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2.2 STREAMFLOW STUDY (WTS 2)

2.2.1 Study Objectives

The objective of the Streamflow Study is to describe flow conditions at selected gages in the Lewis River watershed. The study analyzed daily flows and peak flows to characterize the hydrology in 6 reaches:

- Lewis River upstream of Swift Reservoir
- Lewis River in the Swift bypass reach
- Lewis River between Merwin Dam and Eagle Island
- Speelyai Creek upstream of the diversion
- Speelyai Creek downstream of the diversion
- Swift No. 2 canal

The rate of flow change (ramping rate) in the Lewis River just downstream of Merwin Dam was also characterized.

2.2.2 Study Area

The study area for the Streamflow Study includes selected stream gages in the Lewis River watershed. These are listed below and shown on Figure 2.2-1.

- Lewis River near Trout Lake, Washington (U.S. Geological Survey [USGS] 14213200)
- Lewis River above Muddy River near Cougar, Washington (USGS 14216000)
- Muddy River below Clear Creek near Cougar, Washington (USGS 14216500)
- Lewis River near Cougar, Washington (USGS 14218000)
- Lewis River near Amboy, Washington (USGS 14219500)
- Speelyai Creek near Cougar, Washington (USGS 14219800)
- Lewis River at Ariel, Washington (USGS 14220500)
- Swift No. 2 canal (maintained by project operators)
- Speelyai Creek at hatchery intake (maintained by Speelyai Hatchery operators)

2.2.3 Methods

The Streamflow Study will include 3 tasks, as described below.

Task 1. Collect Available Data

Mean daily and annual peak flow data will be collected from selected stream gages in the basin (see table below). These data are available from the USGS Internet site, Cowlitz PUD, or the Speelyai Hatchery. Both PacifiCorp and Cowlitz PUD project spill and outflow records will be used for the Swift bypass reach. In addition, 15-minute or 1-hour (as available) flood flow hydrograph data will be requested from the USGS for chosen floods to analyze rates of flow change during historic and current conditions.

Stream gage data are available for Speelyai Creek upstream of the point where it is diverted into Yale Lake. Speelyai hatchery records and observations of the stream channel will be used to determine current conditions in the reach downstream of the diversion.

Monthly precipitation records at the climatic station in the watershed with the longest record will also be collected for comparison with annual streamflow records. The weather station at Merwin Dam has precipatation data back to 1948; weather stations in Portland and Vancouver have records back to the late 1800s.

			Period of Record	
USGS Gage Number	**Station Name**	**Drainage Area (sq. mi.)**	**Peak Flows**	**Daily Flows**
1421320	Lewis River near Trout Lake, Washington	127	1958-1972	1958-1971
14216000	Lewis River above Muddy River near Cougar, Washington	227	1927-1934; 1954-1977	1927-1934; 1954-1970
14216500	Muddy River below Clear Creek near Cougar, Washington	135	1927-34; 1954-73; 1983-present	1927-34; 1954-73; 1983-present
14218000	Lewis River near Cougar, Washington	481	1917-1977	1924-1958
14219500	Lewis River near Amboy, Washington	665	1911-1930	1910-1930
14219800	Speelyai Creek near Cougar, Washington	12.6	1959-present	1959-present
14220500	Lewis River at Ariel, Washington	731	1923-present	1923-present
Other Flow Data:				
Cowlitz PUD	Swift No. 2 Power Canal	481	n/a	1958-present
Speelyai Hatchery	Speelyai Creek at Hatchery intake	15	n/a	weekly flows

Task 2. Analyze Data and Extend Record

Streamflow data from the selected stream gages will be analyzed using standard computer programs (HECEXE) and spreadsheets. The following steps will be undertaken:

- Develop monthly flow duration curves (one graph for each month of the year showing percent of time flow exceeded on x-axis and flow on y-axis);

- Develop daily exceedance curves (graph with month of year on x-axis, flow on y-axis, and curves for 10%, 25%, 50%, 75%, and 90% exceedance values for each month based on an analysis of daily flows);

- Determine baseflows (annual 1-day, 3-day, and 10-day minimum flow magnitudes and timing);

- Develop flood frequency curves (graph of high flow magnitude versus recurrence interval based on U.S. Water Resources Council method);

- Analyze flood timing (graph annual peak flow magnitude and time of year for period of record);

- Document project spill events (prepare table of spill magnitude and date at each project);

- Display historic and current rates of flow change (during flood and ramping events) based on analysis of 15-minute flow record of selected floods. Selection of flood events for analysis will in some part depend upon availability of 15-minute data from USGS; and

- Compare total annual water year runoff (total discharge from October 1 to September 30) for each year of record at Lewis River near Ariel/Lewis River near Amboy gages (to provide record from 1910 to present) with total annual precipitation for same period (October through September, 1910 to present). Examine and describe trends in runoff and precipitation, including wet/dry/normal years and any observed cyclic nature of runoff/precipitation patterns.

Some data sets may need to be extended to complete the analysis. For example, the peak flow record for the Lewis River at the Ariel gage (downstream of Merwin Dam) extends from 1923 to present. This means that the record contains only 8 peak flows prior to construction of Lake Merwin. This is not long enough to provide an adequate record for flood flow analysis following the guidelines of Bulletin 17B (U.S. Water Resources Council 1981), so the data will be extended back to 1911 (the longest period of record available) using information from the Lewis River near the Amboy gage and correlation methods such as those described in Maidment (1993) and Linsley et al. (1982).

