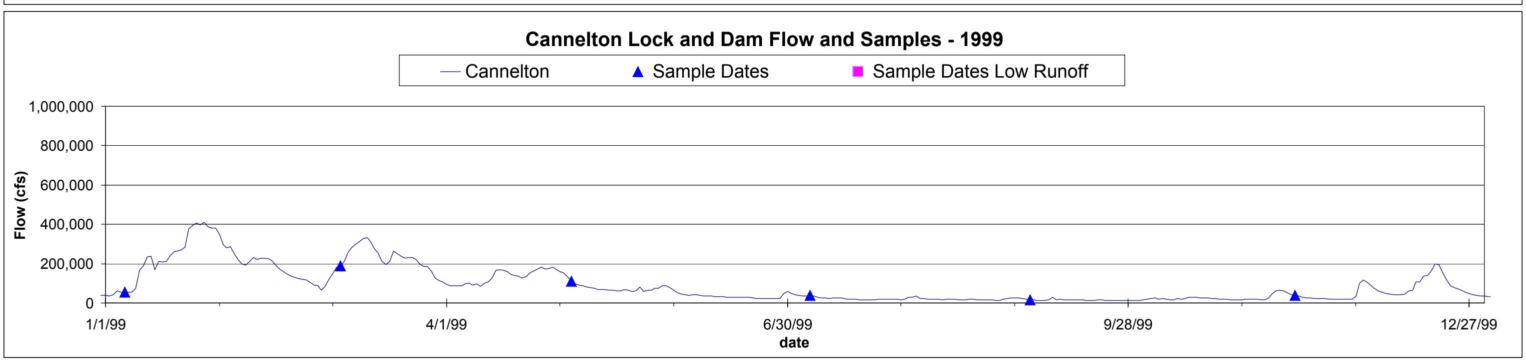
Cannelton Lock and Dam Flow and Samples - 1996
Cannelton
Sample Dates
Sample Dates Low Runoff
1,000,000
800,000
600,000
400,000
200,000
0
Flow (cfs)
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date



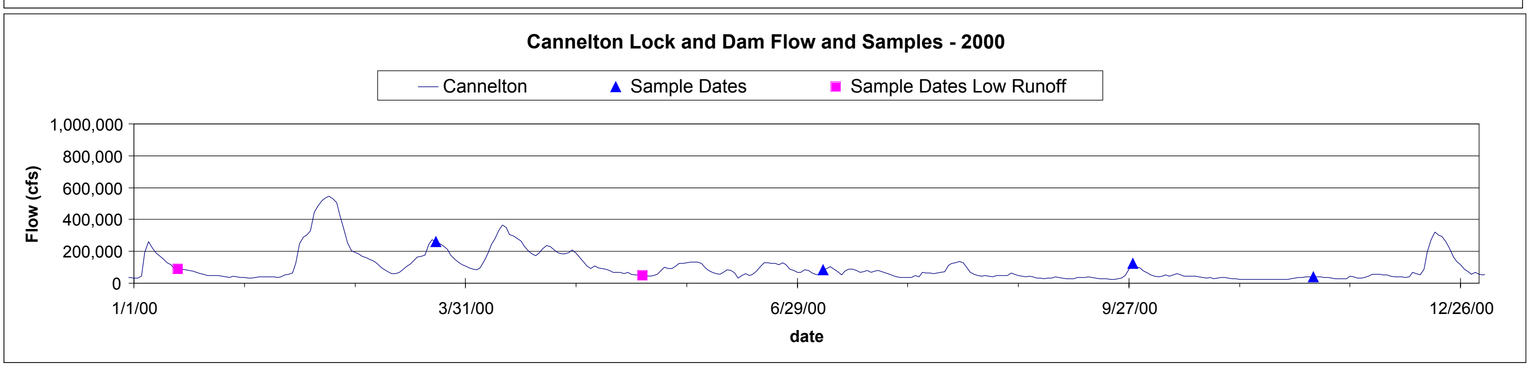
Cannelton Lock and Dam Flow and Samples - 1997
Cannelton
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date



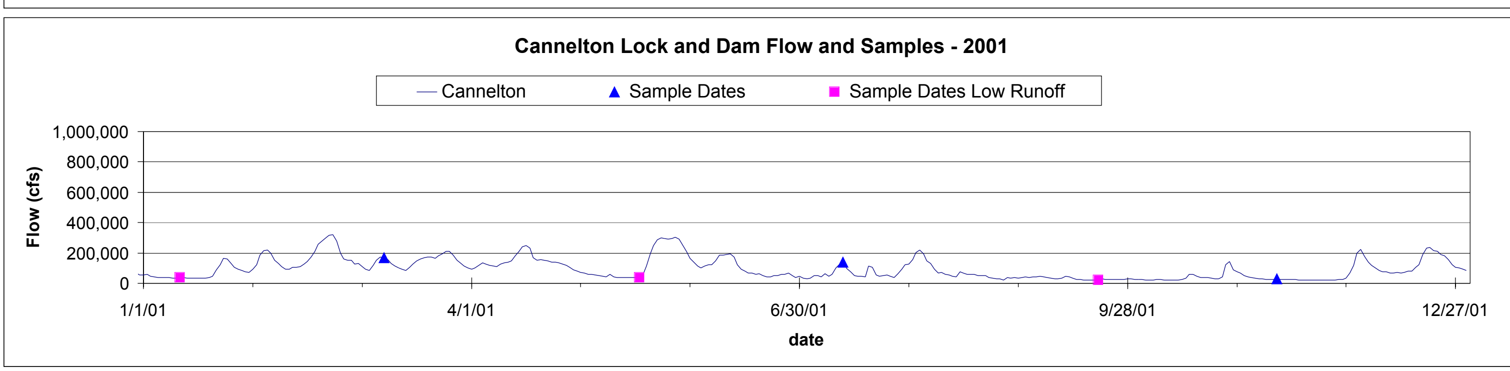
Cannelton Lock and Dam Flow and Samples - 1998
Cannelton
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date



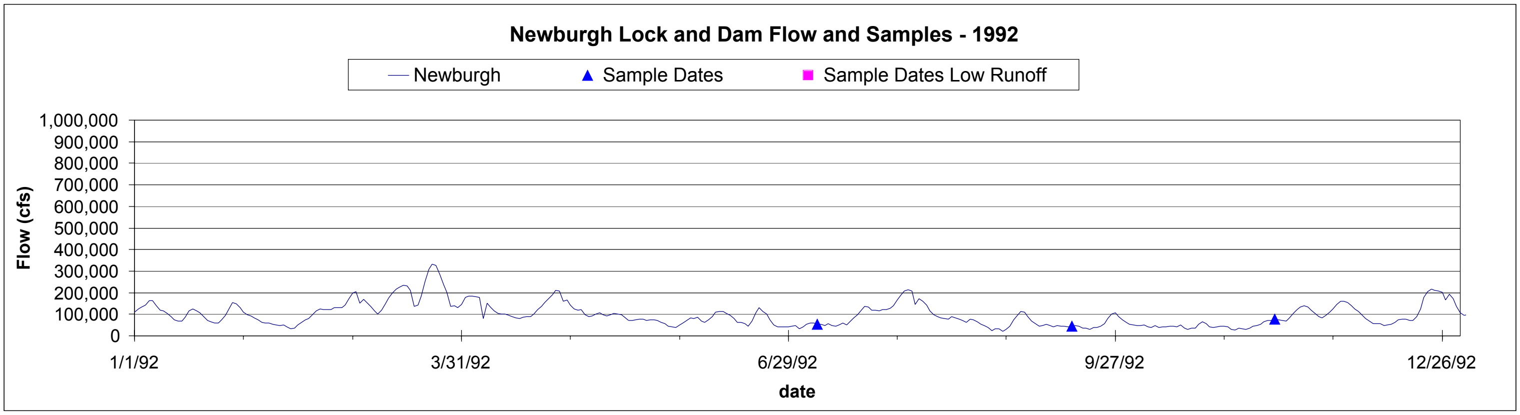
Cannelton Lock and Dam Flow and Samples - 1999
Cannelton
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date

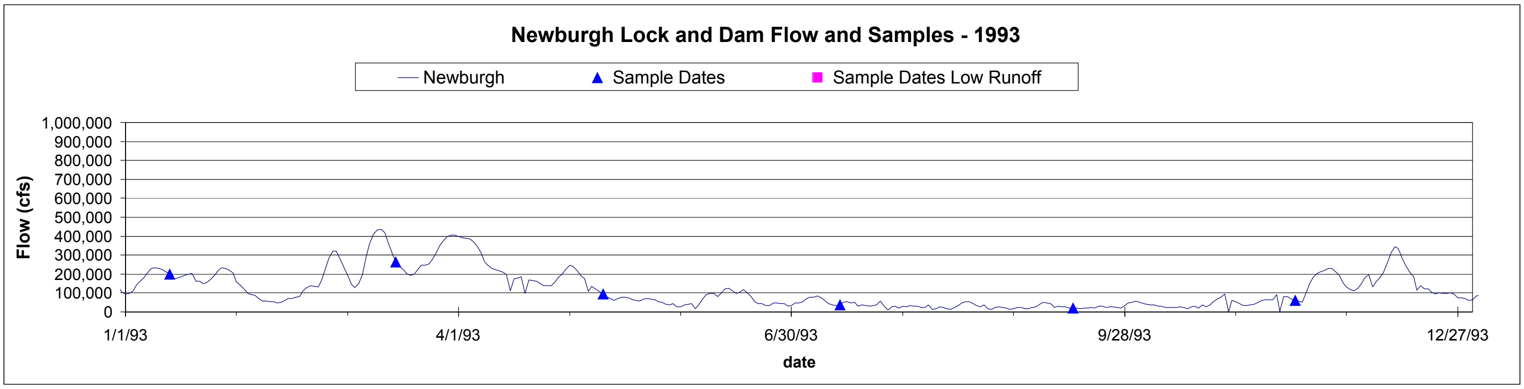


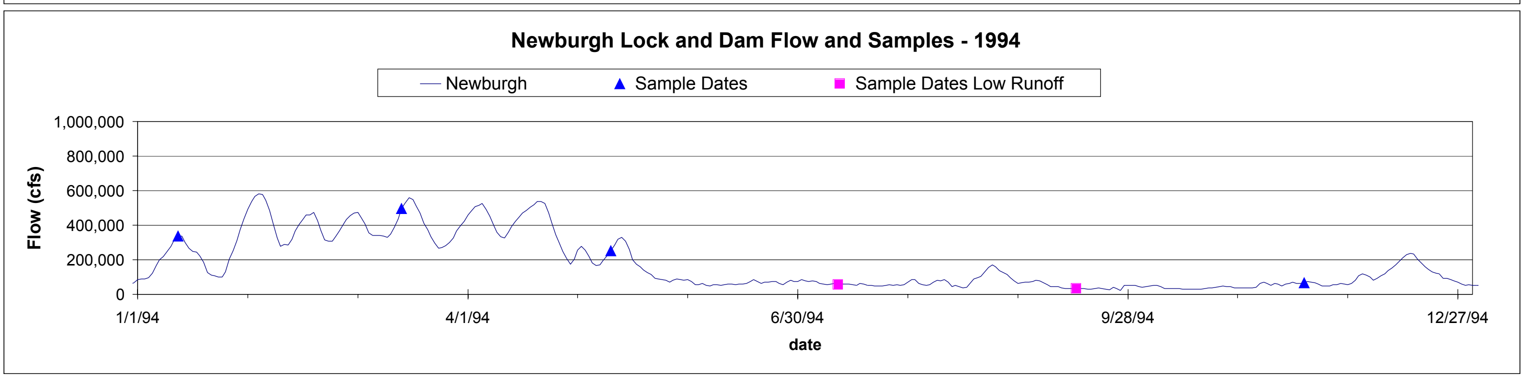
Cannelton Lock and Dam Flow and Samples - 2000
Cannelton
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

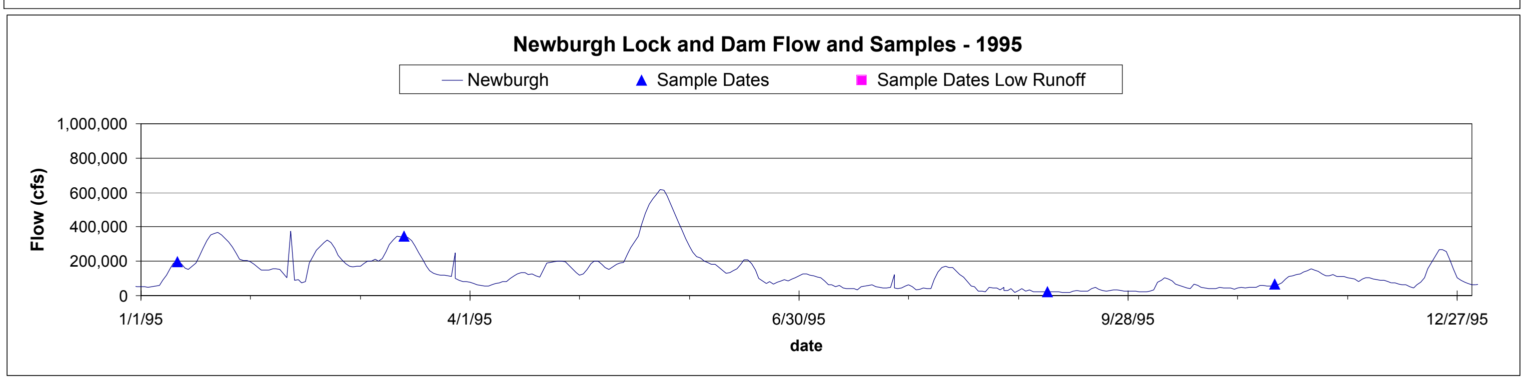


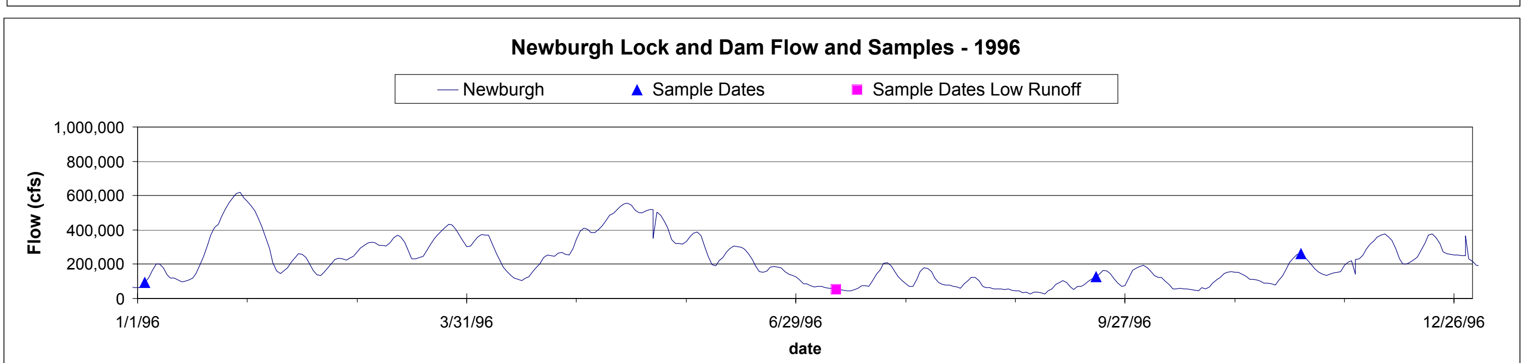
Cannelton Lock and Dam Flow and Samples - 2001
Cannelton
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date

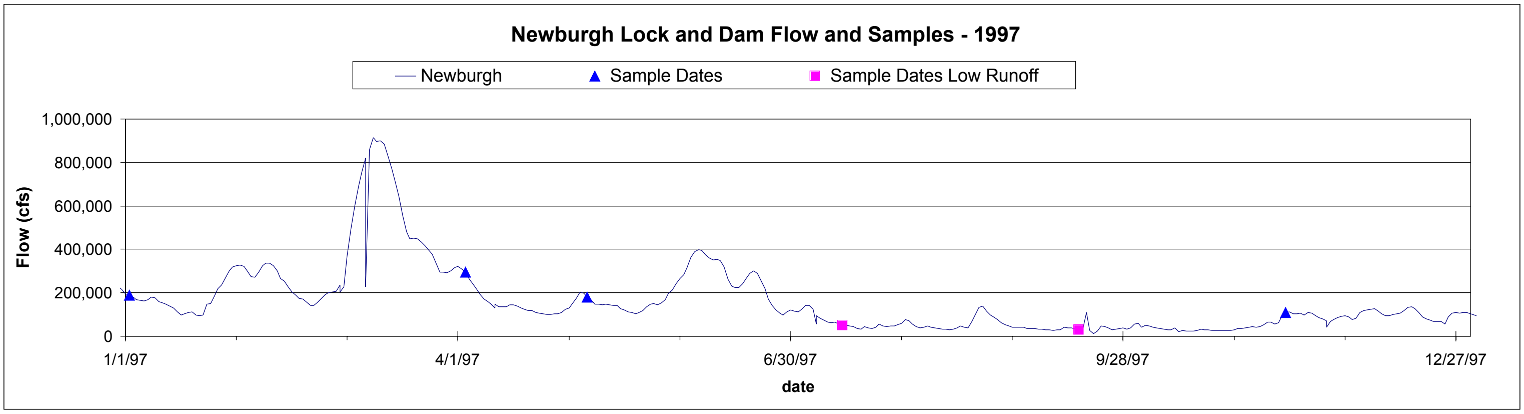

Newburgh Lock and Dam Flow and Samples - 1992
Newburgh
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date

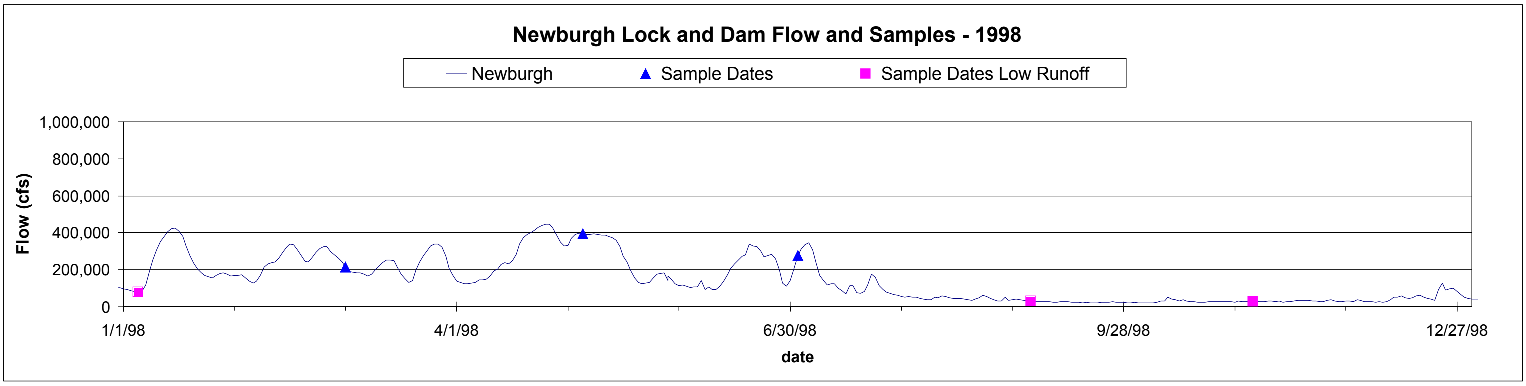

Newburgh Lock and Dam Flow and Samples - 1993
Newburgh
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date

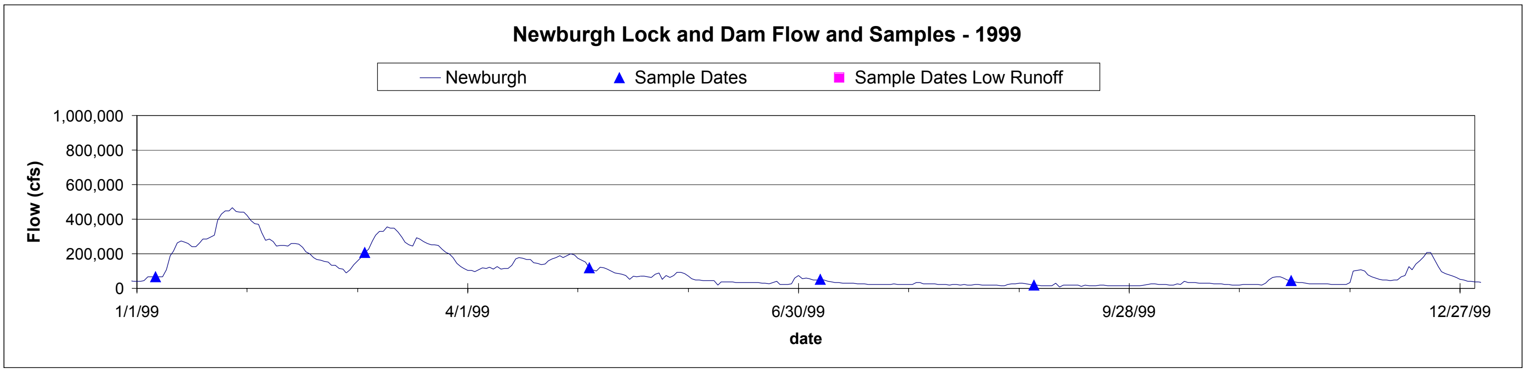

Newburgh Lock and Dam Flow and Samples - 1994
Newburgh
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date