Task 3. Prepare Plots and Tables Comparing Historic and Current Conditions, and Evaluate Differences

Plots and/or tables will be prepared for all analyses displaying the differences between historic and with-project conditions. For daily flows, the past 10 years of streamflow data will also be analyzed to display the effect of current project operations.

These plots and data will be used to satisfy FERC and NEPA requirements and as part of the Aquatic Resources, Terrestrial Resources, Stream Channel Morphology and Aquatic Habitat, and Flood Management studies. In addition to the standard monthly flow duration curves and flood frequency graphs, plots will be used to help display the magnitude, frequency, and timing of flows in project-affected reaches. A summary of this study is presented in the table below.

Topic	Description
Study Type	Descriptive
Study Area	Selected stream gages in the Lewis River Watershed
Schedule	October 1999 – August 2000
Budget	$20,000
Requested by	Lewis River Watershed Studies Aquatic Working Group
Key Personnel	Kathy Dubé, Yunbing Shi (HARZA)

2.2.4 Key Questions

This report helps address the following "key" watershed questions identified during the Lewis River Cooperative Watershed Studies meetings:

- What are the historical and current hydrological patterns?
- How do the hydroelectric projects affect baseflows in the Lewis River downstream of the dams?
- How do the hydroelectric projects affect the timing, frequency, magnitude, and/or duration of high flows in the Lewis River downstream of the dams?

The following key question is partially addressed in this report based on existing gage information, and more fully addressed in the Speelyai Creek Connectivity and Hatchery Protection Study (AQU 9) and the Swift Bypass Synthesis Report (WTS 4):

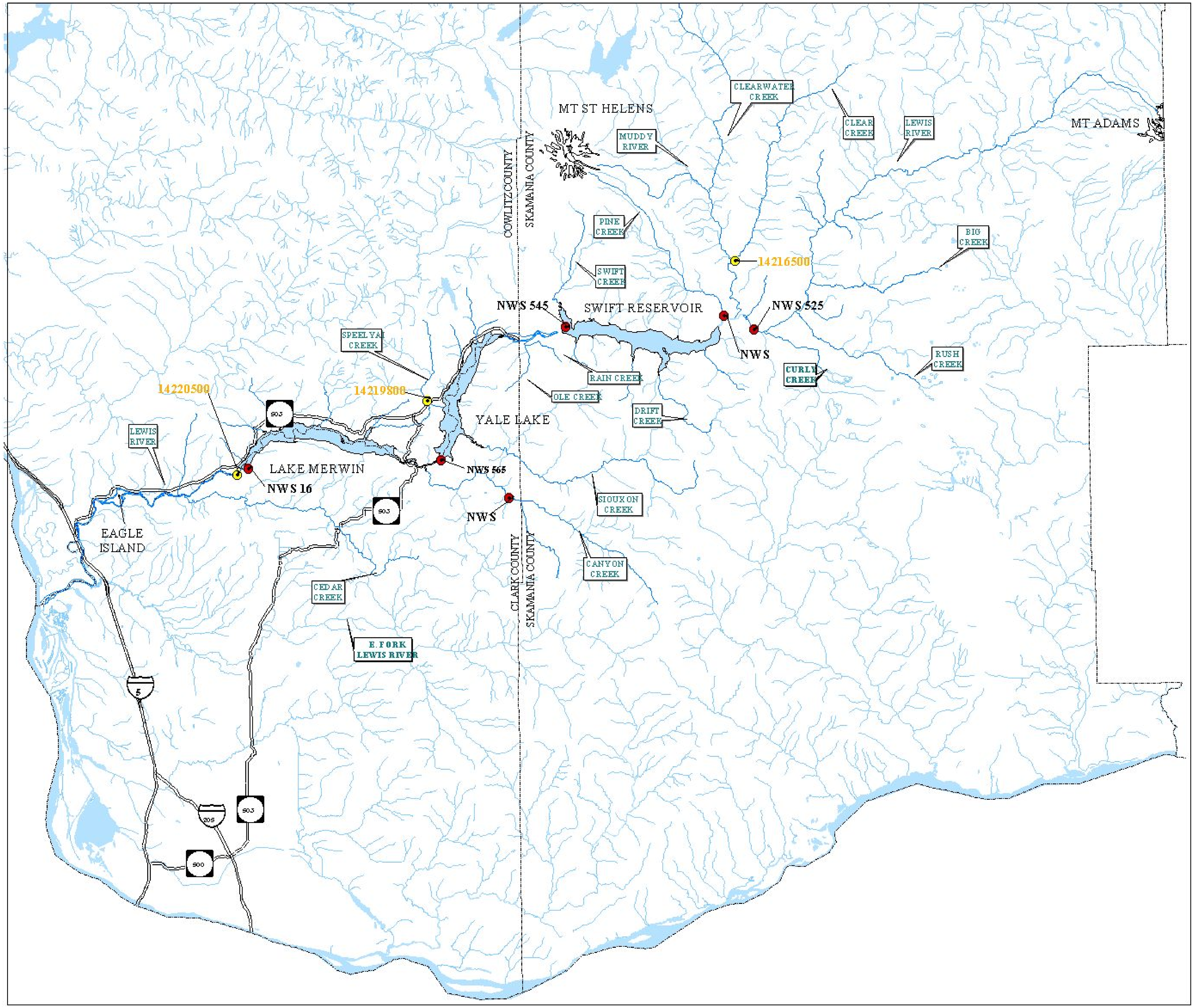
- How are instream flows in Speelyai Creek and the Swift bypass reach affected by diversions?

2.2.5 Results

Flow information was analyzed for 7 USGS gages and 1 other streamflow measurement site in the basin (Table 2.2-1; Figure 2.2-1). At each site, streamflow data were separated into pre-project and with-project periods, if appropriate for that site. The Study Plan Document stated that flows in Speelyai Creek at the hatchery intake would be analyzed. However, based on recent discussions with Speelyai Hatchery personnel, they do not actually measure flows in the stream or at the intake, so no data were available to analyze.

Lewis River
Hydroelectric Projects

Figure 2.2-1
USGS Gage Stations



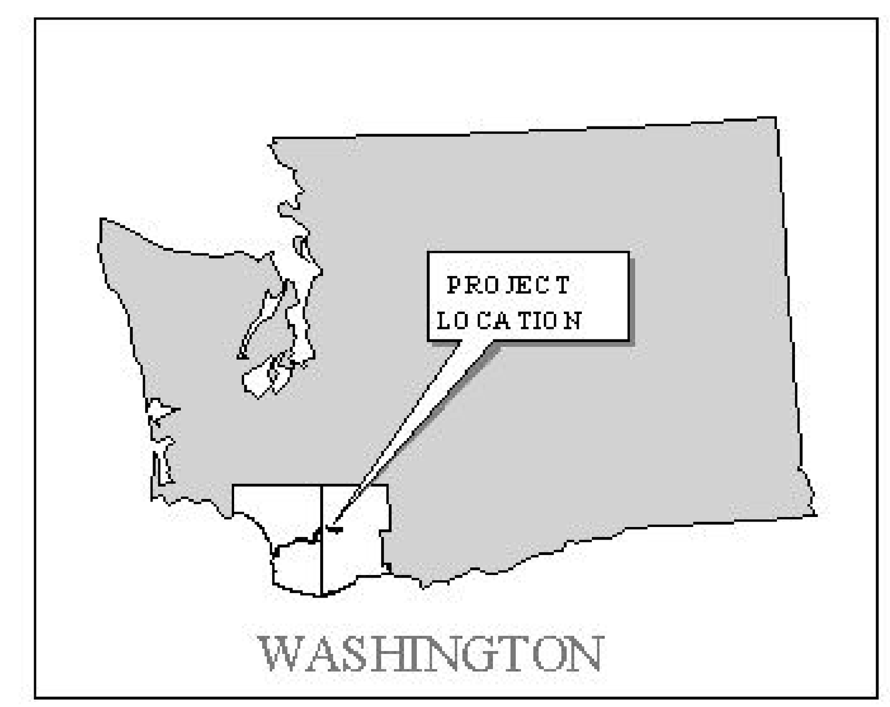
USGS Gage Locations

NWS National Weather Service Transmitters

Major Tributary

Major Road

County



5 0 5 10

Miles

PACIFICORP

Geographic Information System

b:/proj_wrk/mapapr/lewisriver/usgsgage-nt.apr

March 22, 2002

Table 2.2-1. Selected stream gages on the Lewis River.

USGS Gage Number	Station Name	Drainage Area (sq. mi.)	Period of Record		Analysis Period	
			Peak Flows	Daily Flows	Pre-Project	With Project
14213200	Lewis River near Trout Lake, WA	127	1958-1972	1958-1971	--	1958-1972
14216000	Lewis River above Muddy River near Cougar, WA	227	1927-1934; 1954-1977	1927-1934; 1954-1970	1927-1934; 1954-1957	1958-1970
14216500	Muddy River below Clear Creek near Cougar, WA	135	1927-34; 1954-73; 1983-present	1927-34; 1954-73; 1983-present	1927-1934; 1954-1957	1958-1973; 1983-1998
14218000	Lewis River near Cougar, WA	481	1917-1977	1924-1958 published; 1959-1975 unpublished	1917-1957	1958-1975
14219500	Lewis River near Amboy, WA	665	1911-1930	1910-1930	1910-1930	--
14219800	Speelyai Creek near Cougar, WA	12.6	1959-present	1959-present	--	1959-1998
14220500	Lewis River at Ariel, WA	731	1924-present	1924-present	1924-1930	1932-1998

Other Flow Data						
Cowlitz PUD	Swift Canal	481	n/a	1958-present	n/a	1958-1999
Speelyai Hatchery	Speelyai Creek at Hatchery intake	15	not available	not available	--	--

2.2.5.1 Monthly Flow Duration Curves

Monthly flow duration curves were developed for each gage site. These graphs display flow versus percent of time that flow is exceeded during a particular month. An example for January at the Lewis River near Trout Lake gage is shown in Figure 2.2-2. Graphs for all gages and all months are included in WTS 2 Appendix 1.