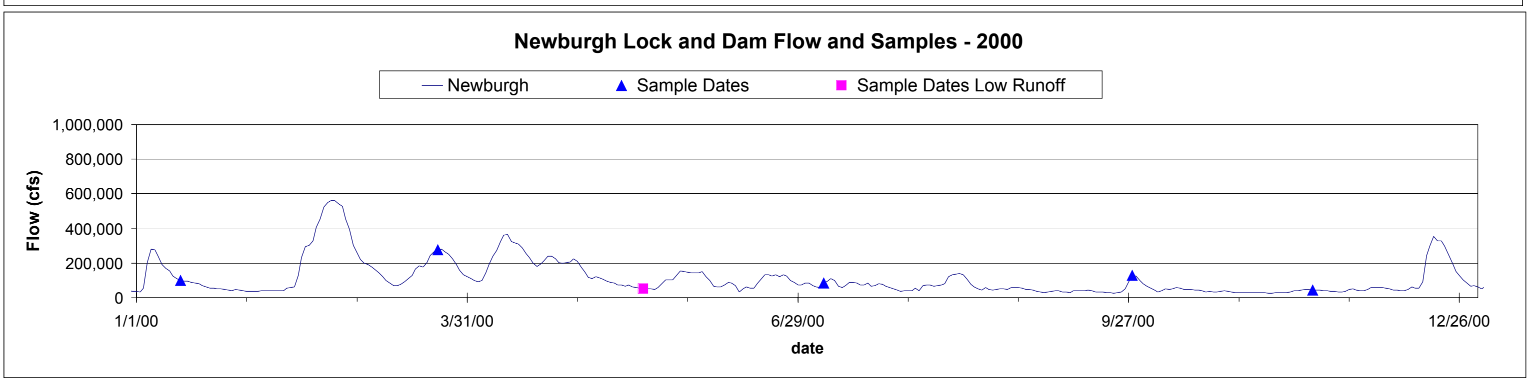

Newburgh Lock and Dam Flow and Samples - 1995
Newburgh
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date

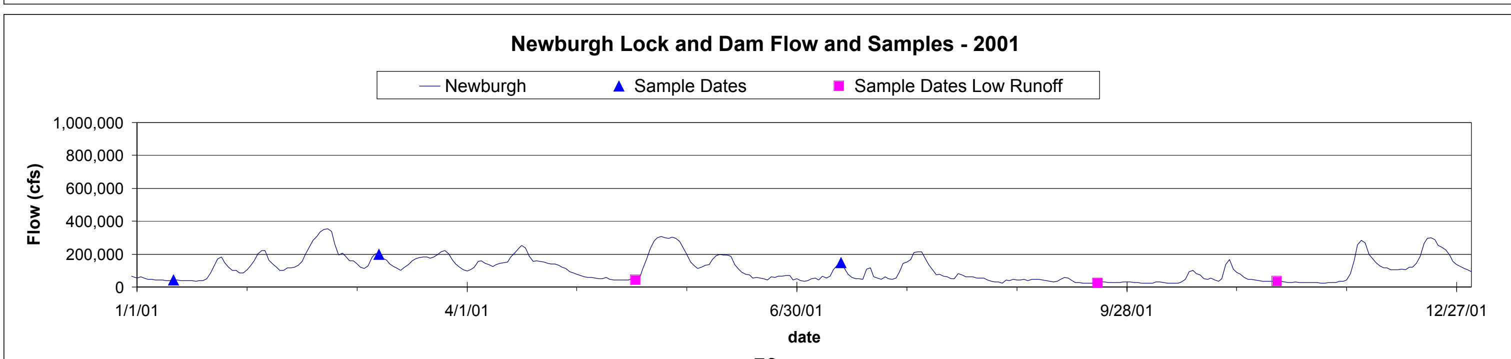

Newburgh Lock and Dam Flow and Samples - 1996
Newburgh
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date

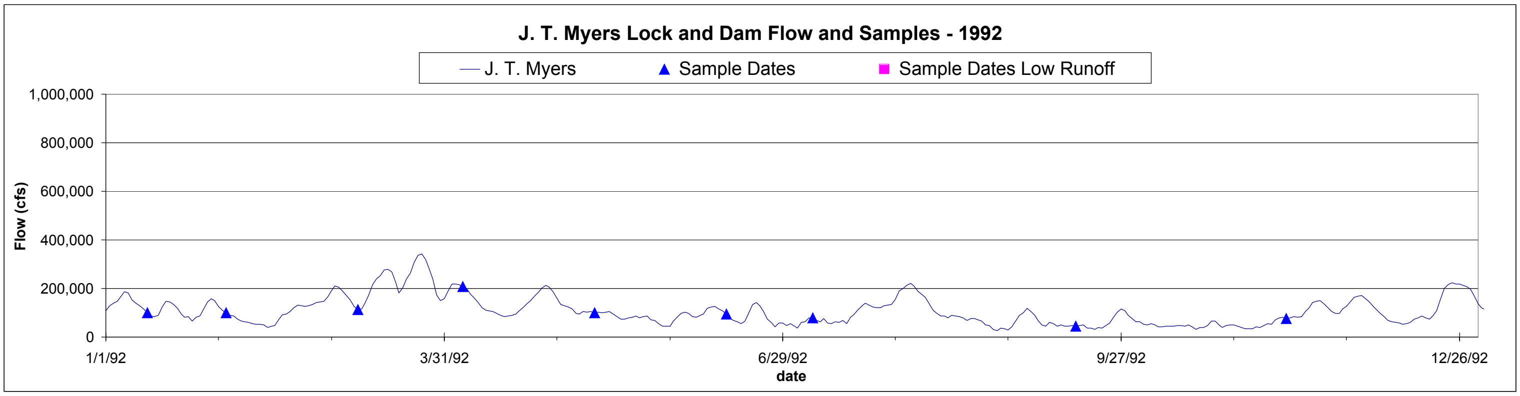

Newburgh Lock and Dam Flow and Samples - 1997
Newburgh
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date

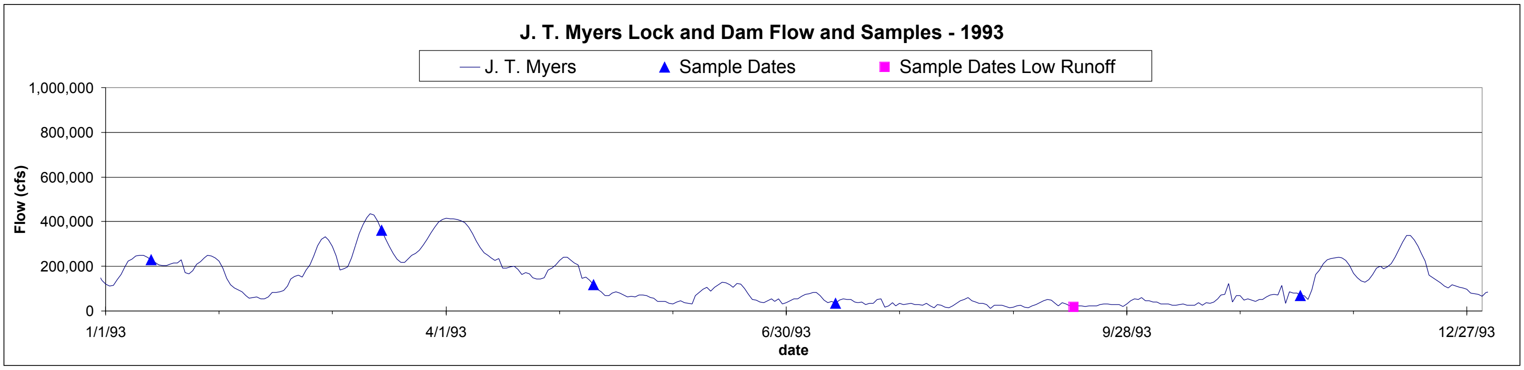

Newburgh Lock and Dam Flow and Samples - 1998
Newburgh
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date

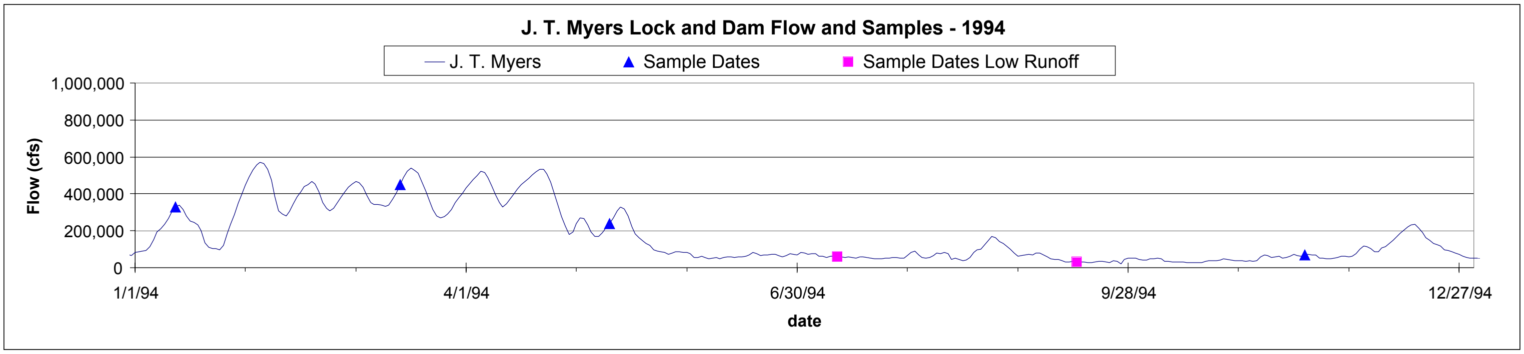

Newburgh Lock and Dam Flow and Samples - 1999
Newburgh
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date

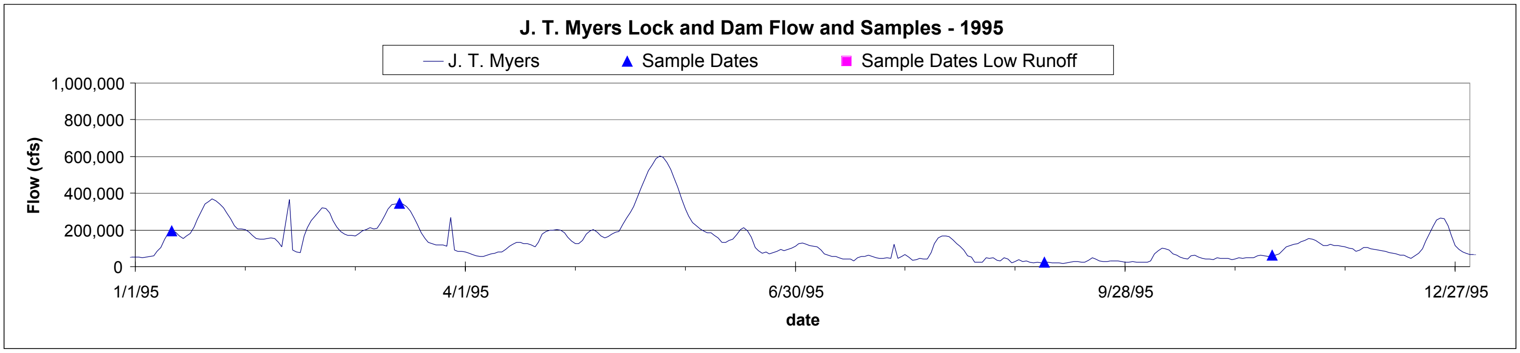

Newburgh Lock and Dam Flow and Samples - 2000
Newburgh
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

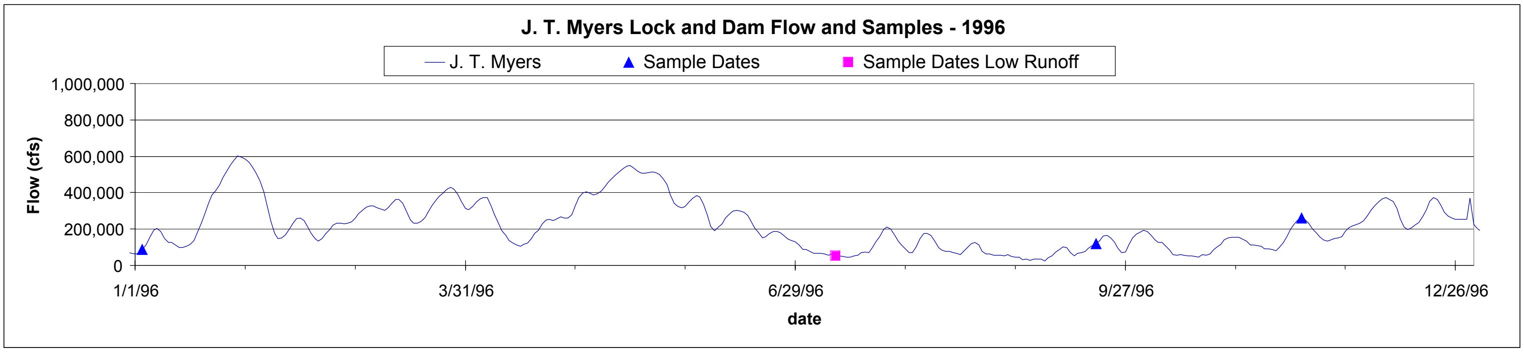

Newburgh Lock and Dam Flow and Samples - 2001
Newburgh
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date

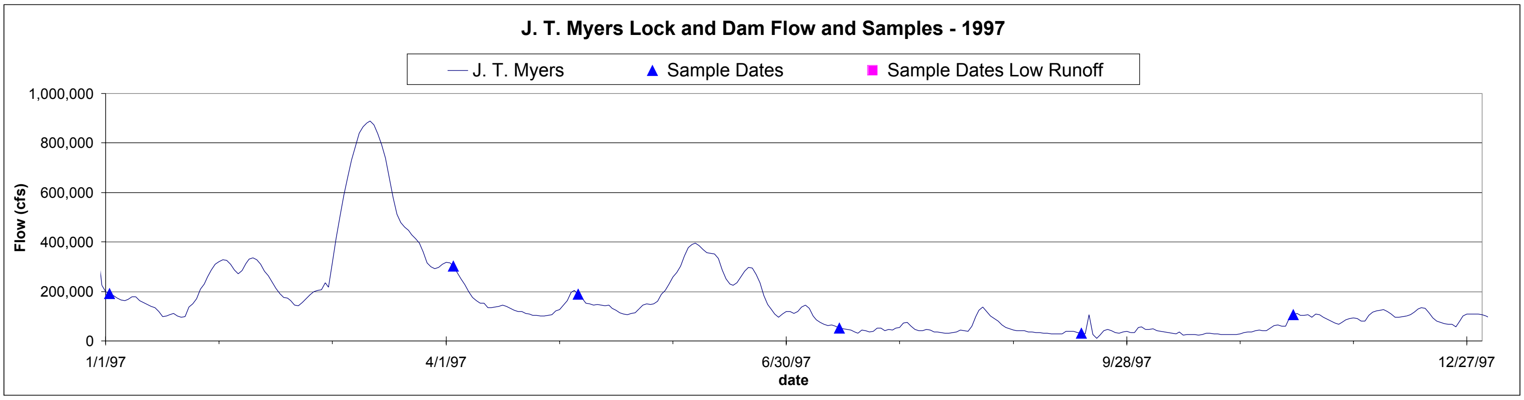

J. T. Myers Lock and Dam Flow and Samples - 1992
J. T. Myers
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date

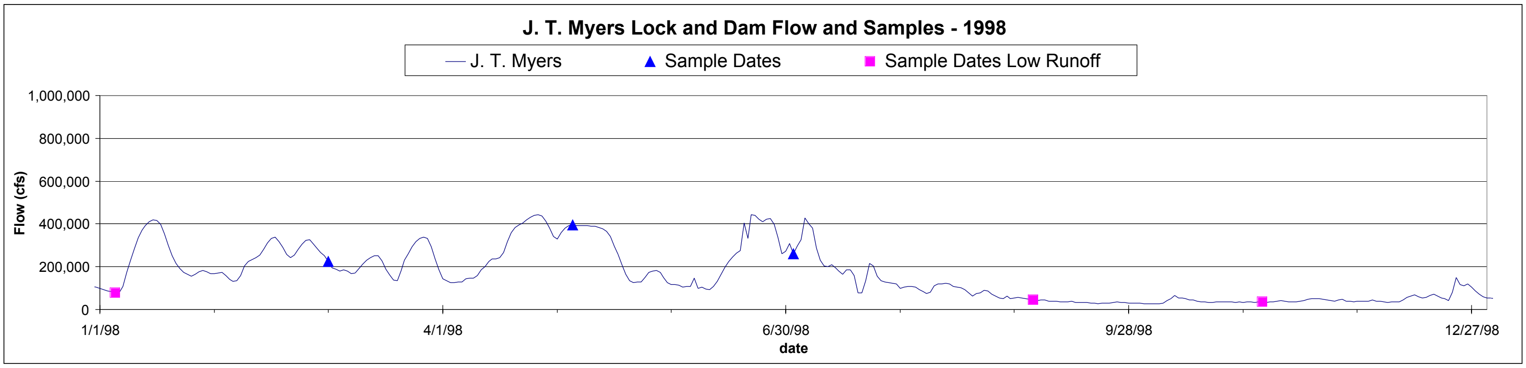

J. T. Myers Lock and Dam Flow and Samples - 1993
J. T. Myers
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date

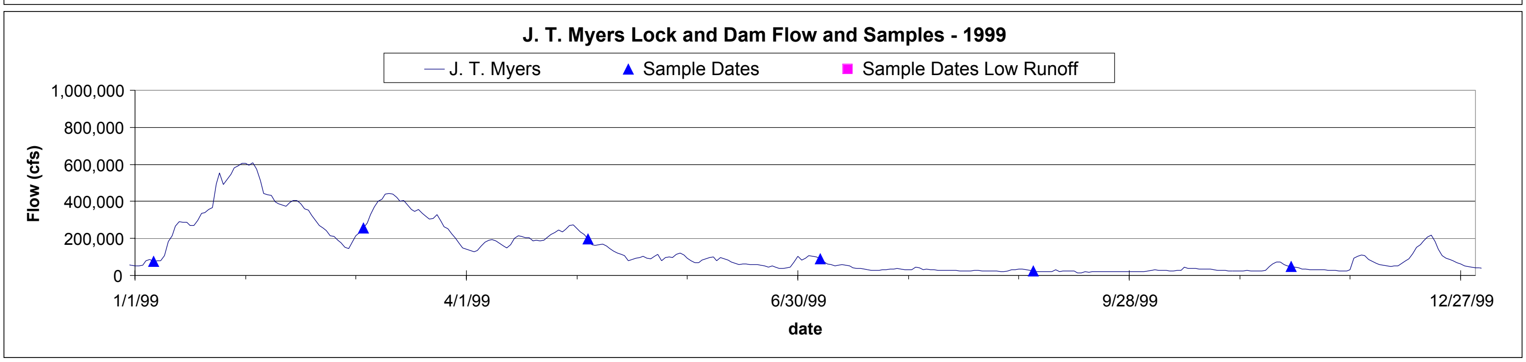

J. T. Myers Lock and Dam Flow and Samples - 1994
J. T. Myers
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date

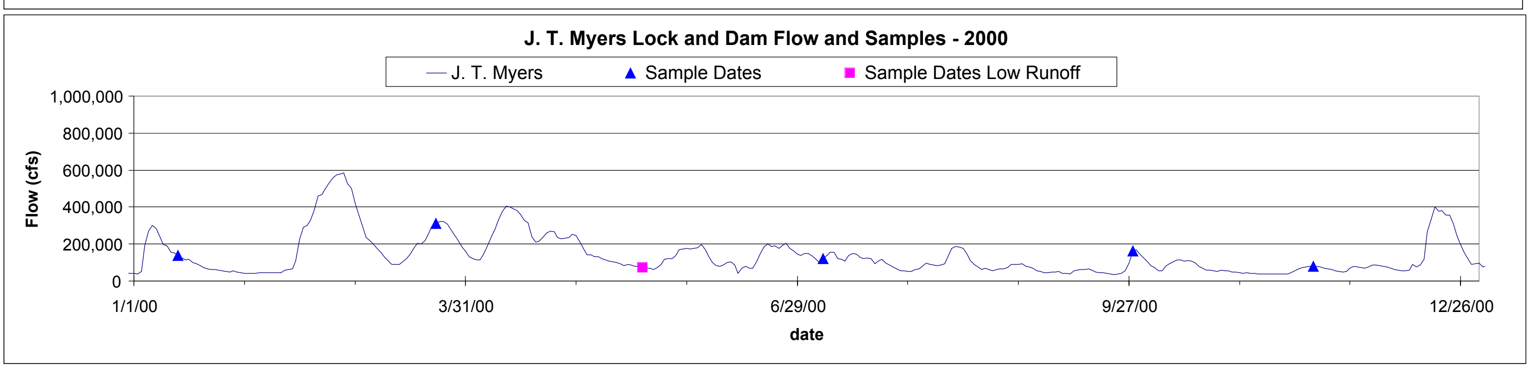

J. T. Myers Lock and Dam Flow and Samples - 1995
J. T. Myers
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date

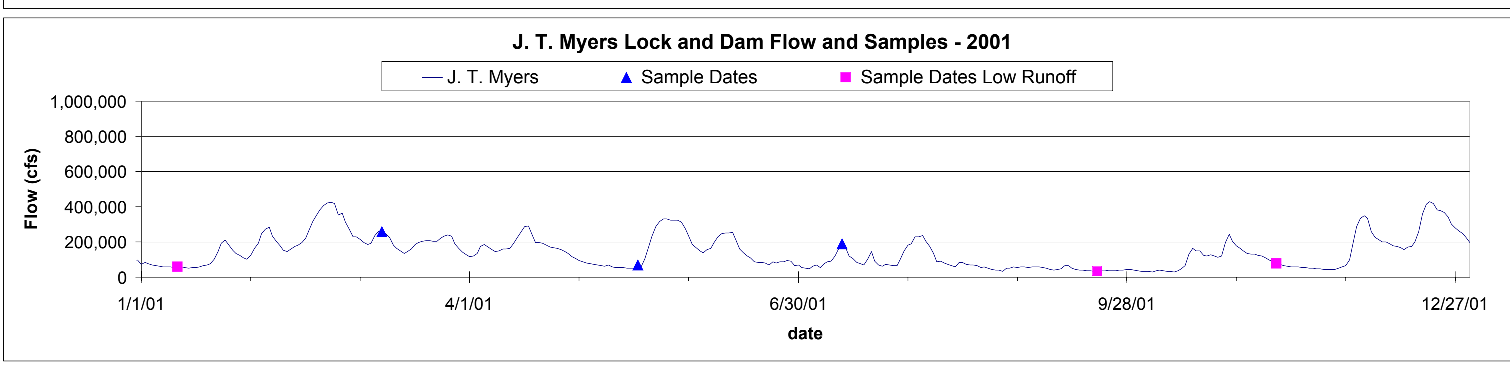

J. T. Myers Lock and Dam Flow and Samples - 1996
J. T. Myers
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/96
3/31/96
6/29/96
9/27/96
12/26/96
date