2.2.5.2 Daily Exceedence Curves

Daily exceedence curves were prepared for all stream gage stations with available flow data (Figures 2.2-3 through 2.2-10). These graphs were prepared from mean daily flow values, grouped by month, and analyzed to produce 10 percent, 25 percent, 50 percent, 75 percent, and 90 percent exceedence values. This is the same analysis performed for the monthly flow duration curves discussed in the previous section, but data are displayed in a different manner. The 5 exceedence curves are all plotted on a single graph of flow vs. month. These plots show how flow varies through the year at each gage site for median as well as extreme values. Two plots are shown for each station, corresponding to the pre-project period (prior to 1958 for all gages upstream from Merwin Dam; prior to 1931 for the gage downstream from Merwin Dam) and the project period. This was done even for stream reaches not affected by project operations to provide consistent analysis periods.

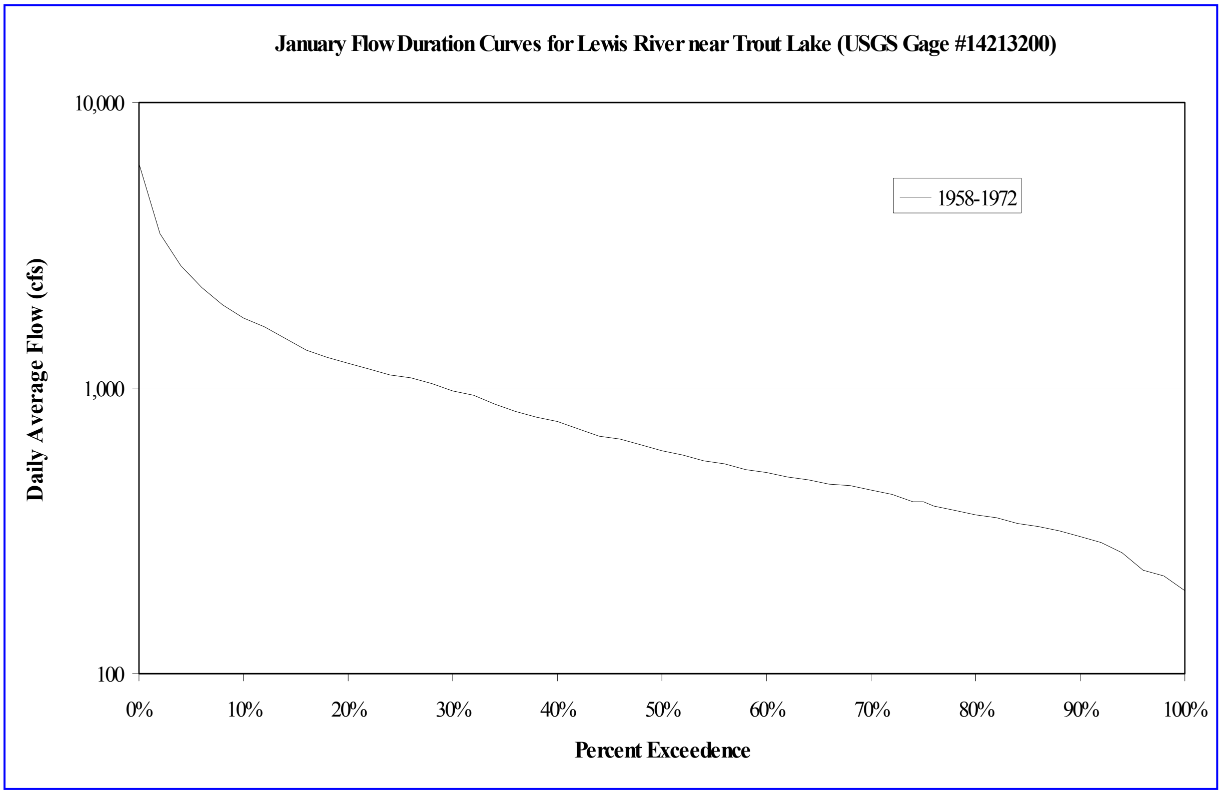
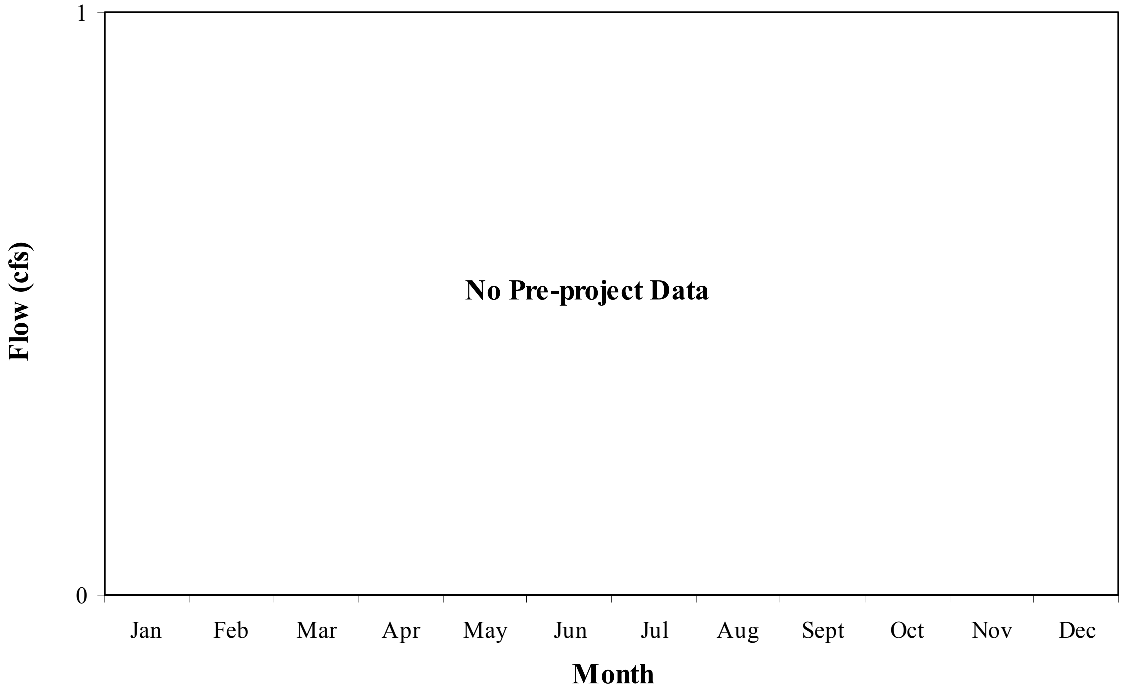


Figure 2.2-2. January flow duration curve for the Lewis River near Trout Lake gage.

2.2.5.3 Baseflows

Baseflows were computed as the lowest 1-day (daily mean), 3-day running mean, and 10-day running mean from the mean daily flow data for each year. The daily mean values correspond to the lowest daily flow recorded at that gage in a given calendar year. The 3-day running mean values and 10-day running mean values correspond to the lowest 3-day and 10-day running mean values in a given year, so they are slightly higher than the daily mean values. Figures 2.2-11 through 2.2-17 show the baseflow values by year for the gage sites. No analysis was performed for the Swift canal since baseflows would be 0 each year when the project was shut down for maintenance or emergency situations or stopped generation for a few days.



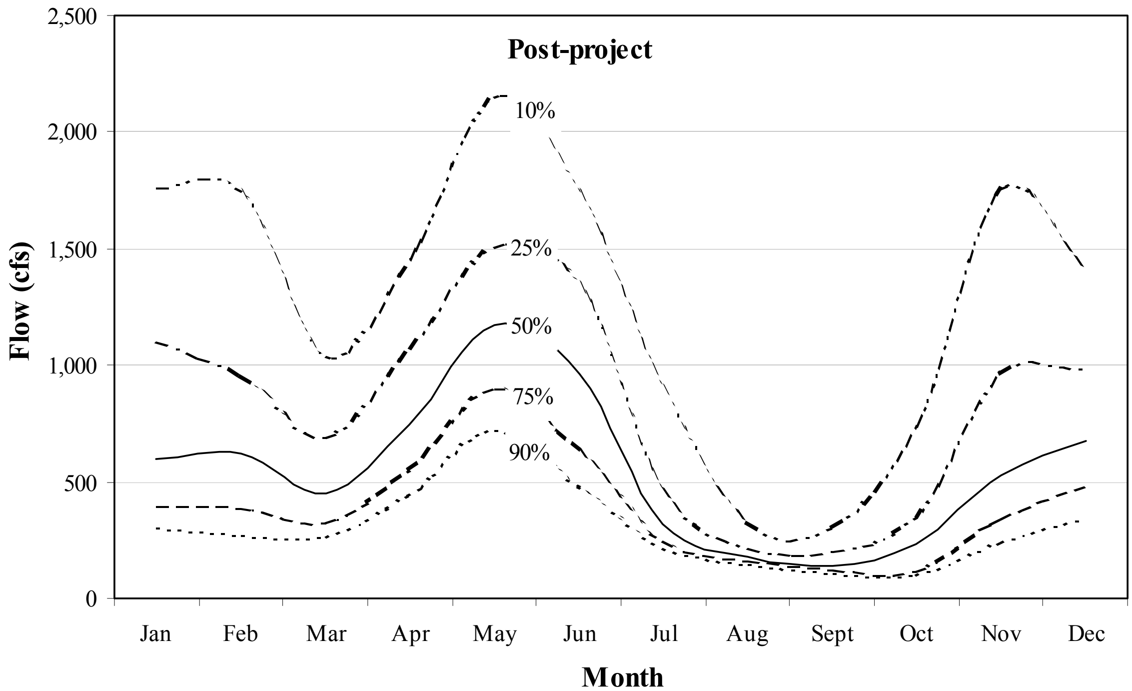


Figure 2.2-3. Daily flow exceedence curves for Lewis River near Trout Lake
(USGS Gage 14213200, post-project data 10/1/58 to 12/7/71).