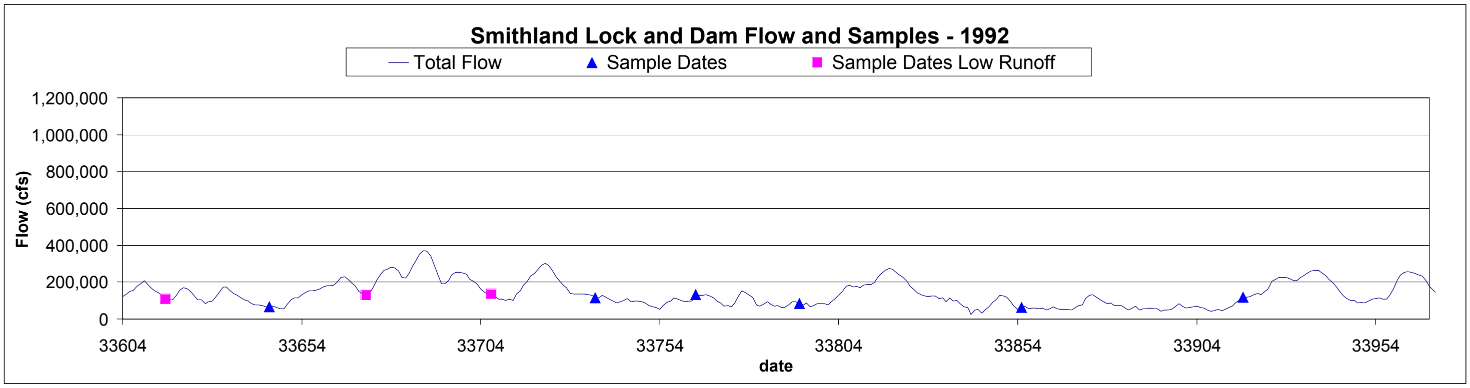

J. T. Myers Lock and Dam Flow and Samples - 1997
J. T. Myers
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/97
4/1/97
6/30/97
9/28/97
12/27/97
date

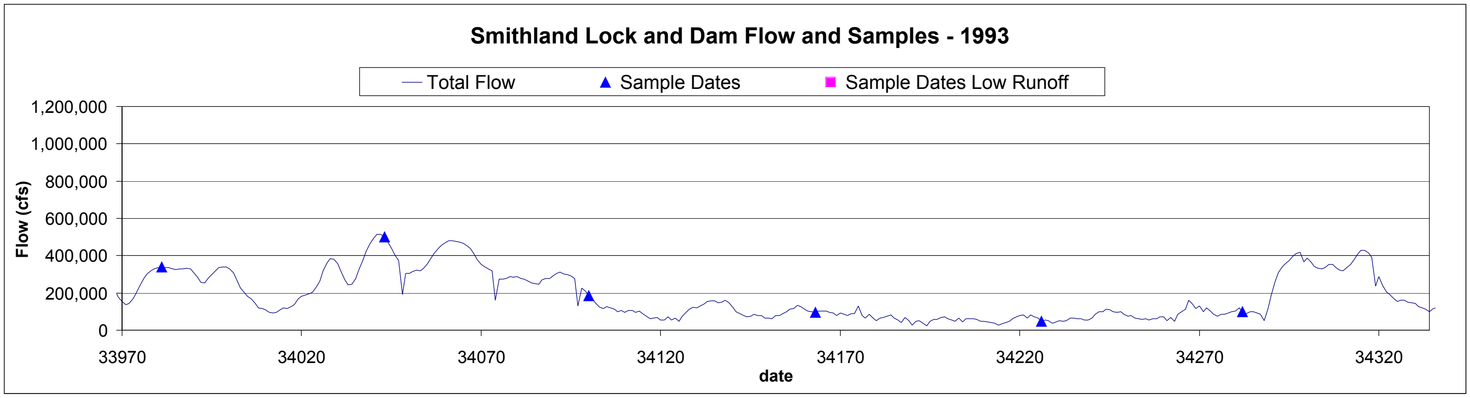

J. T. Myers Lock and Dam Flow and Samples - 1998
J. T. Myers
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/98
4/1/98
6/30/98
9/28/98
12/27/98
date

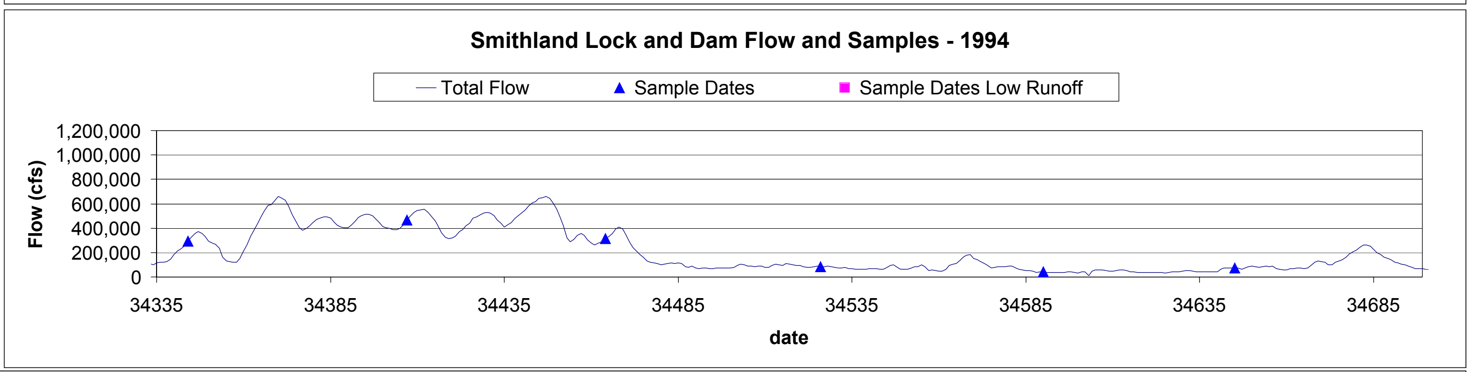

J. T. Myers Lock and Dam Flow and Samples - 1999
J. T. Myers
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/99
4/1/99
6/30/99
9/28/99
12/27/99
date

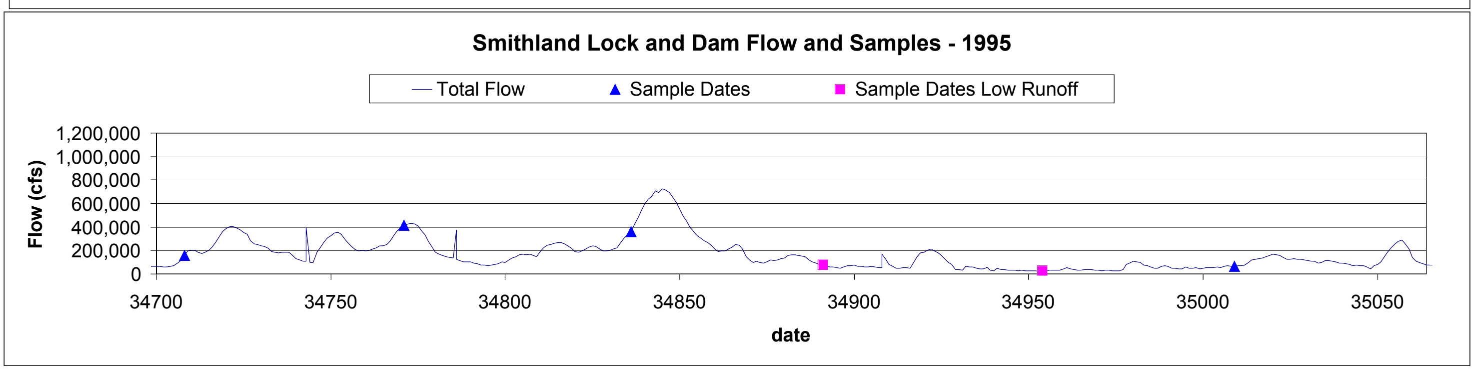

J. T. Myers Lock and Dam Flow and Samples - 2000
J. T. Myers
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/00
3/31/00
6/29/00
9/27/00
12/26/00
date

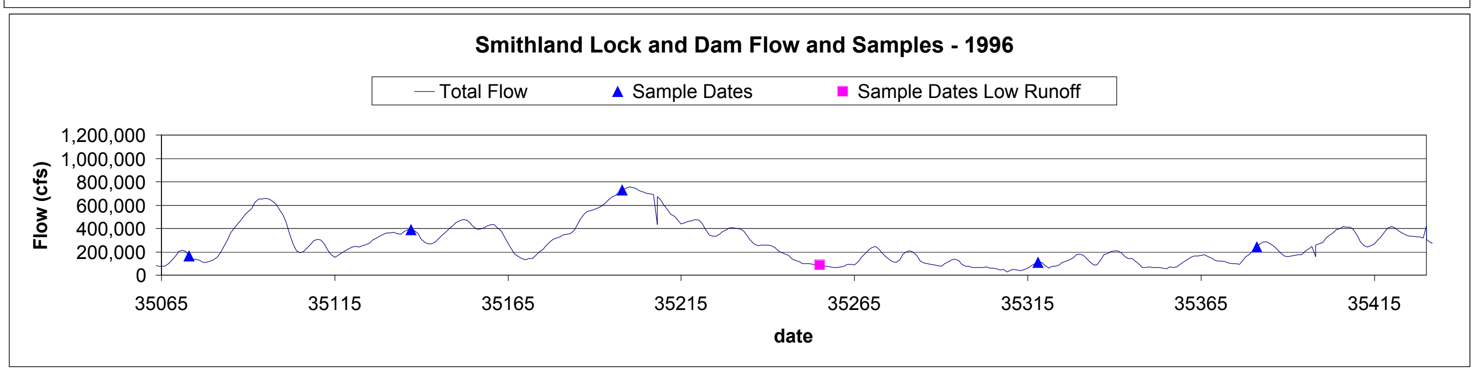

J. T. Myers Lock and Dam Flow and Samples - 2001
J. T. Myers
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,000,000
800,000
600,000
400,000
200,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date

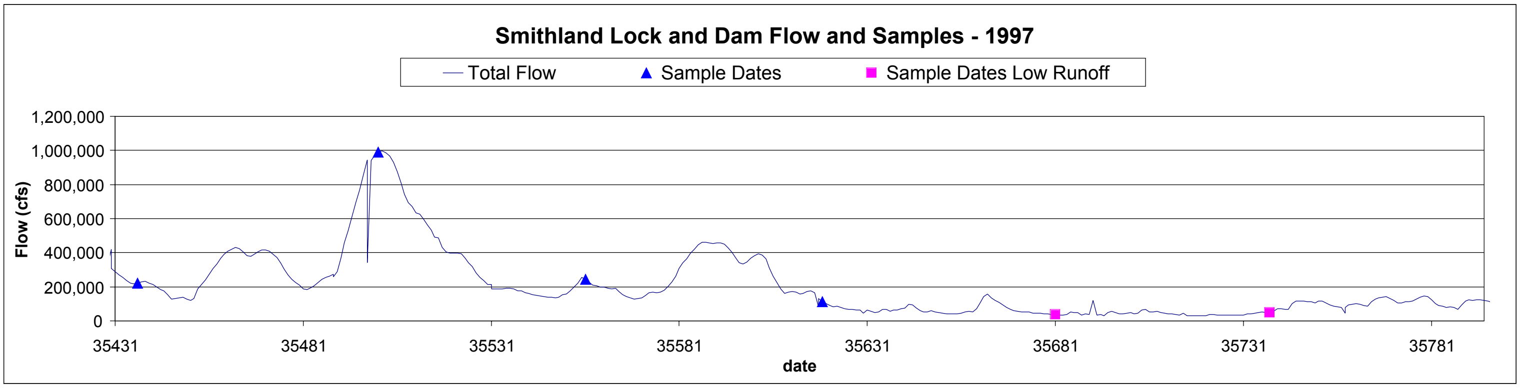

Smithland Lock and Dam Flow and Samples - 1992
Total Flow
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
33604
33654
33704
33754
33804
33854
33904
33954
date

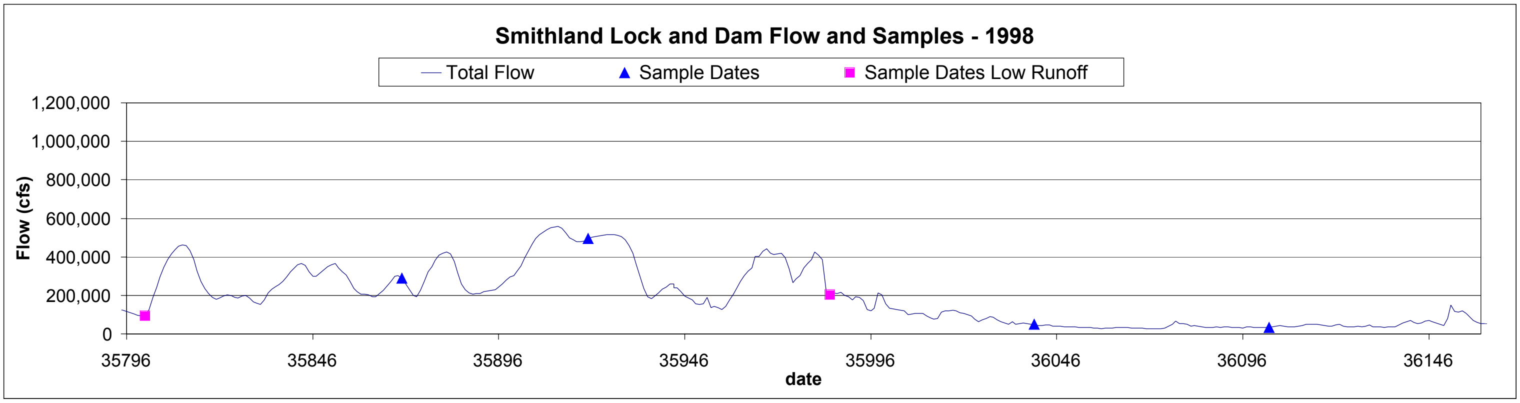

Smithland Lock and Dam Flow and Samples - 1993
Total Flow
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
33970
34020
34070
34120
34170
34220
34270
34320
date

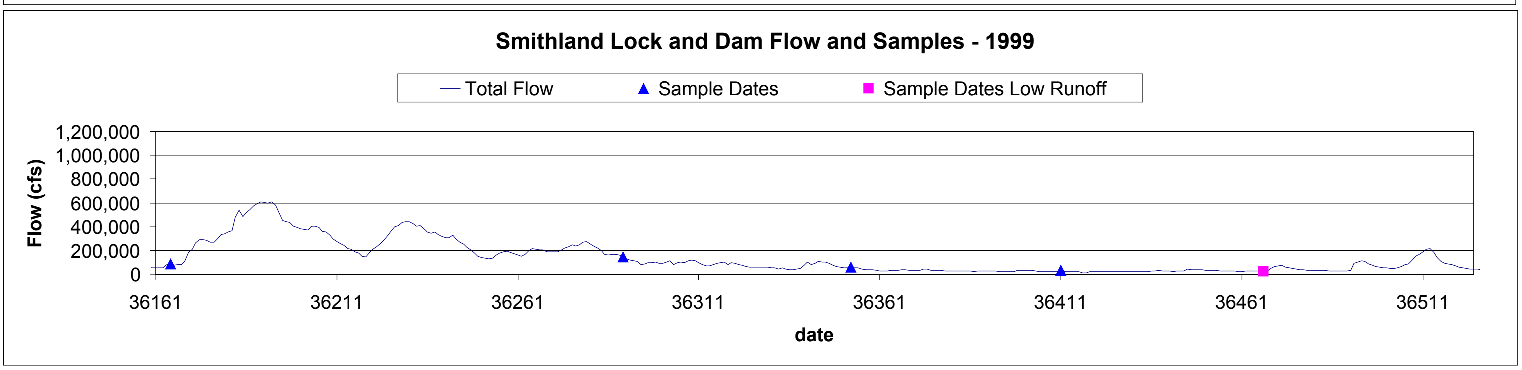

Smithland Lock and Dam Flow and Samples - 1994
Total Flow
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
34335
34385
34435
34485
34535
34585
34635
34685
date

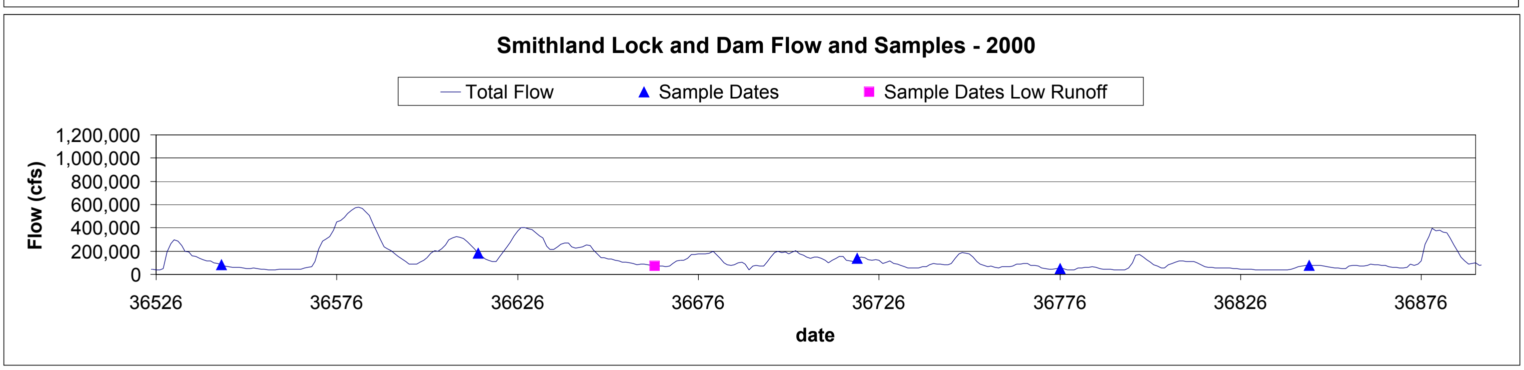

Smithland Lock and Dam Flow and Samples - 1995
Total Flow
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
34700
34750
34800
34850
34900
34950
35000
35050
date

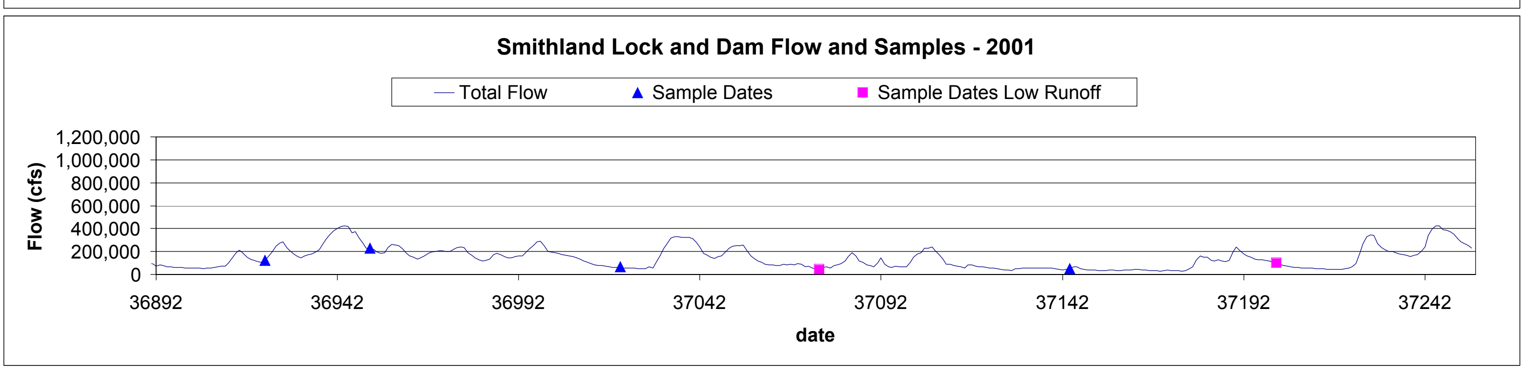

Smithland Lock and Dam Flow and Samples - 1996
Total Flow
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
35065
35115
35165
35215
35265
35315
35365
35415
date