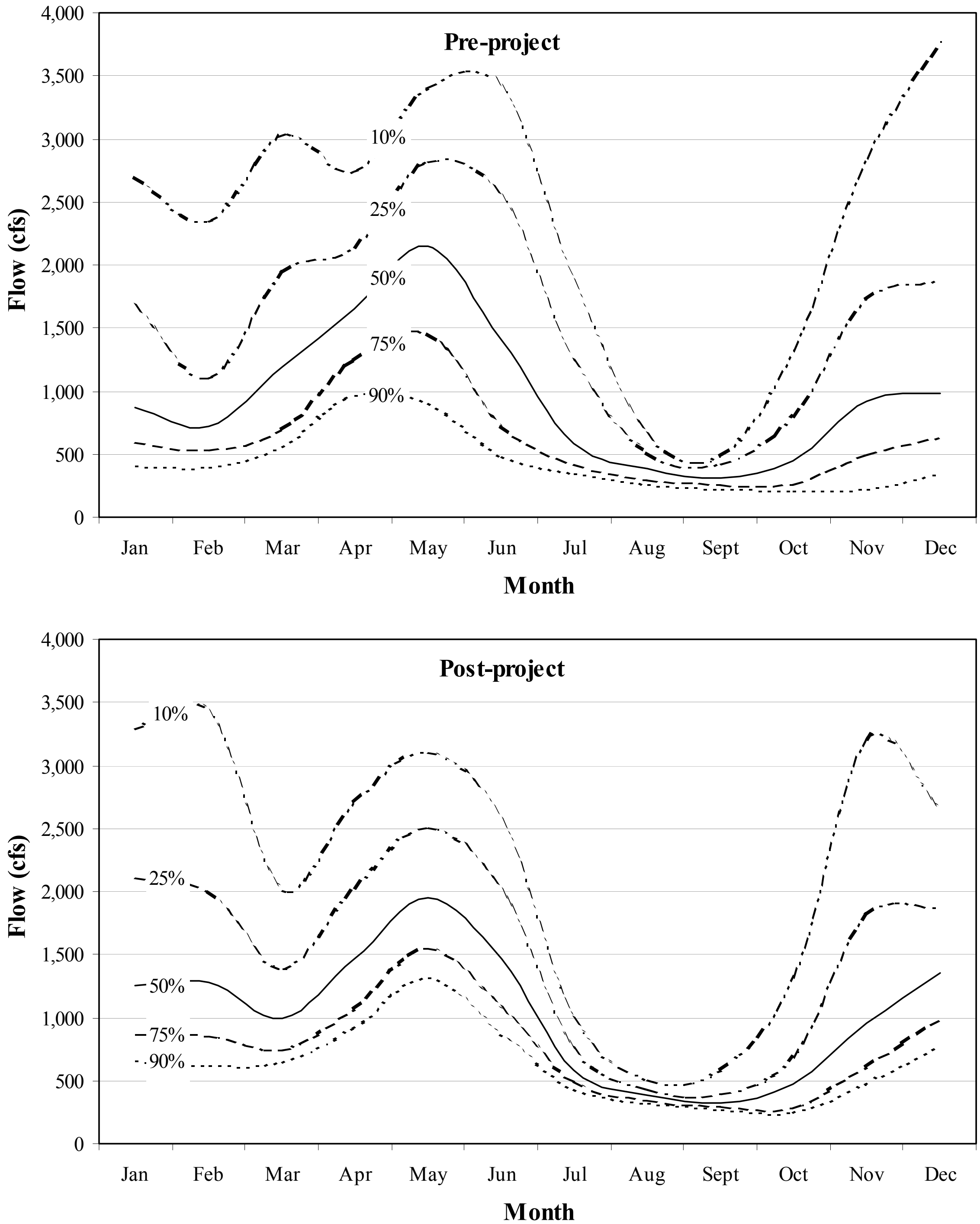


Figure 2.2-4. Daily flow exceedence curves for Lewis River above Muddy River near Cougar (USGS Gage 14216000: pre-project data 9/1/27 to 9/30/34 and 10/1/54 to 9/31/57; post-project 10/1/58 to 9/30/70).

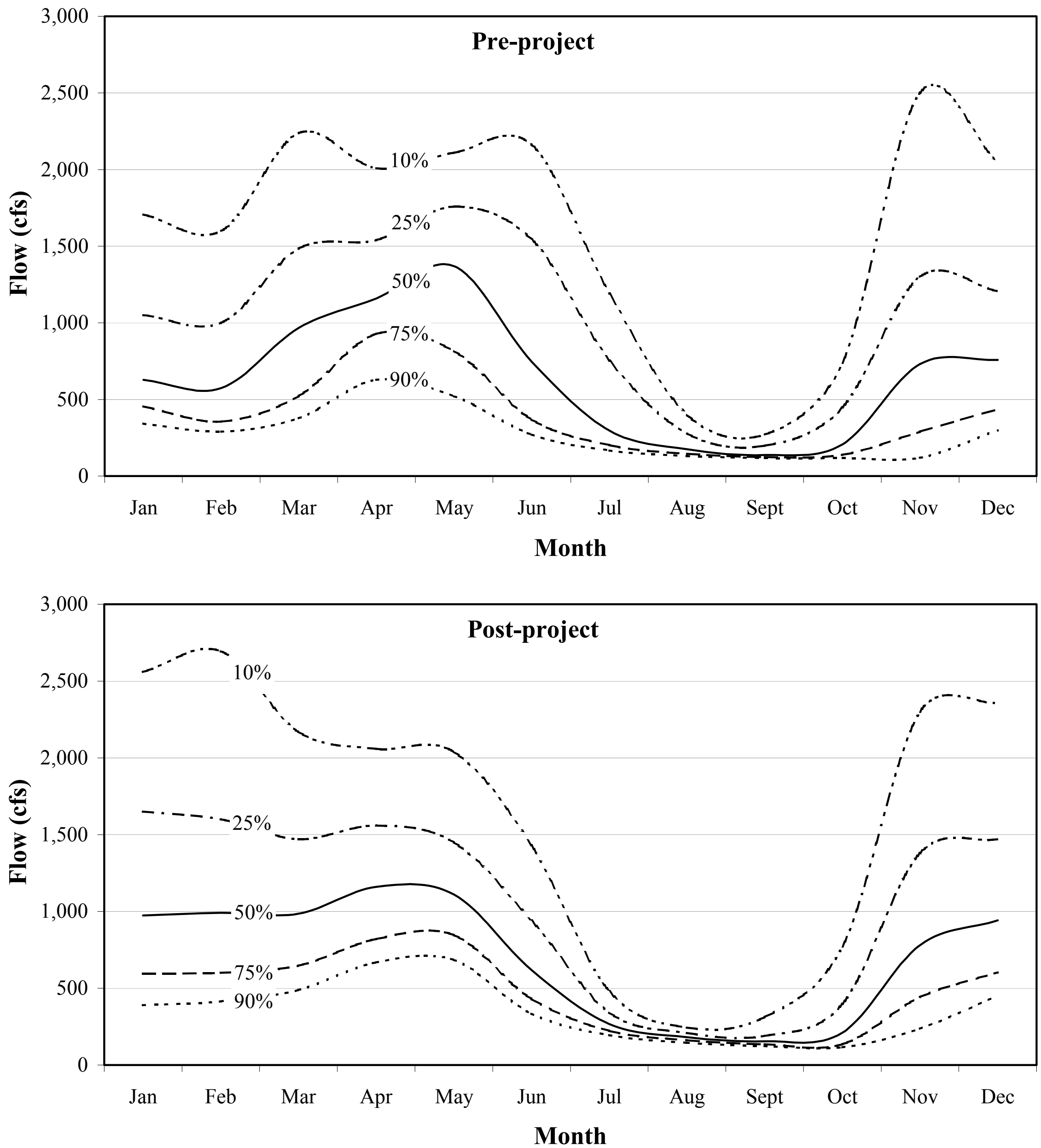


Figure 2.2-5. Daily flow exceedence curves for Muddy River below Clear Creek near Cougar (USGS Gage 1426500: pre-project 10/1/27 to 9/30/34 and 10/1/54 to 9/31/57; post-project 10/1/58 to 12/31/73 and 10/1/83 to 9/30/98).

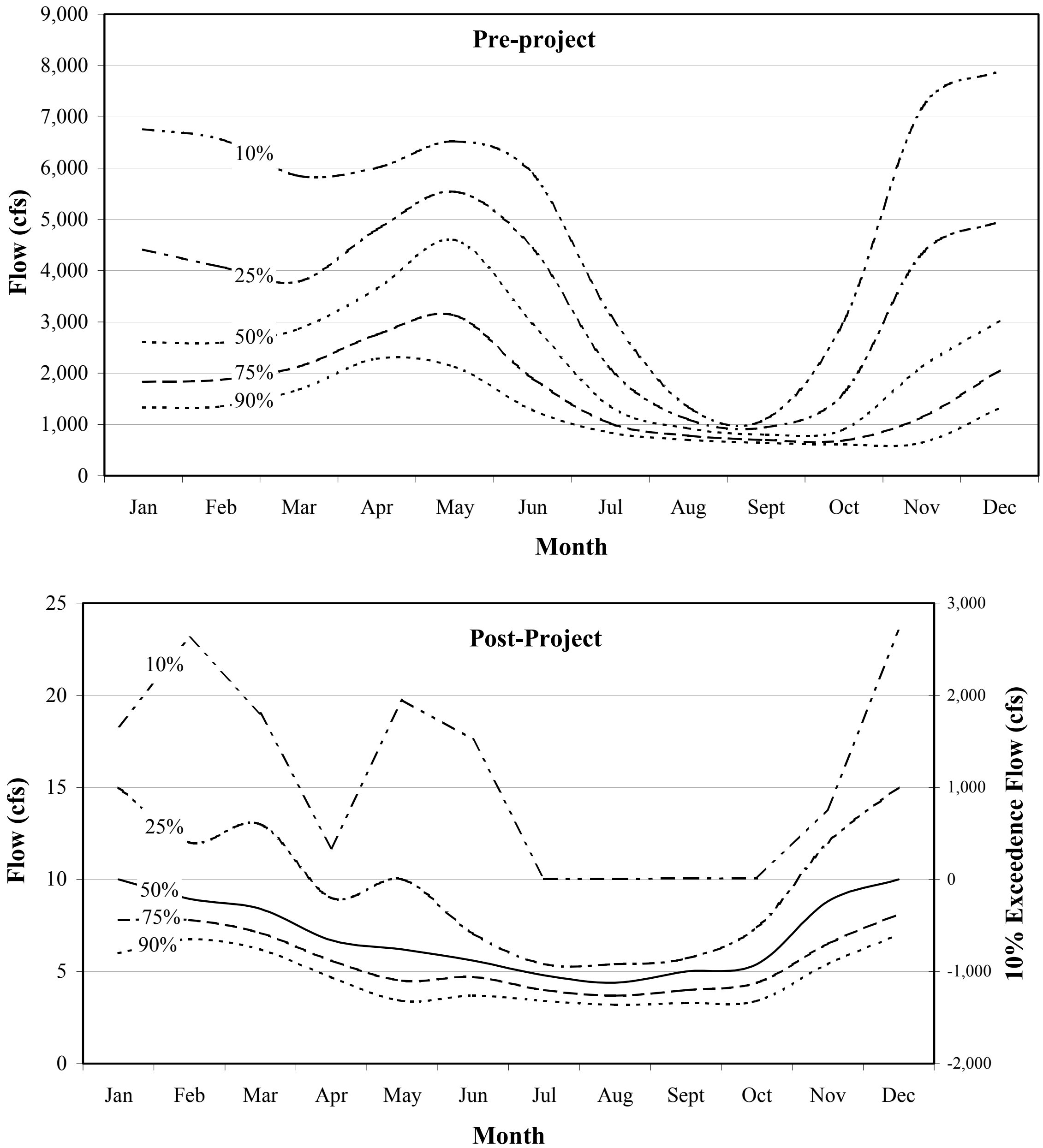
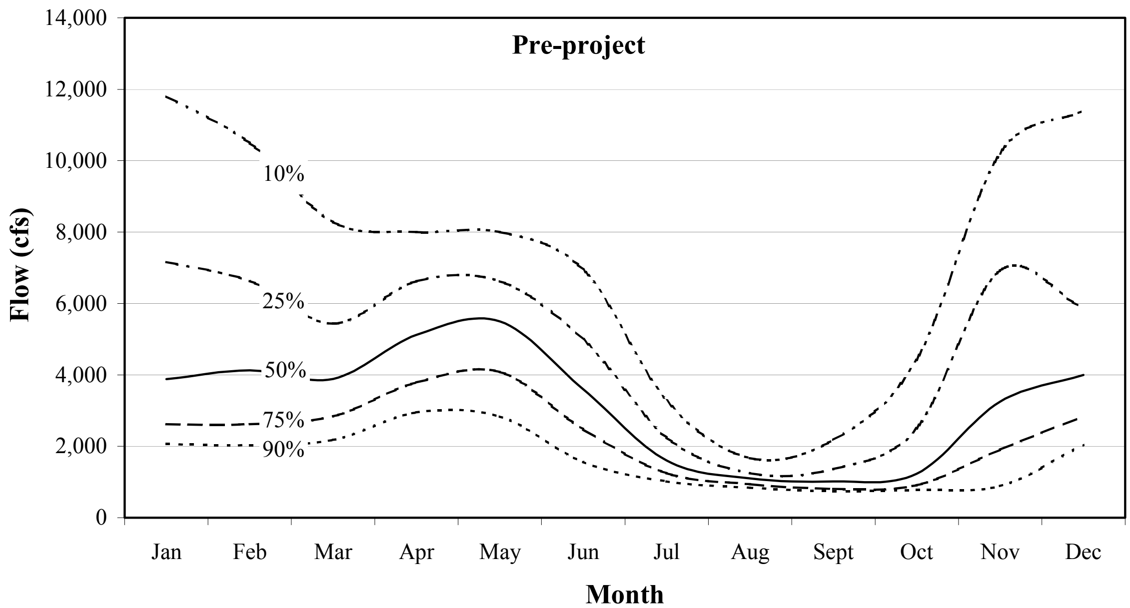