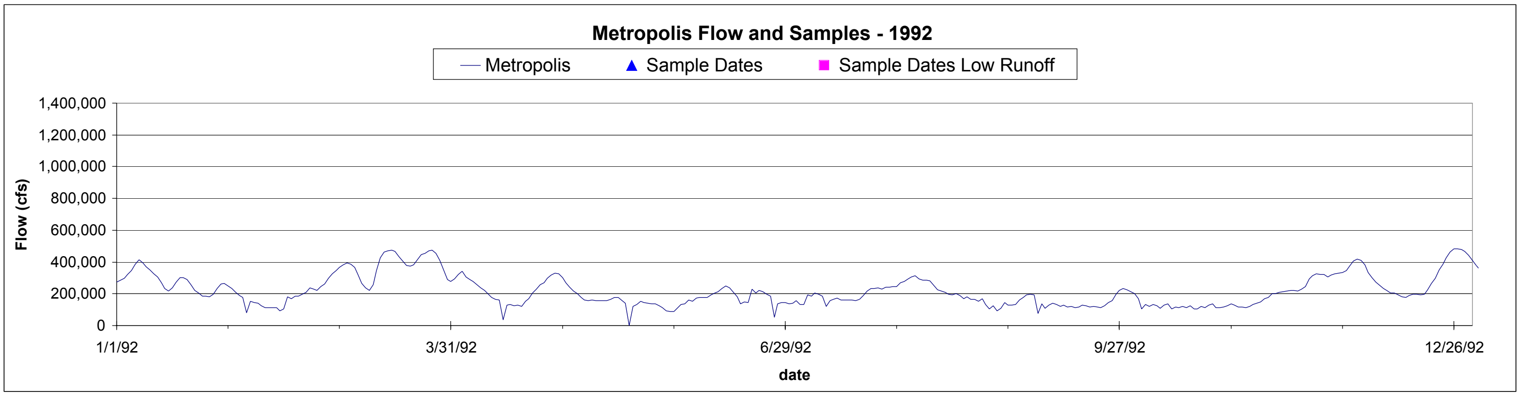

Smithland Lock and Dam Flow and Samples - 1997
Total Flow
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
35431
35481
35531
35581
35631
35681
35731
35781
date


Smithland Lock and Dam Flow and Samples - 1998
Total Flow
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
35796
35846
35896
35946
35996
36046
36096
36146
date

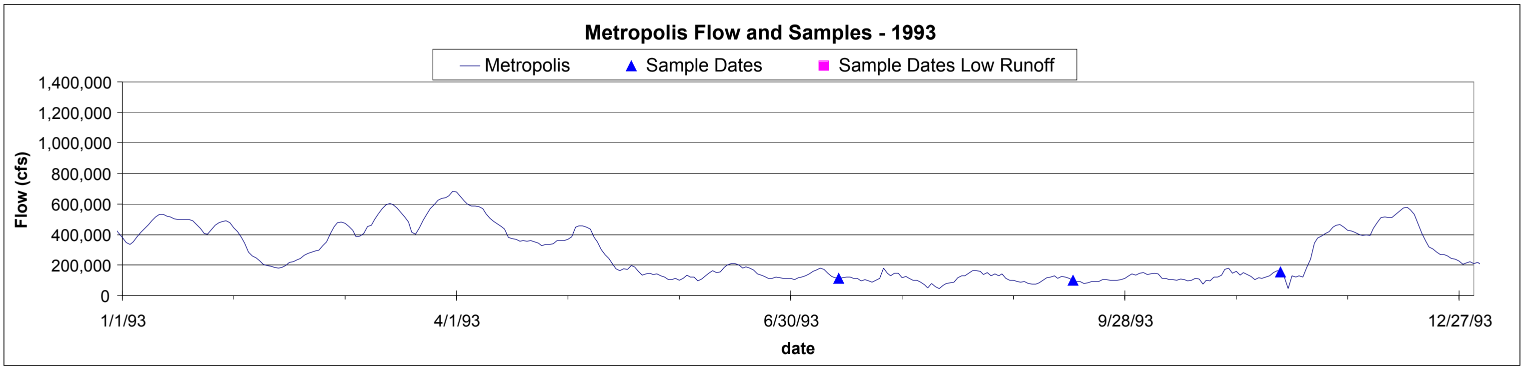

Smithland Lock and Dam Flow and Samples - 1999
Total Flow
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
36161
36211
36261
36311
36361
36411
36461
36511
date


Smithland Lock and Dam Flow and Samples - 2000
Total Flow
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
36526
36576
36626
36676
36726
36776
36826
36876
date

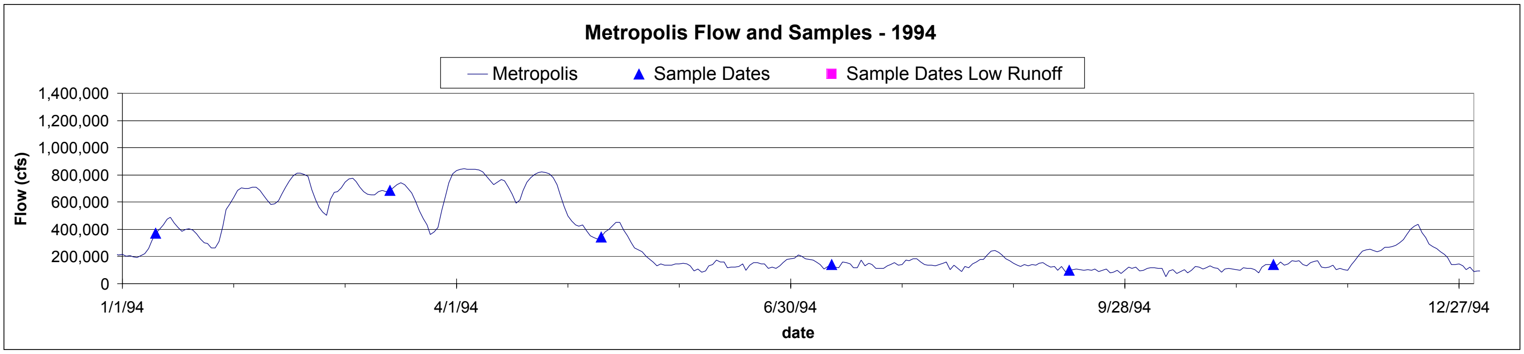

Smithland Lock and Dam Flow and Samples - 2001
Total Flow
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
36892
36942
36992
37042
37092
37142
37192
37242
date



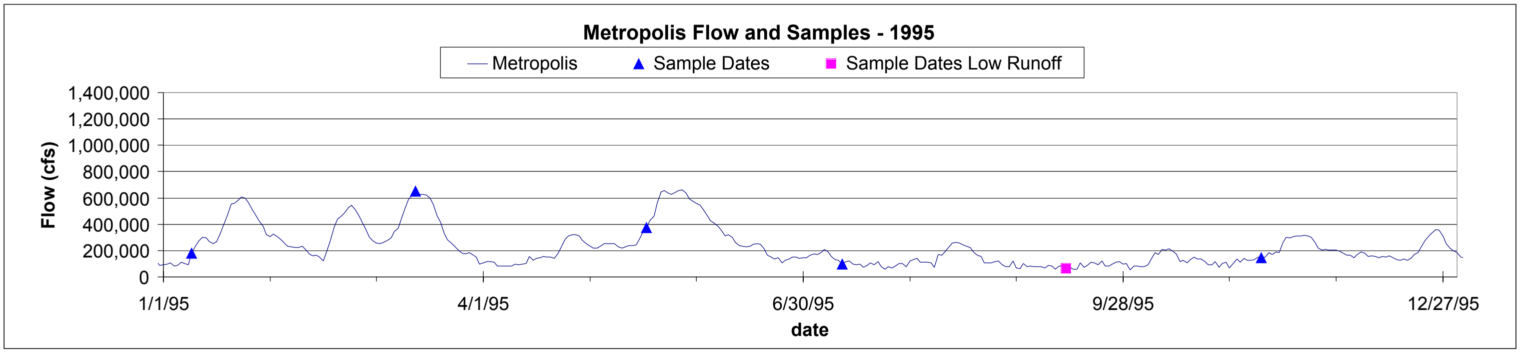
Metropolis Flow and Samples - 1992
Metropolis
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1/1/92
3/31/92
6/29/92
9/27/92
12/26/92
date



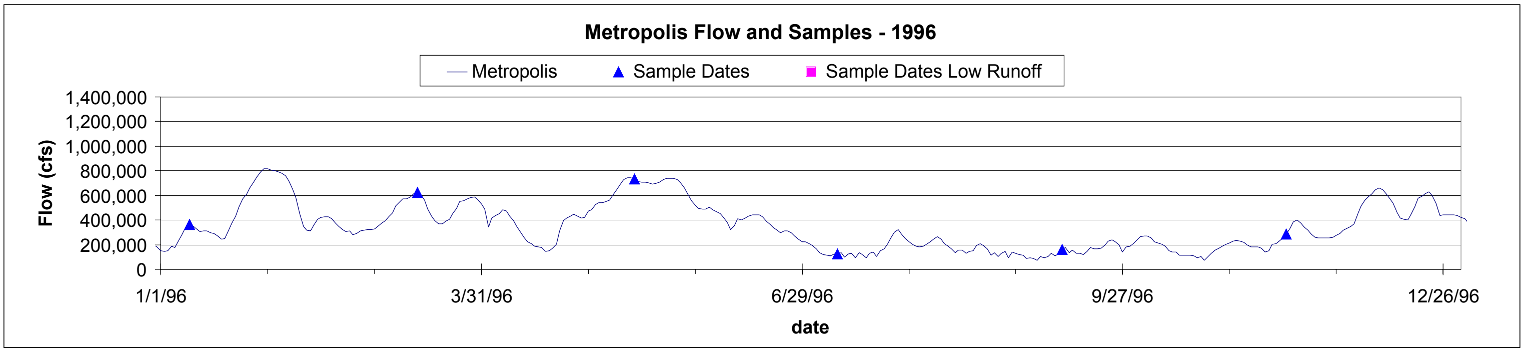
Metropolis Flow and Samples - 1993
Metropolis
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1/1/93
4/1/93
6/30/93
9/28/93
12/27/93
date



Metropolis Flow and Samples - 1994
Metropolis
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1/1/94
4/1/94
6/30/94
9/28/94
12/27/94
date



Metropolis Flow and Samples - 1995
Metropolis
Sample Dates
Sample Dates Low Runoff
Flow (cfs)
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1/1/95
4/1/95
6/30/95
9/28/95
12/27/95
date



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Sample Dates
Sample Dates Low Runoff
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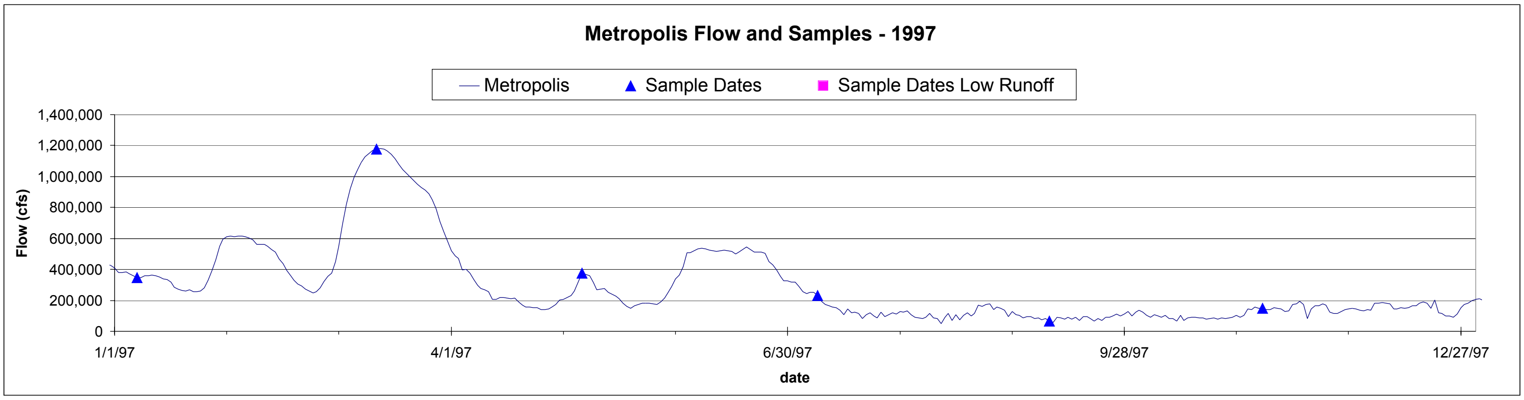
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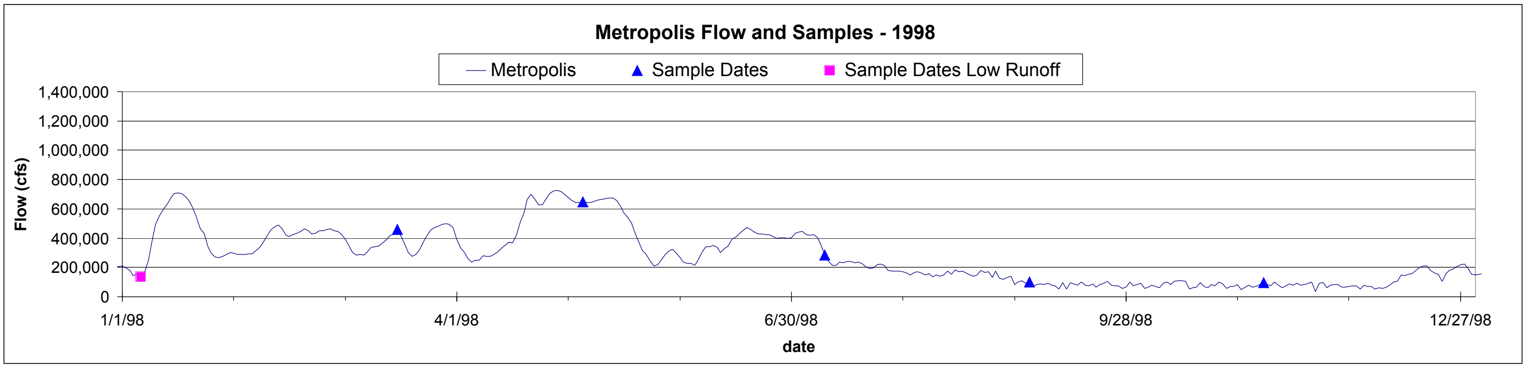
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Sample Dates
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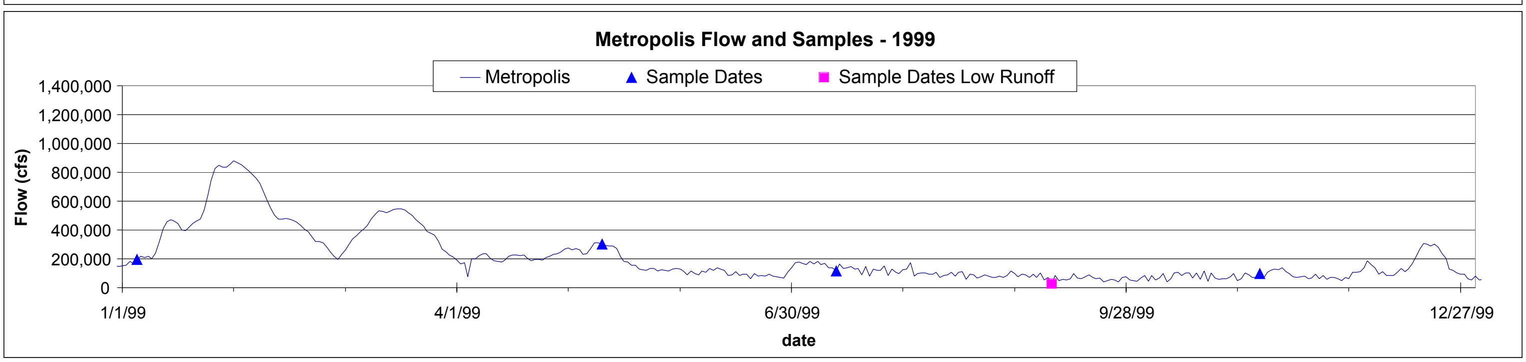
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Metropolis
Sample Dates
Sample Dates Low Runoff
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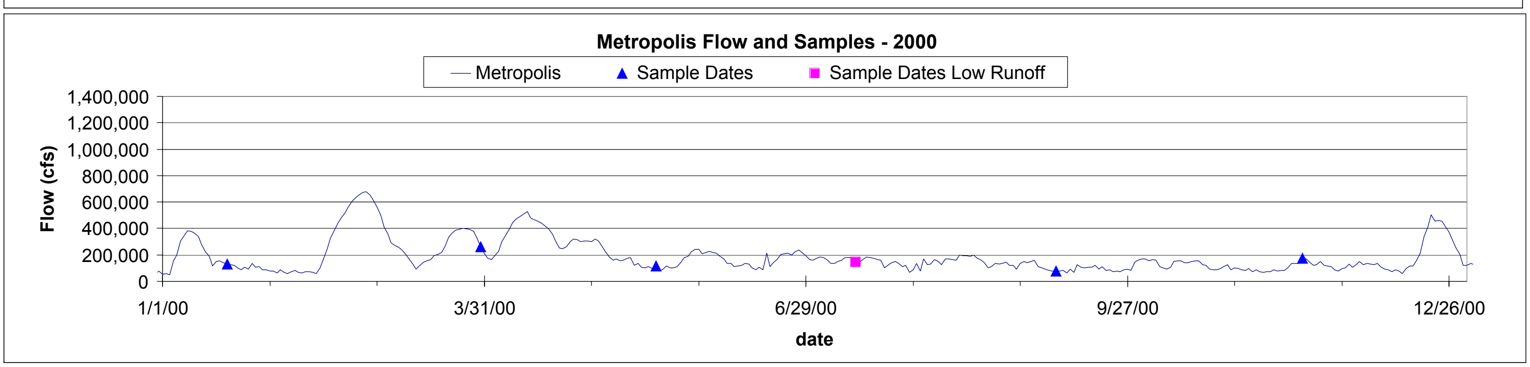
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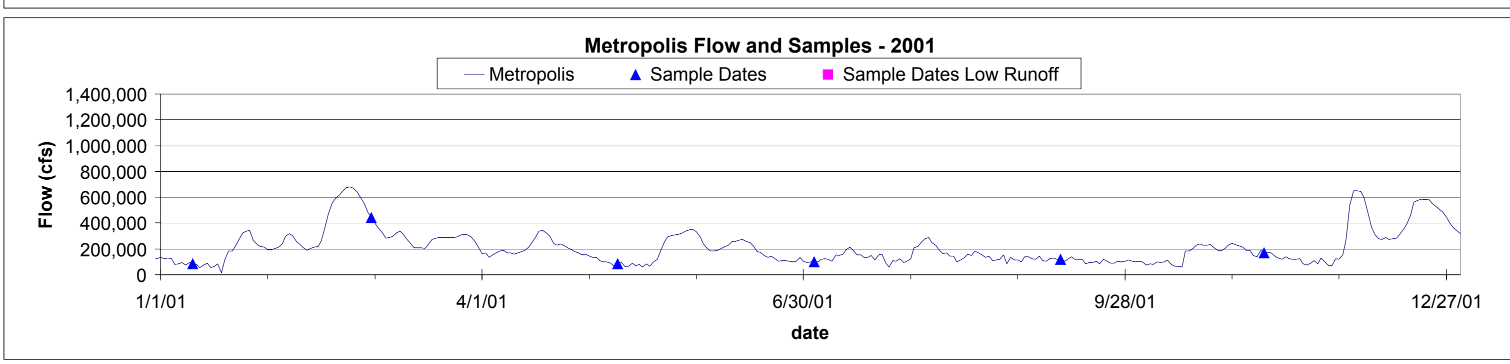
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400,000
200,000
0
1/1/01
4/1/01
6/30/01
9/28/01
12/27/01
date

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Appendix C

ORSANCO Bimonthly Sampling Program Locations

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Appendix C

ORSANCO Bimonthly Sampling Program Locations and Descriptions

Mile Point	Station Name	Station Description
7.4	Allegheny R. at Pittsburgh	Directly from the river at intake structure - Pittsburgh Water
4.5	Monongahela R. at S. Pittsburgh	Outside of intake pump station Becks Run Road - PA American Water Co.
5.3	Beaver R. at Beaver Falls	Inlet chamber in the treatment building - Beaver Water Works
54.4	Ohio R. at New Cumberland	Outside downstream guide wall, New Cumberland Lock and Dam
84.2	Ohio R. at Pike Island	Outside upstream guide wall Pike Island Lock and Dam
126.4	Ohio R. at Hannibal	Outside upstream guide wall Hannibal lock & Dam
161.8	Ohio R. at Willow Island	Outside upstream guide wall Willow Island Lock & Dam
0.8	Muskingum R. at Marietta	Directly from river, off boat landing, beneath Rt. 7 bridge
203.9	Ohio R at Belleville	Outside upstream guide wall Belleville Lock & Dam
31.1	Kanawha R. at Winfield	Directly from river off concrete structure on hydroelectric plant side
279.2	Ohio R. at R.C. Byrd	Outside upstream guide wall R. C. Byrd Lock & Dam
20.3	Big Sandy R. at Louisa	Outside raw water intake structure - AEP Kentucky Power Co.
341.0	Ohio R at Greenup	Outside upstream guide wall Greenup Lock & Dam
15.0	Scioto R. at Lucasville	Directly from river - from center of State Highway Rt. 348 bridge
436.2	Ohio R at Meldahl	Outside upstream guide wall Meldahl Lock & Dam
7.5	Little Miami R at Newtown	Directly from river, center of Newtown Road bridge
4.7	Licking R. at Covington	Directly from river, off of concrete pier at intake on left descending bank
477.5	Ohio R. at Anderson Ferry	Directly from river, off of ferry center of stream
8.0	Great Miami R at Cleves	Directly from river, off of St. Rt. 50 bridge near right descending bank
531.5	Ohio R. at Markland	Outside upstream guide wall Markland Lock & Dam
600.6	Ohio R. at Louisville	Directly from river from outside intake down stairs to river
625.9	Ohio R. at West Point	Directly from river from intake structure through screen opening
720.7	Ohio R. at Cannelton	Outside upstream guide wall Cannelton Lock & Dam
41.3	Green R. at Sebree	Directly from river off walkway on intake structure at Big Rivers electric plant
776.1	Ohio R. at Newburgh	Outside upstream guide wall Newburgh Lock & Dam
846.0	Ohio R. at J.T. Meyers	Outside upstream guide wall Uniontown Lock & Dam
28.5	Wabash R. at Mt Vernon	Directly from river, beneath roadway center of Rte. 62 Bridge
918.5	Ohio R. at Smithland	Outside upstream guide wall Smithland Lock & Dam
16.0	Cumberland R. at Pinckneyville	Raw water line in basement of Crittenden-Livingston water plant
6.0	Tennessee R. at Paducah	Directly from river off outside barge at fleeting operation
938.9	Ohio R. at L&D 52 Metropolis, IL	Directly from river from lock side of dam 52

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Appendix D

Calculated Runoff Loads by Season

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Appendix D
Runoff Loads by Ohio River Monitoring Point

New Cumberland

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	84707	1047	57	455	861418	13597	98978	7297	1054	3860	3948
average low runoff daily load	34970	1192	22	225	664015	9320	77888	7066	360	2996	3362
average daily runoff load	49737	(146)	35	231	197403	4277	21090	231	695	863	586
Wet Season (October - April)											
average daily load	294273	3388	254	1675	3369226	77862	297984	31451	6679	8765	19246
average low runoff daily load	47157	1752	31	295	858813	14063	103330	8566	488	3886	5132
average daily runoff load	247116	1637	223	1380	2510413	63799	194654	22885	6191	4879	14114

Pike Island

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	100,149	1,151	90		1,059,271	19,645	99,074	10,033	1,467	4,861	7,060
average low runoff daily load	28,279	1,037	19		733,086	8,739	79,924	5,037	297	3,356	9,948
average daily runoff load	71,870	113	71		326,185	10,907	19,151	4,996	1,170	1,505	(2,889)
Wet Season (October - April)											
average daily load	424,324	3,574	363		2,059,340	82,486	280,502	60,977	7,483	8,834	19,158
average low runoff daily load	83,439	1,450	57		1,206,347	28,447	134,907	11,728	749	5,372	7,095
average daily runoff load	340,885	2,124	38		852,993	54,039	145,595	49,249	6,733	3,463	12,062

Appendix D
Runoff Loads by Ohio River Monitoring Point

Hannibal Station

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	93,375	1,347	72	912	1,044,605	15,246	99,682	10,333	1,434	4,619	6,369
average low runoff daily load	24,938	1,467	18	280	772,470	9,096	96,143	10,845	379	3,381	4,572
average daily runoff load	68,437	(120)	54	632	272,135	6,149	3,539	(512)	1,054	1,238	1,797
Wet Season (October - April)											
average daily load	242,615	3,729	215	1,634	1,995,750	132,815	281,659	32,807	5,045	9,410	15,849
average low runoff daily load	40,447	1,589	30	724	1,016,702	16,862	121,276	(3,845)	624	4,204	8,112
average daily runoff load	202,168	2,140	185	910	979,048	115,953	160,383	36,652	4,421	5,207	7,737

Willow Island

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	152,482	1,458	117	938	1,151,111	19,129	103,001	14,528	2,405	5,365	7,723
average low runoff daily load	33,675	1,518	19	220	833,773	8,392	94,114	33,828	291	3,824	5,669
average daily runoff load	118,807	(60)	99	717	317,338	10,737	8,887	(19,300)	2,114	1,541	2,054
Wet Season (October - April)											
average daily load	386,235	3,808	320	1,700	2,174,588	65,708	285,102	33,327	5,506	9,454	16,057
average low runoff daily load	103,317	2,383	70	671	1,462,424	33,849	193,033	(15,260)	765	6,631	9,716
average daily runoff load	282,917	1,424	25	1,029	712,164	31,859	92,069	48,586	4,741	2,823	6,341

Appendix D
Runoff Loads by Ohio River Monitoring Point

Belleville

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	260095	2004	183	1119	1849105	26487	145555	15698	3489	7221	9018
average low runoff daily load	60040	1831	27	324	1192808	10228	109168	9801	468	4349	4062
average daily runoff load	200055	173	157	795	656297	16259	36387	5897	3021	2872	4955
Wet Season (October - April)											
average daily load	422085	4900	34	2111	3227264	70612	416205	40123	7628	12494	14310
average low runoff daily load	107726	2807	77	1446	2026251	28116	217121	10742	1111	6823	8861
average daily runoff load	314359	2092	263	665	1201013	42496	199084	29382	6517	5671	5449

R C Byrd

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	616,016	3,715	552	6,263	2,966,576	80,468	238,421	44,494	11,741	11,111	21,123
average low runoff daily load	28,437	1,683	3	6,296	1,069,895	9,718	96,002	10,569	401	4,049	5,901
average daily runoff load	587,579	2,032	53	(33)	1,896,681	70,750	142,418	33,925	11,340	7,063	15,222
Wet Season (October - April)											
average daily load	877,445	6,543	818	11,468	4,064,508	162,525	546,844	61,717	18,599	15,796	26,726
average low runoff daily load	126,872	2,923	79	7,743	1,931,309	37,143	222,081	20,890	1,195	7,281	9,847
average daily runoff load	750,572	3,620	740	3,725	2,133,200	125,382	324,762	40,827	17,404	8,515	16,879

Appendix D
Runoff Loads by Ohio River Monitoring Point

Greenup

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	713,973	3,255	54	5,782	3,381,648	69,859	279,960	39,956	12,511	12,786	25,094
average low runoff daily load	41,205	1,844	27	848	1,386,889	8,974	122,028	12,809	570	6,622	1,464
average daily runoff load	672,768	1,411	477	4,933	1,994,759	60,884	157,932	27,146	11,942	6,164	23,630
Wet Season (October - April)											
average daily load	938,140	5,562	2,275	8,038	4,780,408	126,075	530,367	69,239	22,915	18,662	31,902
average low runoff daily load	94,642	2,309	60	2,602	1,970,024	18,378	202,596	21,955	1,051	7,920	4,842
average daily runoff load	843,498	3,253	2,215	5,435	2,810,384	107,697	327,771	47,284	21,864	10,742	27,060

Meldahl

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	544972	3375	355	1406	3941434	37187	379453	29218	7444	10667	19493
average low runoff daily load	75428	2517	58	449	2319777	12651	220745	16598	1424	7338	3828
average daily runoff load	469544	858	297	957	1621657	24536	158707	12620	6020	3328	15665
Wet Season (October - April)											
average daily load	1249538	7872	131	4403	8113405	143054	984645	79875	31528	19001	33239
average low runoff daily load	389479	3349	259	1153	3931407	51334	375464	32824	6541	10042	13193
average daily runoff load	860059	4523	773	3250	4181998	91720	609182	47051	24987	8958	20046

Appendix D
Runoff Loads by Ohio River Monitoring Point

Anderson ferry

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	1,193,349	4,120	838	3,463	4,236,992	99,405	429,140	41,604	23,383	12,590	35,986
average low runoff daily load	6,519	2,348	69	229	2,212,412	13,191	210,864	41,789	1,466	6,483	(4,868)
average daily runoff load	1,186,830	1,772	769	3,234	2,024,580	86,214	218,276	(184)	21,917	6,107	40,853
Wet Season (October - April)											
average daily load	2,038,077	8,993	1,635	4,976	6,875,815	229,141	763,495	94,142	36,113	20,909	48,675
average low runoff daily load	1,491,225	4,799	970	2,911	5,361,713	142,625	467,932	66,740	13,709	15,583	18,271
average daily runoff load	546,852	4,194	666	2,065	1,514,102	86,516	295,563	27,402	22,404	5,326	30,403

Markland

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	664,646	3,939	445	2,827	4,345,279	55,303	552,623	38,071	14,420	11,946	34,141
average low runoff daily load	177,807	3,733	116	705	3,419,346	19,137	357,744	30,182	2,728	9,554	7,147
average daily runoff load	486,839	206	329	2,122	925,933	36,166	194,879	7,889	11,692	2,392	26,993
Wet Season (October - April)											
average daily load	1,596,014	10,964	155	4,188	8,573,608	135,811	1,229,824	158,761	29,456	21,848	45,483
average low runoff daily load	423,776	5,145	335	1,397	5,330,470	51,762	592,999	60,800	7,301	13,282	13,490
average daily runoff load	1,172,238	5,819	719	2,792	3,243,139	84,049	636,824	97,961	22,154	8,565	31,992

Appendix D
Runoff Loads by Ohio River Monitoring Point

Louisville

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	832,139	4,937	624	5,545	4,932,248	79,753	469,214	40,933	19,523	12,191	50,515
average low runoff daily load	80,431	2,851	72	803	2,070,737	13,959	206,967	40,148	2,348	6,416	9,179
average daily runoff load	751,708	2,086	552	4,742	2,861,510	65,794	262,247	784	17,176	5,774	41,336
Wet Season (October - April)											
average daily load	2,035,508	8,662	1,612	6,194	7,540,716	169,540	974,199	143,303	43,040	21,825	44,197
average low runoff daily load	114,821	3,226	92	1,050	2,313,633	17,674	261,975	42,151	3,388	7,513	10,464
average daily runoff load	1,920,687	5,436	1,519	5,144	5,227,084	151,866	712,224	101,152	39,651	14,312	33,734

West Point

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	1,020,628	4,816	8	3,629	4,691,900	92,419	461,583	50,661	21,289	12,434	23,192
average low runoff daily load	137,865	3,412	100	888	2,544,865	17,355	243,724	21,153	2,853	8,119	11,102
average daily runoff load	882,763	1,404	7	2,742	2,147,035	75,064	217,858	29,509	18,435	4,315	12,090
Wet Season (October - April)											
average daily load	1,802,505	9,293	1,563	5,532	7,588,629	215,206	923,588	131,361	40,708	23,108	39,357
average low runoff daily load	168,620	3,703	125	1,151	2,783,326	20,959	282,563	25,438	3,575	8,925	11,967
average daily runoff load	1,633,885	5,590	1,438	4,382	4,805,303	194,247	641,025	105,923	37,133	14,182	27,389

Appendix D
Runoff Loads by Ohio River Monitoring Point

Cannelton

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	673,961	4,508	479	2,700	5,114,587	50,970	607,979	50,103	13,250	14,504	18,498
average low runoff daily load	113,459	2,847	56	495	2,453,722	6,449	286,678	24,214	1,286	7,807	2,900
average daily runoff load	560,502	1,662	423	2,206	2,660,865	44,522	321,301	25,889	11,964	6,698	15,598
Wet Season (October - April)											
average daily load	1,521,419	7,604	1,237	5,023	7,147,847	156,694	849,996	124,270	35,611	21,980	39,175
average low runoff daily load	345,487	4,082	162	803	3,411,029	11,662	499,550	33,848	2,995	15,099	4,110
average daily runoff load	1,175,932	3,522	174	4,220	3,736,818	145,032	350,446	90,422	32,617	6,881	35,065

Newburgh

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	856,224	4,389	552	2,114	5,758,981	63,726	593,773	52,039	16,007	13,726	28,662
average low runoff daily load	54,358	2,772	33	482	3,103,455	6,546	264,348	19,569	1,077	7,497	2,774
average daily runoff load	801,866	1,616	519	1,632	2,655,527	57,180	329,425	32,470	14,929	6,229	25,888
Wet Season (October - April)											
average daily load	2,063,257	8,663	1,545	5,542	8,388,605	208,556	927,192	190,050	41,886	25,065	55,372
average low runoff daily load	61,702	3,118	37	604	3,560,999	7,246	308,261	22,106	1,211	8,341	3,339
average daily runoff load	2,001,555	5,545	158	4,938	4,827,607	201,310	618,931	167,945	40,675	16,724	52,033

Appendix D
Runoff Loads by Ohio River Monitoring Point

J. T. Myers

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	761858	4951	479	2407	5710759	58878	662245	87475	11918	15665	20317
average low runoff daily load	68571	2689	39	636	2879080	7148	283355	22880	1089	7859	2391
average daily runoff load	693287	2262	45	1771	2831678	51730	378890	64595	10829	7806	17925
Wet Season (October - April)											
average daily load	2226213	9303	1533	5503	8977073	178894	1051155	144550	45221	26376	52009
average low runoff daily load	75604	3611	54	889	3857605	9615	443161	32580	1564	10231	3353
average daily runoff load	2150610	5692	1480	4614	5119467	169280	607994	111970	43658	16145	48656
		%									

Smithland

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	1,682,000	15,626	113	11,546	8,395,696	92,129	1,149,913	115,270	21,146	18,497	41,361
average low runoff daily load	399,147	12,346	242	2,875	5,303,360	25,100	686,469	53,453	3,624	12,886	26,429
average daily runoff load	1,282,854	3,280	78	8,671	3,092,336	67,028	463,444	61,817	17,522	5,612	14,932
Wet Season (October - April)											
average daily load	3,592,115	22,313	229	24,298	11,592,346	198,955	1,616,900	172,443	47,999	30,971	68,591
average low runoff daily load	557,602	13,862	359	3,823	5,905,860	33,671	823,554	66,370	9,057	14,590	30,133
average daily runoff load	3,034,512	8,451	1,932	20,475	5,686,486	165,283	793,345	106,073	38,942	16,381	38,457

Metropolis*

	Aluminum (lb/day)	Chloride (tons/day)	Iron (tons/day)	Lead (lb/day)	Magnesium (lb/day)	Manganese (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Suspended Solids (tons/day)	Sulfate (tons/day)	Zinc (lb/day)
Dry Season (May - September)											
average daily load	1,539,225	19,844	947	8,270	10,968,511	101,227	1,448,953	110,348	21,646	25,529	81,749
Wet Season (October - April)											
average daily load	4,586,375	35,855	2,956	12,826	18,043,702	263,934	2,319,468	226,662	63,237	45,838	114,728
average low runoff daily load	229,073	10,578	17		5,642,384	21,191	892,276	87,850	4,223	12,124	27,656

* This station yielded only four sample dates meeting the recession criteria. Low runoff loads by season are not available.

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Appendix E

Ohio River Load Graphs by Parameter

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Appendix E
Total Loads Mainstem Stations

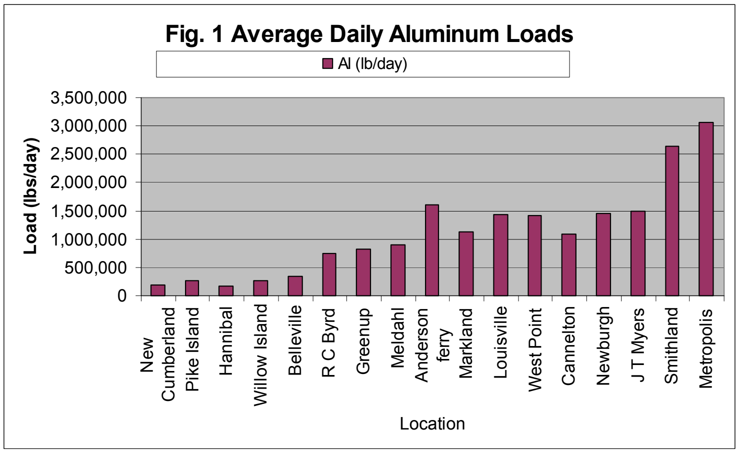


Fig. 1 Average Daily Aluminum Loads

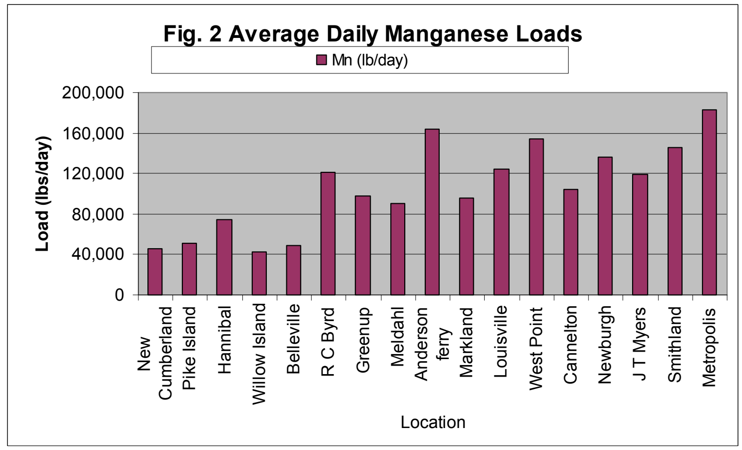


Fig. 2 Average Daily Manganese Loads

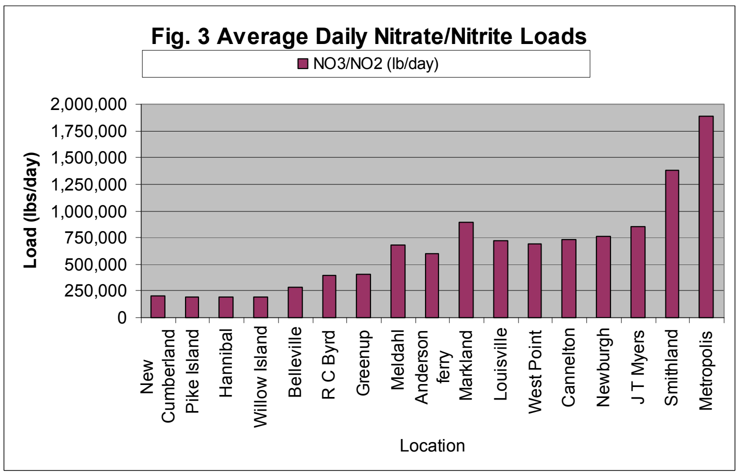


Fig. 3 Average Daily Nitrate/Nitrite Loads

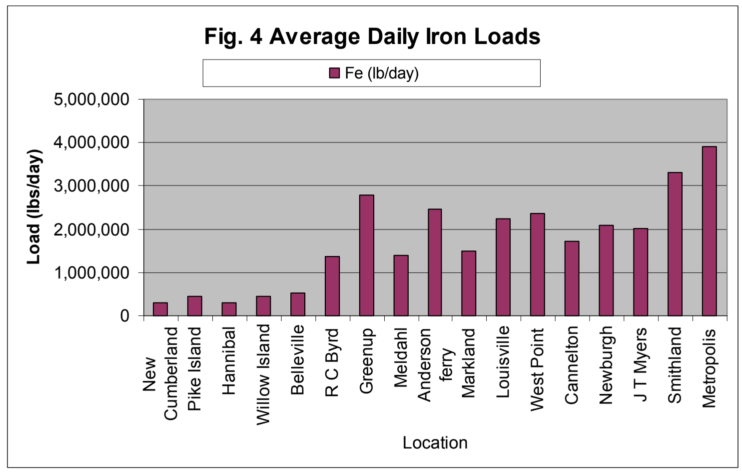


Fig. 4 Average Daily Iron Loads

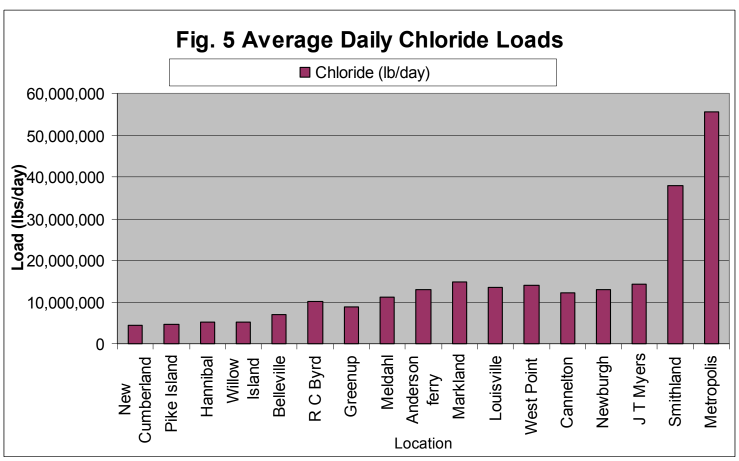


Fig. 5 Average Daily Chloride Loads

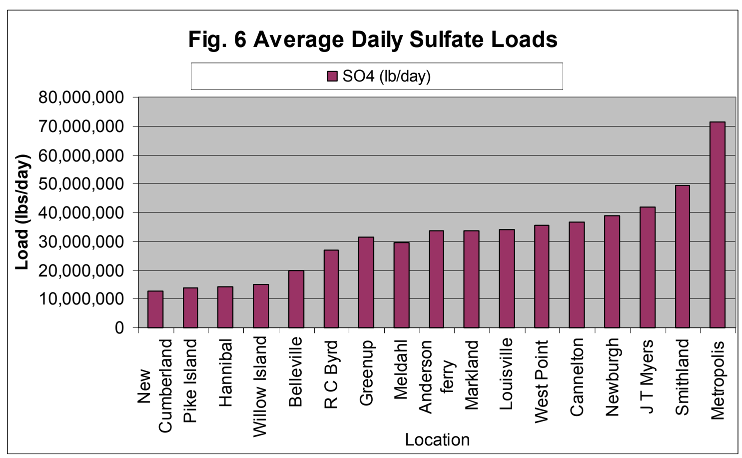


Fig. 6 Average Daily Sulfate Loads

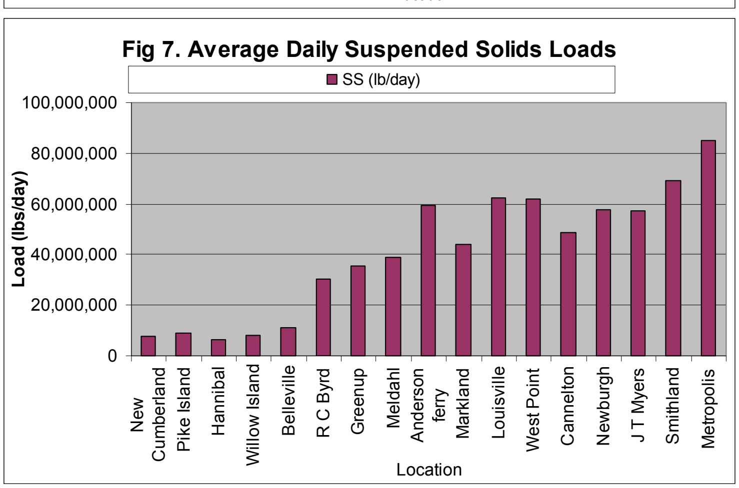


Fig 7. Average Daily Suspended Solids Loads

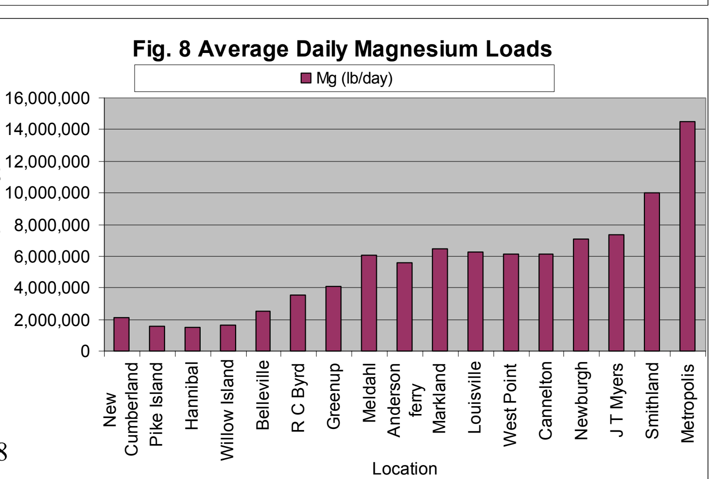
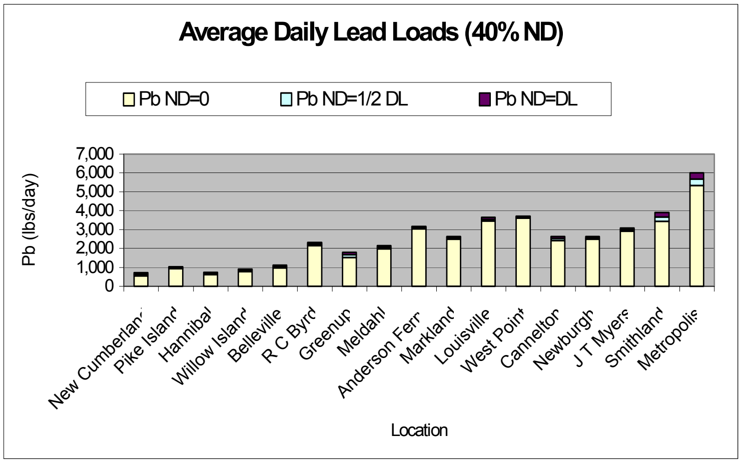
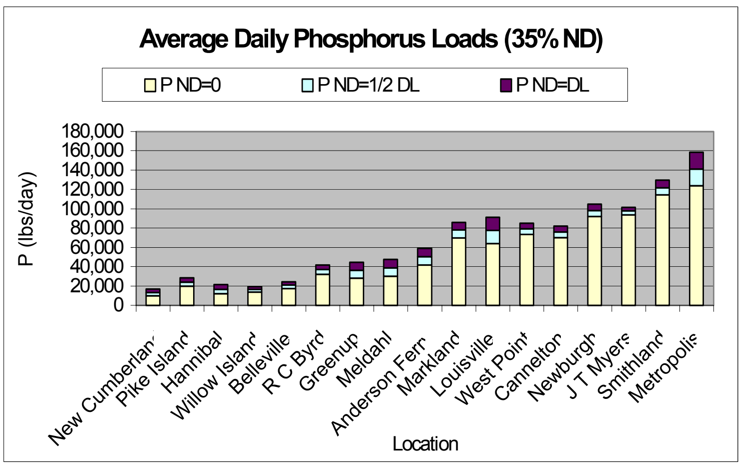
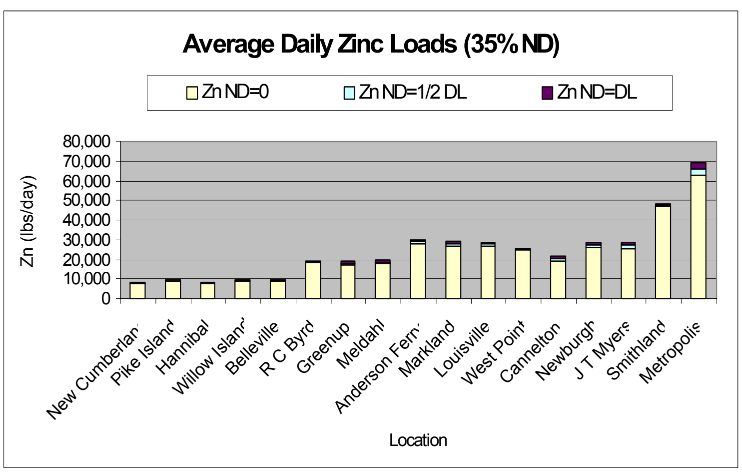


Fig. 8 Average Daily Magnesium Loads

Appendix E continued
Total Loads Mainstem Stations, parameters requireing treatment of non-detects







Appendix F
Ohio River Loads Table

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Appendix F
Average Daily Loads at Ohio River Monitoring Points of Eleven Runoff Pollutants

Station	Ohio River Mile Point	Aluminum (lbs/day)	Chloride (lbs/day)	Iron (lbs/day)	Magnesium (lbs/day)	Manganese (lbs/day)	Nitrite/ Nitrate (lbs/day)	Lead (lbs/day)	Sulfate (lbs/day)	Suspended Solids (lbs/day)	Total Phosphorus (lbs/day)	Zinc (lbs/day)
New Cumberland	54.4	189,490	4,434,878	310,922	2,115,322	45,729	198,481	638	12,624,634	7,733,036	13,394	8,064
Pike Island	84.2	262,236	4,724,941	452,723	1,559,305	51,066	189,788	975	13,695,211	8,949,247	24,031	9,440
Hannibal	126.4	167,995	5,076,320	287,046	1,520,178	74,030	190,670	680	14,029,641	6,479,376	16,663	7,833
Willow Island	161.8	269,358	5,265,831	437,331	1,662,850	42,418	194,051	842	14,819,308	7,911,113	16,357	9,113
Belleville	203.9	341,090	6,903,515	523,043	2,538,184	48,550	280,880	1,038	19,714,547	11,117,301	20,955	9,146
R C Byrd	279.2	746,730	10,257,898	1,368,941	3,515,542	121,497	392,632	2,232	26,907,674	30,339,840	37,020	18,621
Greenup	341	826,057	8,816,680	2,779,301	4,081,028	97,967	405,163	1,660	31,447,956	35,426,615	36,385	18,064
Meldahl	436.2	897,255	11,247,324	1,386,261	6,027,420	90,120	682,049	2,071	29,667,093	38,971,608	38,804	18,611
Anderson ferry	477.5	1,615,713	13,112,713	2,472,916	5,556,403	164,273	596,317	3,099	33,499,235	59,496,140	50,270	28,993
Markland	531.5	1,130,330	14,903,128	1,499,332	6,459,444	95,557	891,223	2,562	33,793,461	43,875,576	77,855	27,941
Louisville	600.6	1,433,823	13,599,493	2,235,468	6,236,482	124,646	721,707	3,548	34,015,593	62,563,031	77,616	27,710
West Point	625.9	1,411,567	14,109,035	2,362,973	6,140,265	153,813	692,585	3,659	35,541,929	61,996,497	79,330	25,008
Cannelton	720.7	1,097,690	12,112,433	1,715,477	6,131,217	103,832	728,987	2,529	36,483,932	48,861,091	76,150	20,210
Newburgh	776	1,459,740	13,051,450	2,096,888	7,073,793	136,141	760,482	2,560	38,791,595	57,892,816	98,443	27,107
J T Myers	846	1,494,036	14,254,361	2,012,009	7,343,916	118,886	856,700	2,991	42,040,951	57,139,032	97,707	27,042
Smithland	918.5	2,637,057	37,938,646	3,302,557	9,994,021	145,542	1,383,406	3,668	49,468,103	69,145,364	121,924	47,702
Metropolis	938.9	3,062,800	55,699,431	3,902,649	14,506,107	182,580	1,884,211	5,671	71,367,065	84,882,608	141,048	65,892

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Appendix G

Tributary Load Graphs by Parameter

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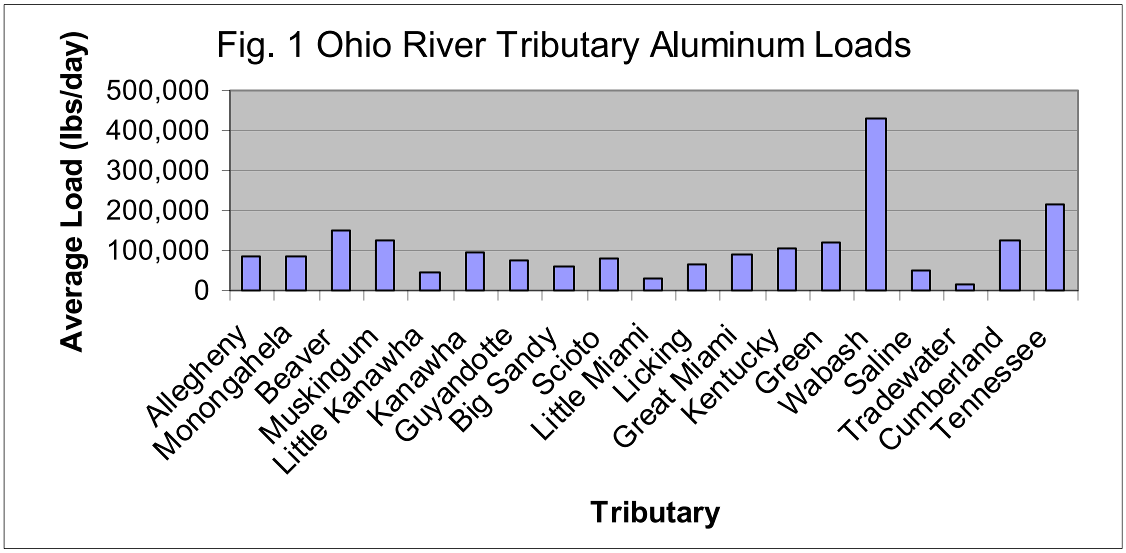
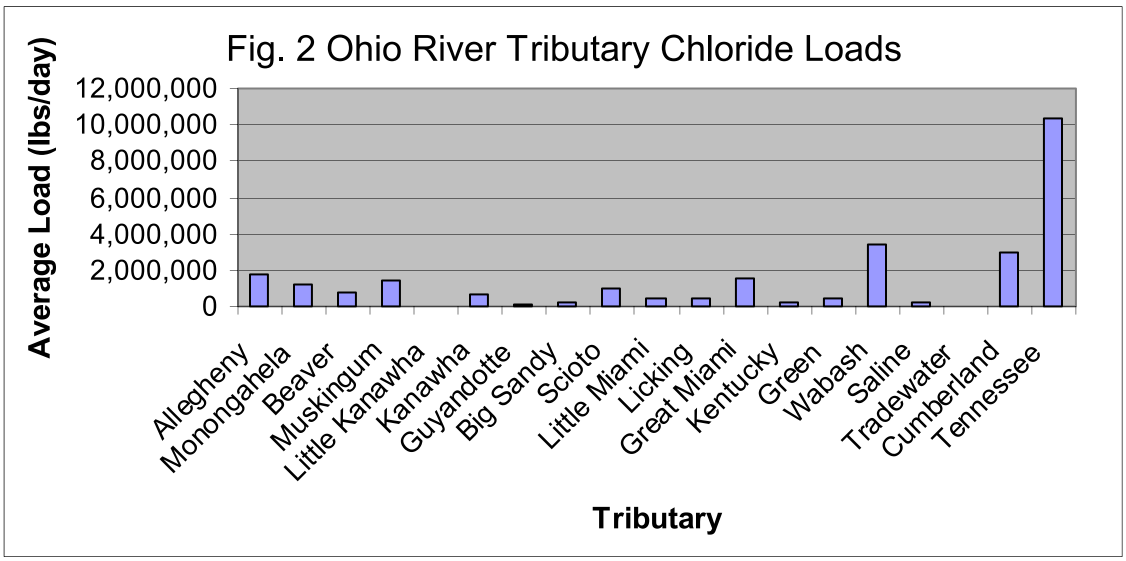
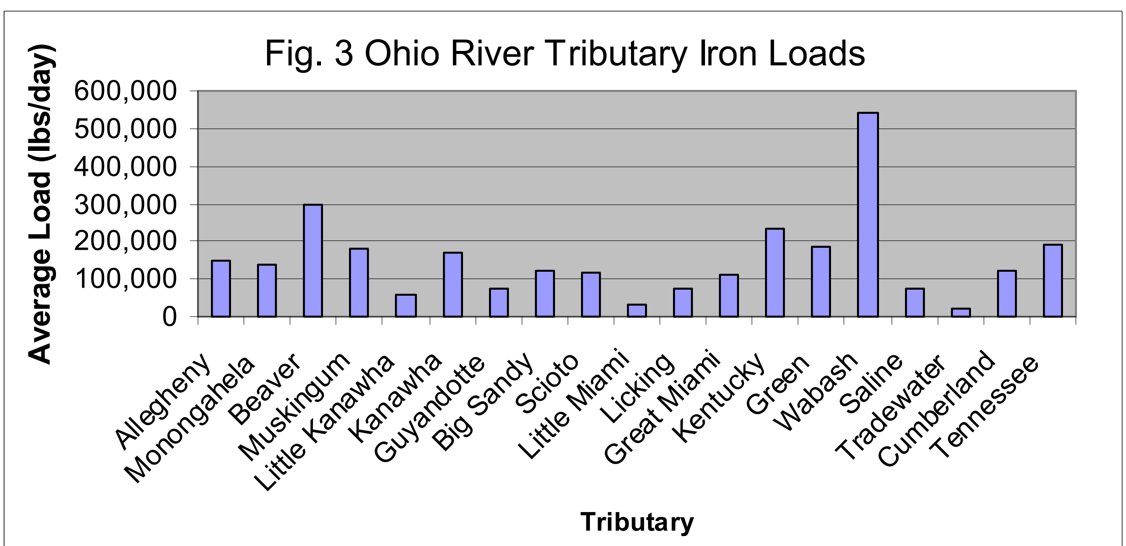
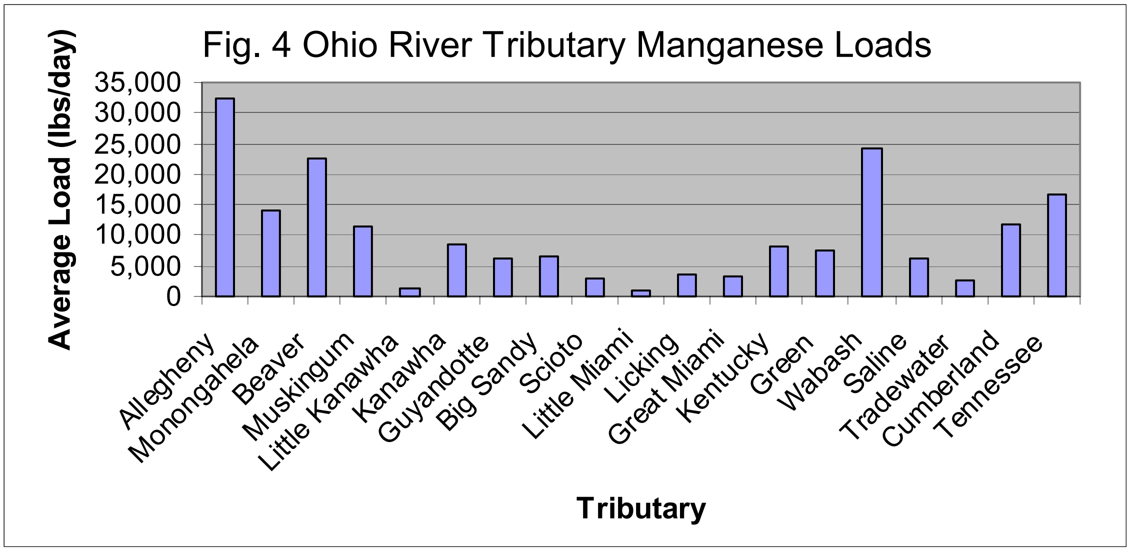
Appendix G
Ohio River Tributary Loads

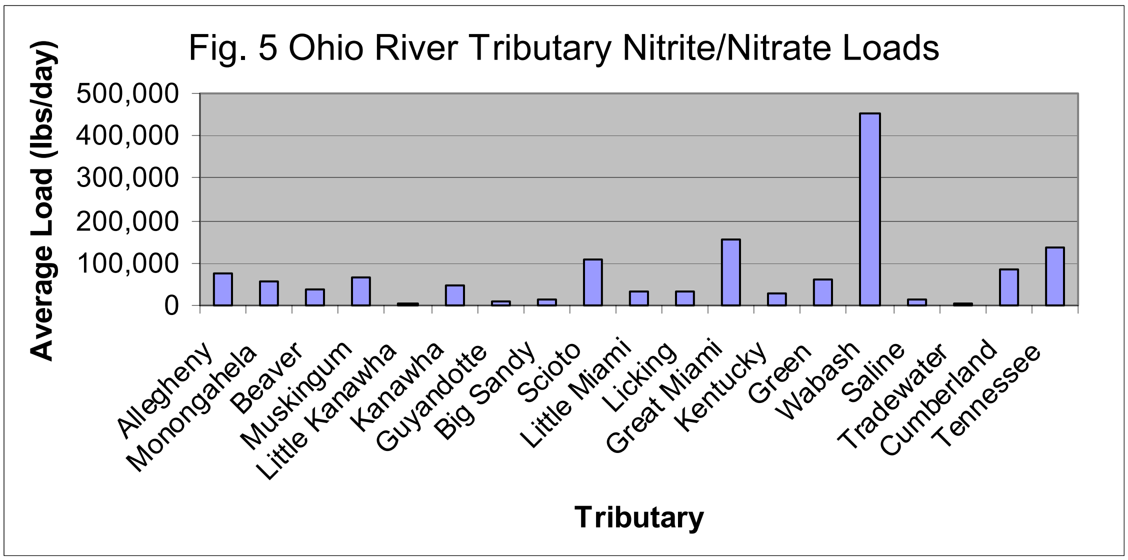


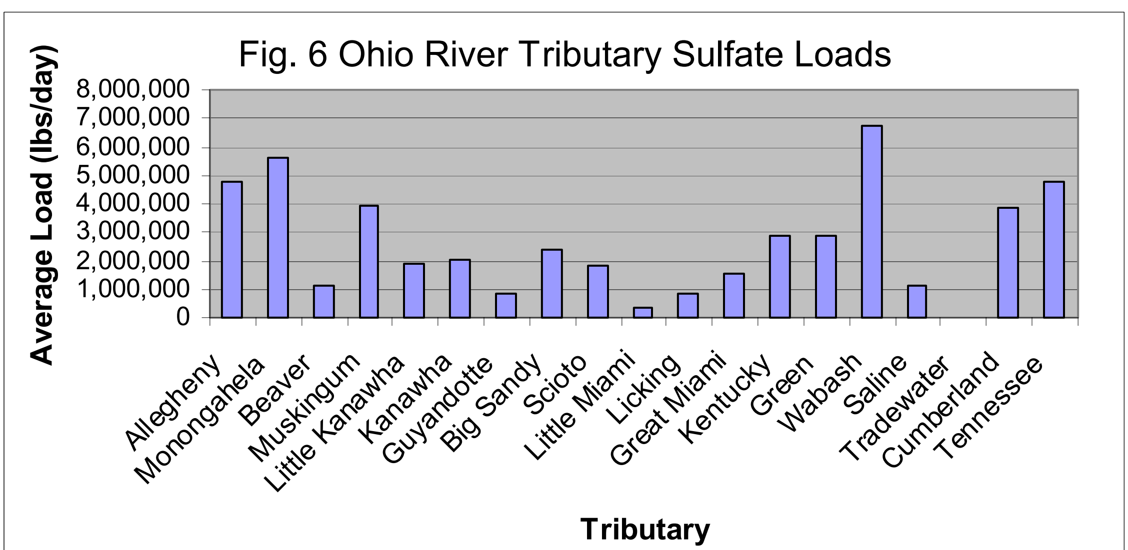




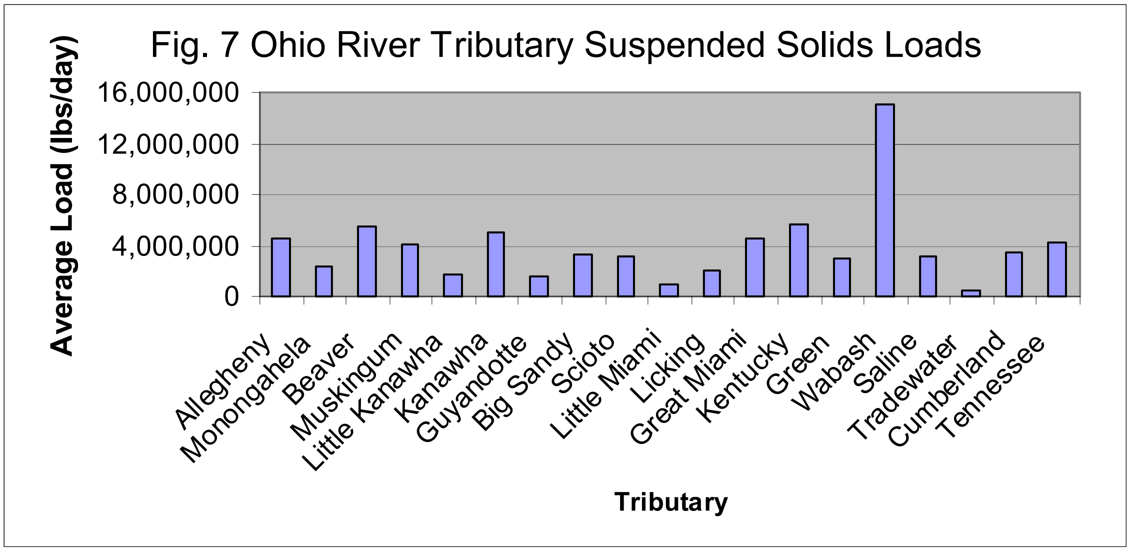
Appendix G continued
Ohio River Tributary Loads

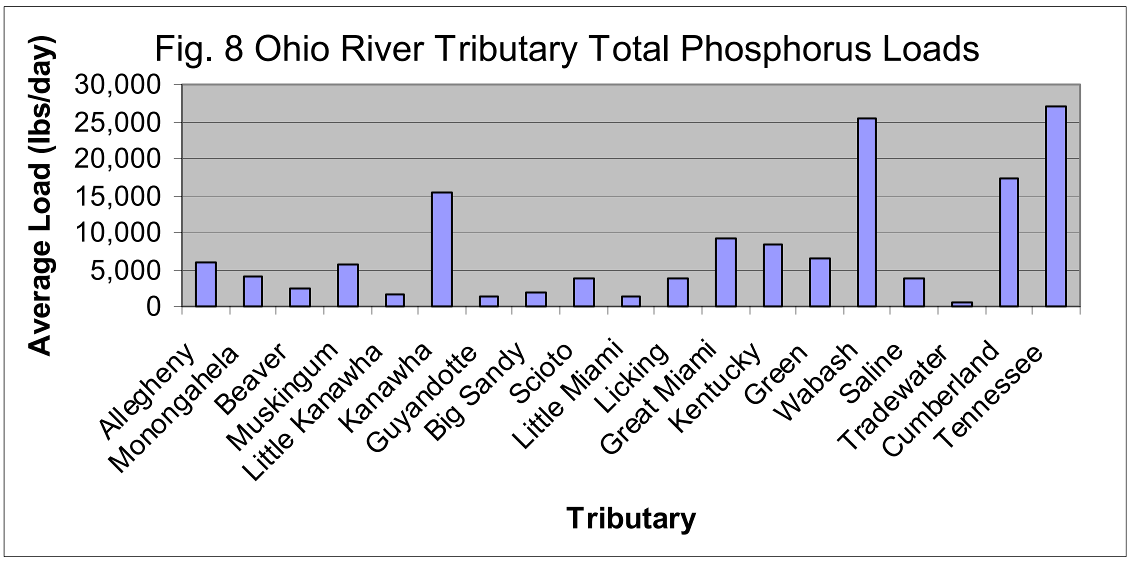


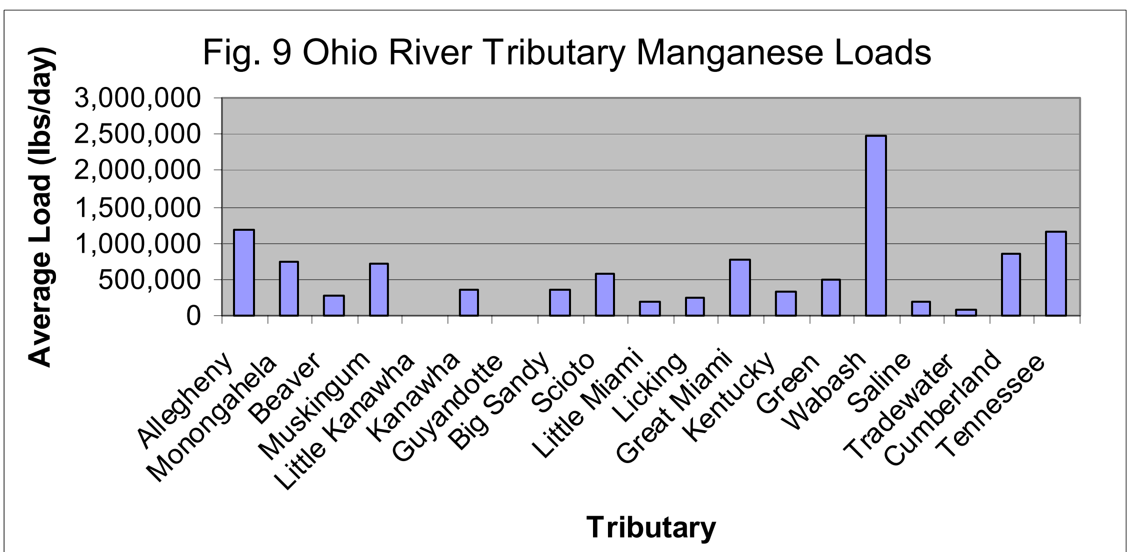




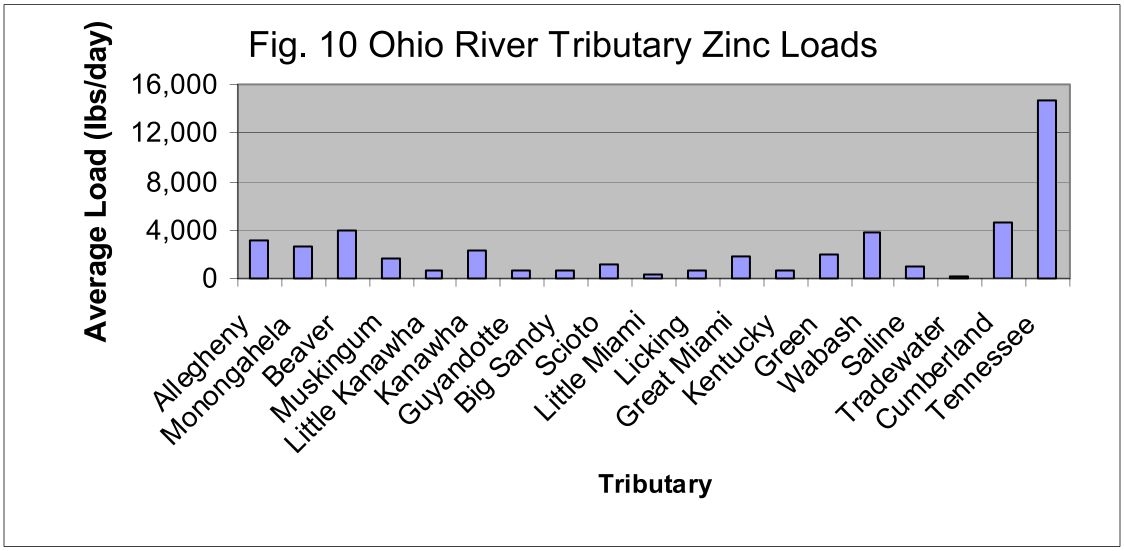
Appendix G continued
Ohio River Tributary Loads

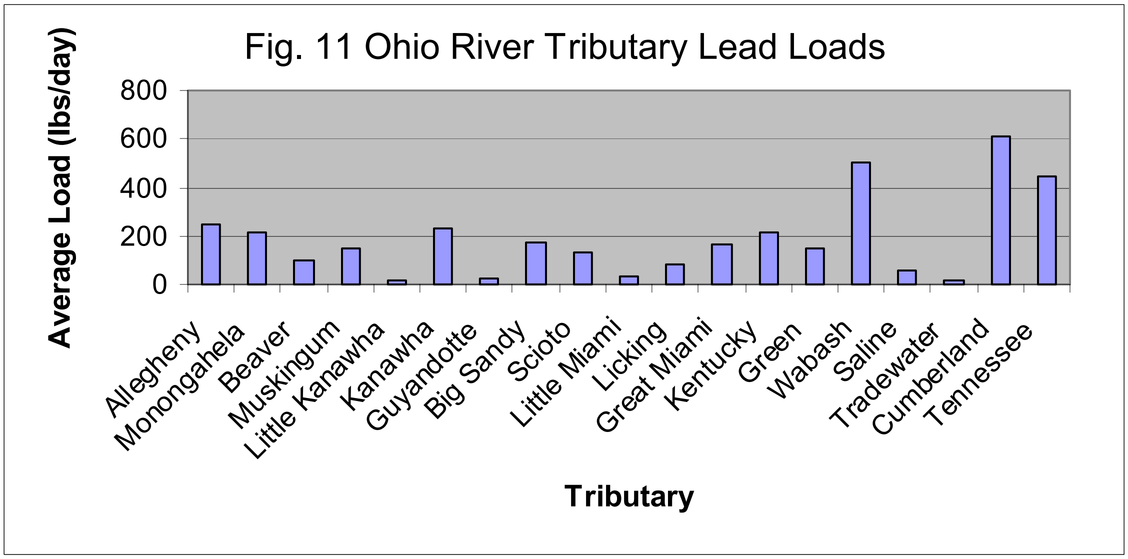






Appendix G continued
Ohio River Tributary Loads





Appendix H

Tributary Loads, Yields, and Ranking Tables

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Appendix H, Table 1
Ohio River Tributary Loads of Eleven Runoff Parameters

Tributary Name	Confluence Mile Point	Aluminum (lb/day)	Chloride (lb/day)	Iron (lb/day)	Lead (lb/day)	Manganese (lb/day)	Magnesium (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Sulfate (lb/day)	Suspended Solids (lb/day)	Zinc (lb/day)
Allegheny	0	84,503	1,722,431	150,383	250	32,253	1,170,809	74,973	5,839	4,774,574	4,499,765	3,117
Monongahela	0	82,684	1,252,387	138,208	211	14,094	741,124	56,931	4,148	5,594,345	2,279,365	2,687
Beaver	25.4	148,665	788,382	295,100	96	22,529	263,834	37,870	2,556	1,095,425	5,425,778	3,977
Muskingum	172.2	126,971	1,393,274	180,842	146	11,418	716,720	65,643	5,740	3,953,616	4,109,007	1,640
Little Kanawha	184.6	43,132	52,777	56,792	20	1,452		4,136	1,640	1,864,289	1,672,304	586
Kanawha	265.7	96,901	635,291	168,406	231	8,652	370,565	45,237	15,475	2,069,766	5,016,193	2,350
Guyandotte	305.2	75,993	118,703	73,304	23	6,083		8,821	1,463	850,796	1,578,406	674
Big Sandy	317.1	62,343	261,271	121,159	173	6,691	344,512	12,607	1,833	2,403,894	3,310,999	714
Scioto	356.5	79,737	955,634	115,828	134	2,965	565,522	109,589	3,864	1,859,034	3,152,110	1,183
Little Miami	464.1	30,918	407,474	31,446	32	981	197,875	33,626	1,478	380,567	966,729	270
Licking	470.2	64,024	452,509	74,480	78	3,710	260,395	33,276	3,763	861,888	2,070,870	621
Great Miami	491.1	89,536	1,576,049	113,806	166	3,340	770,216	155,322	9,177	1,522,735	4,483,218	1,856
Kentucky	545.8	104,365	210,489	235,266	212	8,018	330,167	29,731	8,490	2,870,337	5,620,518	711
Green	784.2	118,961	394,340	184,074	149	7,661	499,653	60,454	6,378	2,887,204	3,024,403	2,049
Wabash	848	428,814	3,396,979	542,836	501	24,313	2,463,998	451,816	25,271	6,756,889	15,002,366	3,773
Saline	867.3	49,447	202,582	76,653	56	6,131	183,361	13,703	3,707	1,103,962	3,112,730	984
Tradewater	873.5	13,783	43,112	22,253	18	2,714	84,516	2,835	556		499,424	101
Cumberland	920.4	126,085	3,003,470	122,388	607	11,747	839,487	82,560	17,367	3,850,251	3,405,575	4,690
Tennessee	934.5	215,549	10,382,375	192,575	449	16,529	1,158,772	139,040	27,029	4,776,096	4,311,591	14,610

Appendix H, Table 2
Ohio River Tributary Yields of Eleven Runoff Parameters

Tributary Name	Confluence Mile Point	Aluminum (lb/day/mi^2)	Chloride (lb/day/mi^2)	Iron (lb/day/mi^2)	Lead (lb/day/mi^2)	Manganese (lb/day/mi^2)	Magnesium (lb/day/mi^2)	Nitrite/Nitrate (lb/day/mi^2)	Total Phosphorus (lb/day/mi^2)	Sulfate (lb/day/mi^2)	Total Suspended Solids (lb/day/mi^2)	Zinc (lb/day/mi^2)
Allegheny	0	7.2	147.2	12.9	0.021	2.8	100.1	6.4	0.5	408.1	384.6	0.27
Monongahela	0	11.2	169.2	18.7	0.028	1.9	100.2	7.7	0.6	756.0	308.0	0.36
Beaver	25.4	47.5	251.9	94.3	0.031	7.2	84.3	12.1	0.8	350.0	1733.5	1.27
Muskingum	172.2	15.8	173.3	22.5	0.018	1.4	89.1	8.2	0.7	491.7	511.1	0.20
Little Kanawha	184.6	18.6	22.7	24.5	0.009	0.6	0.0	1.8	0.7	803.6	720.8	0.25
Kanawha	265.7	7.9	52.1	13.8	0.019	0.7	30.4	3.7	1.3	169.7	411.2	0.19
Guyandotte	305.2	45.5	71.1	43.9	0.014	3.6	0.0	5.3	0.9	509.5	945.2	0.40
Big Sandy	317.1	14.6	61.0	28.3	0.040	1.6	80.5	2.9	0.4	561.7	773.6	0.17
Scioto	356.5	12.2	146.8	17.8	0.021	0.5	86.9	16.8	0.6	285.6	484.2	0.18
Little Miami	464.1	18.5	244.0	18.8	0.019	0.6	118.5	20.1	0.9	227.9	578.9	0.16
Licking	470.2	17.4	123.3	20.3	0.021	1.0	71.0	9.1	1.0	234.8	564.3	0.17
Great Miami	491.1	16.6	291.9	21.1	0.031	0.6	142.6	28.8	1.7	282.0	830.2	0.34
Kentucky	545.8	15.0	30.2	33.8	0.030	1.2	47.4	4.3	1.2	411.8	806.4	0.10
Green	784.2	12.9	42.7	19.9	0.016	0.8	54.1	6.5	0.7	312.8	327.7	0.22
Wabash	848	13.0	102.6	16.4	0.015	0.7	74.4	13.7	0.8	204.1	453.2	0.11
Saline	867.3	42.3	173.1	65.5	0.048	5.2	156.7	11.7	3.2	943.6	2660.5	0.84
Tradewater	873.5	13.8	43.1	22.3	0.018	2.7	84.5	2.8	0.6	0.0	499.4	0.10
Cumberland	920.4	7.0	167.6	6.8	0.034	0.7	46.8	4.6	1.0	214.9	190.0	0.26
Tennessee	934.5	5.3	253.8	4.7	0.011	0.4	28.3	3.4	0.7	116.7	105.4	0.36

Appendix H, Table 3
Ohio River Tributary Ranking by Eleven Pollutants

Tributary Name	Drainage	Aluminum (lb/day)	Chloride (lb/day)	Iron (lb/day)	Lead (lb/day)	Manganese (lb/day)	Magnesium (lb/day)	Nitrite/Nitrate (lb/day)	Total Phosphorus (lb/day)	Sulfate (lb/day)	Suspended Solids (lb/day)	Zinc (lb/day)
Tennessee	40,910	2	1	4	3	4	3	3	1	3	7	1
Wabash	33,100	1	2	1	2	2	1	1	2	1	1	4
Cumberland	17,920	5	3	10	1	6	4	5	3	6	9	2
Kanawha	12,200	8	10	7	5	8	10	10	4	10	4	7
Allegheny	11,700	10	4	8	4	1	2	6	8	4	5	5
Green	9,230	6	13	5	10	10	9	8	7	7	13	8
Muskingum	8,040	4	6	6	11	7	7	7	9	5	8	10
Monongahela	7,400	11	7	9	7	5	6	9	10	2	14	6
Kentucky	6,970	7	15	3	6	9	12	14	6	8	2	14
Scioto	6,510	12	8	12	12	16	8	4	11	12	11	11
Great Miami	5,400	9	5	13	9	15	5	2	5	13	6	9
Big Sandy	4,280	15	14	11	8	11	11	16	15	9	10	13
Licking	3,670	14	11	15	14	14	14	13	12	16	15	16
Beaver	3,130	3	9	2	13	3	13	11	14	15	3	3
Little Kanawha	2,320	17	18	17	18	18	19	18	16	11	16	17
Guyandotte	1,670	13	17	16	17	13	18	17	18	17	17	15
Little Miami	1,670	18	12	18	16	19	15	12	17	18	18	18
Saline	1,170	16	16	14	15	12	16	15	13	14	12	12
Tradewater	1,000	19	19	19	19	17	17	19	19	19	19	19

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Appendix I

Tributary Yield Graphs by Parameter

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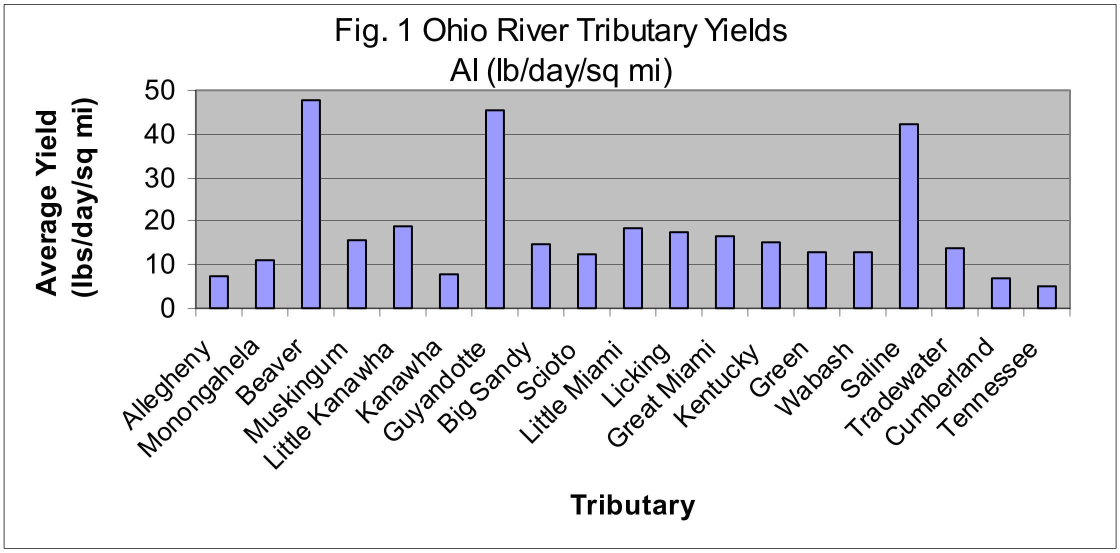
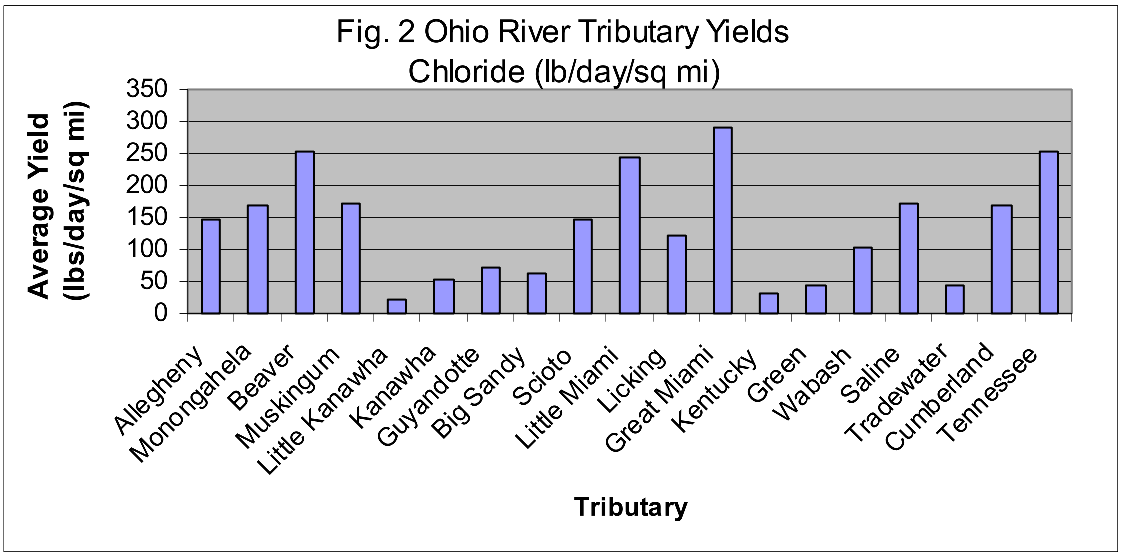
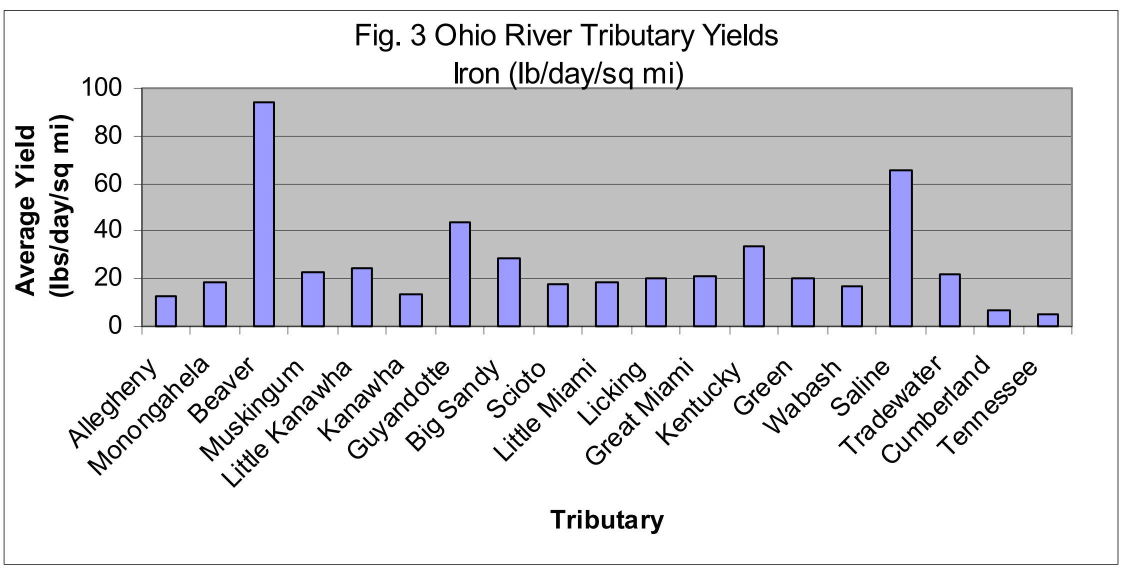
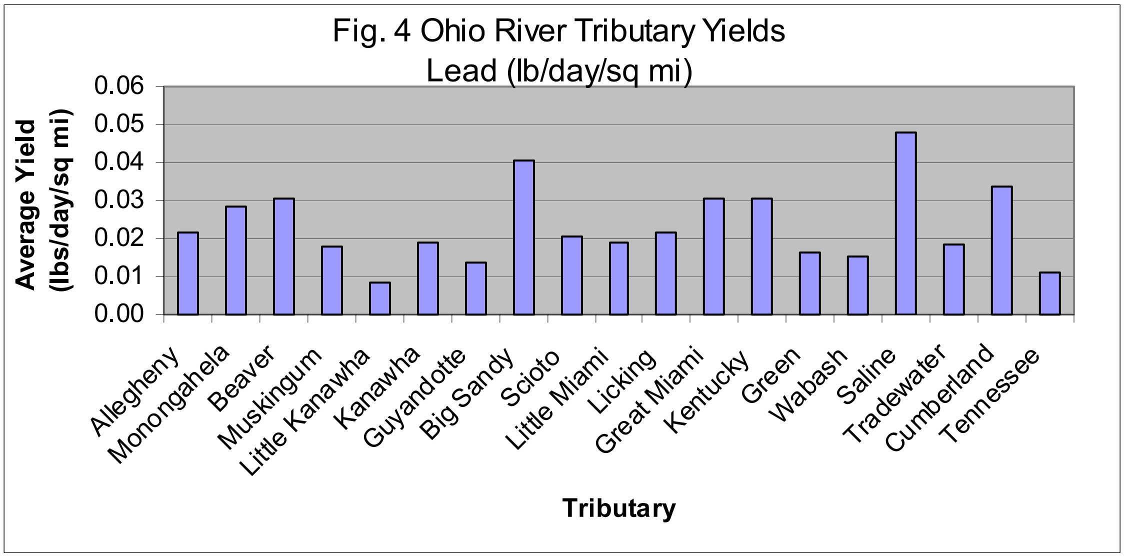
Appendix I
Ohio River Tributary Yields

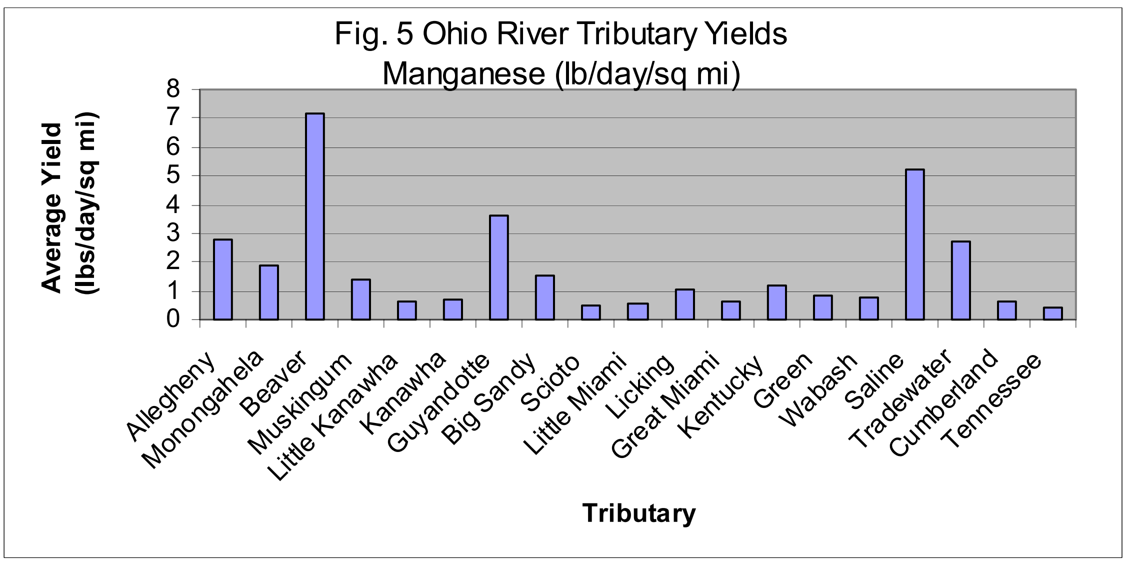


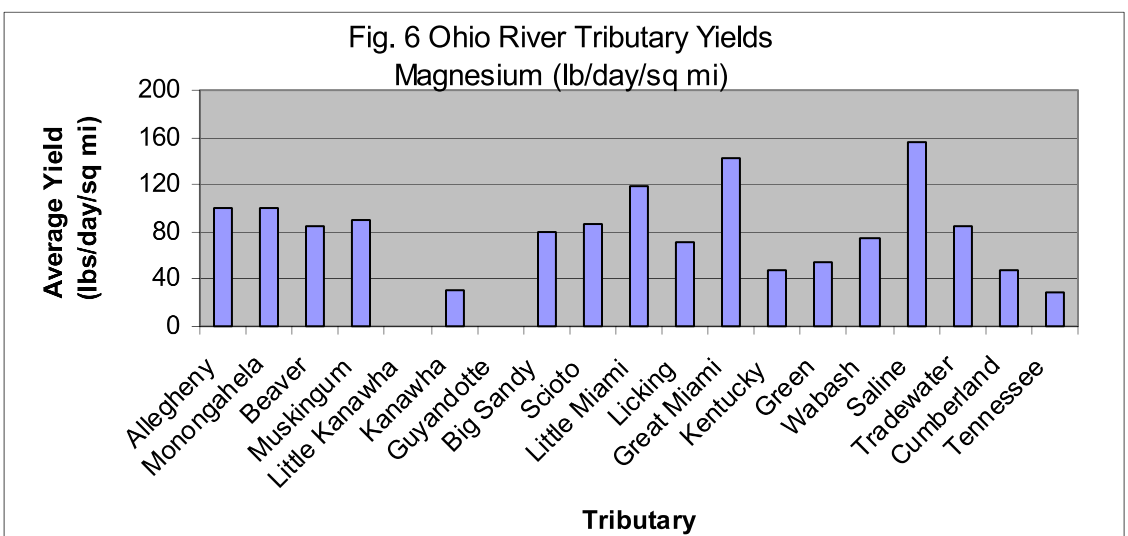




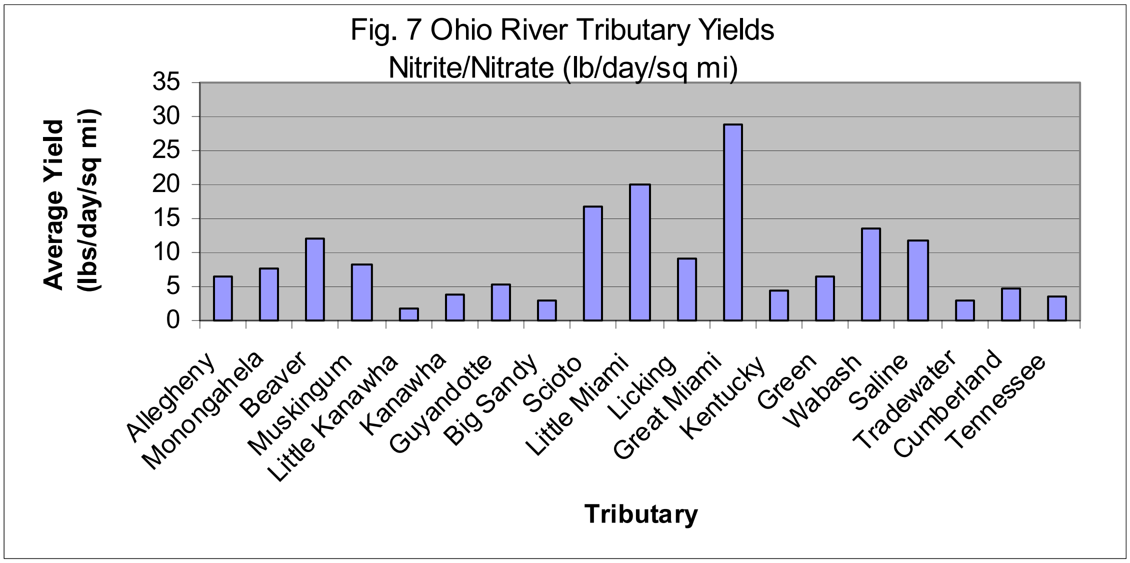
Appendix I continued
Ohio River Tributary Yields

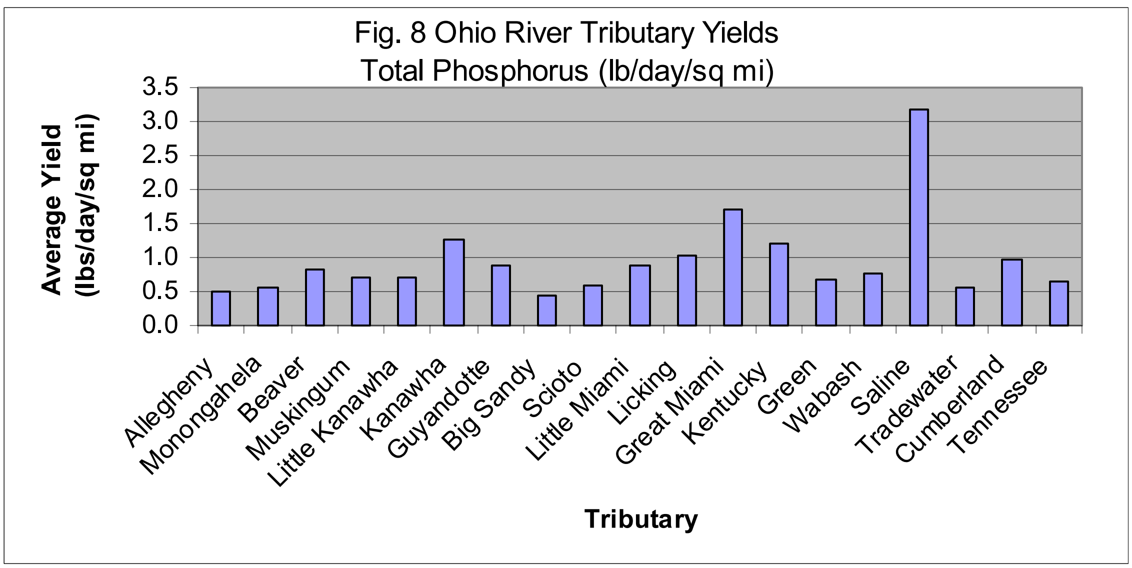


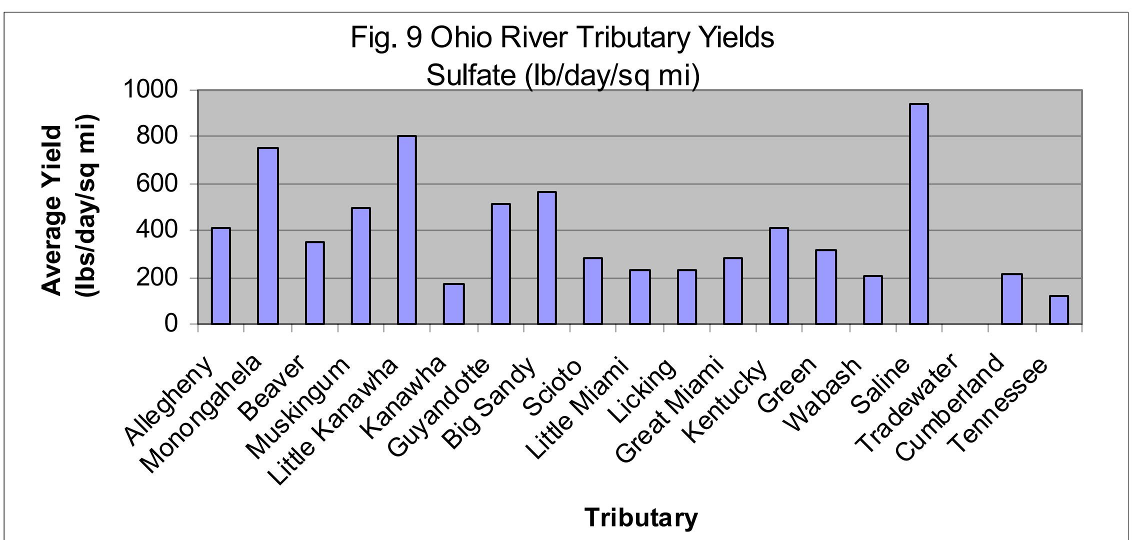




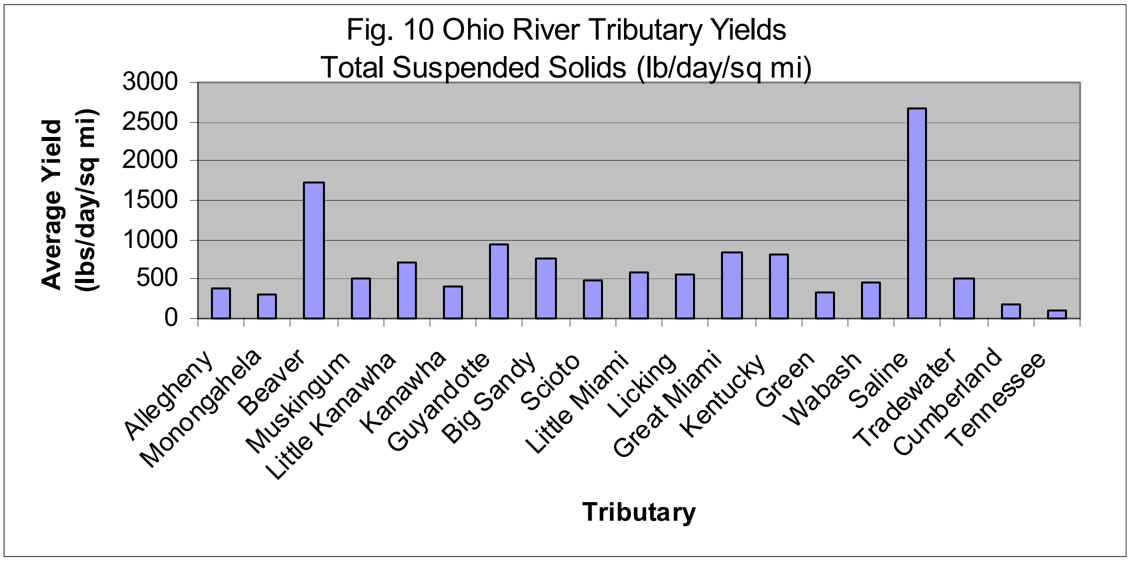
Appendix I continued
Ohio River Tributary Yields

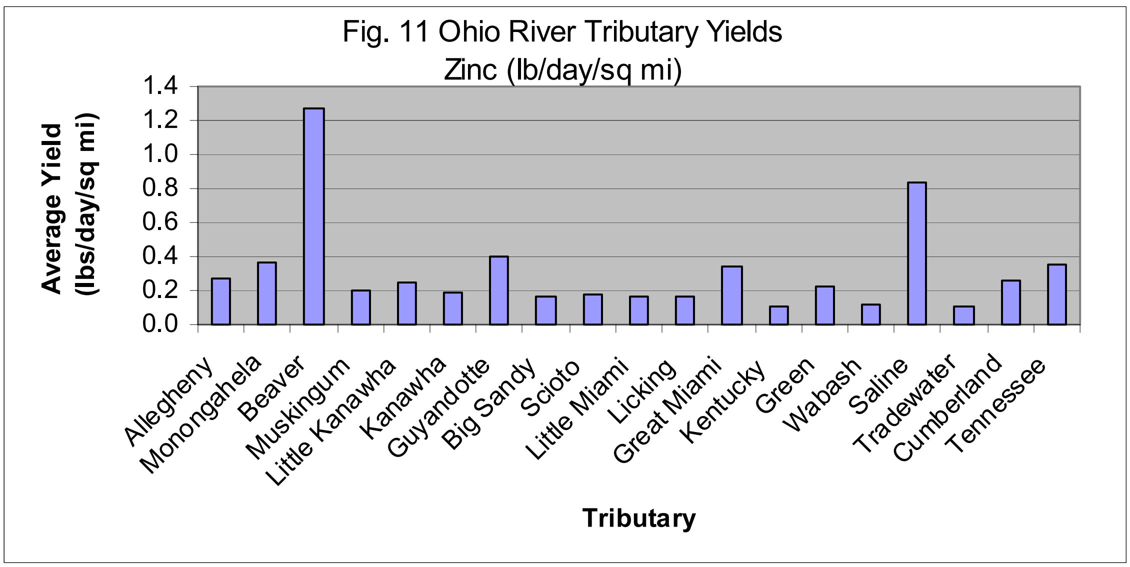






Appendix I continued
Ohio River Tributary Yields





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