Figure 2.2-6. Daily flow exceedence curve for Lewis River near Cougar (Swift No. 2 bypass reach, USGS Gage 14218000: pre-project 7/1/24 to 9/31/57; post-project 10/1/58 to 12/31/77). Note: On the post-project graph, the 10% exceedence flow curve is plotted on different scale.



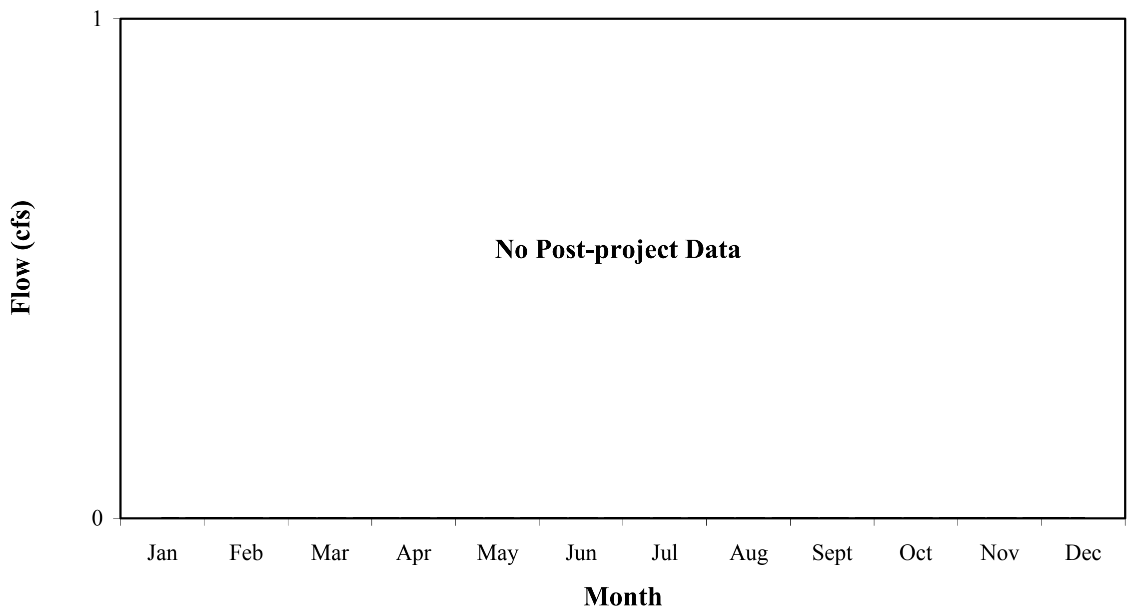
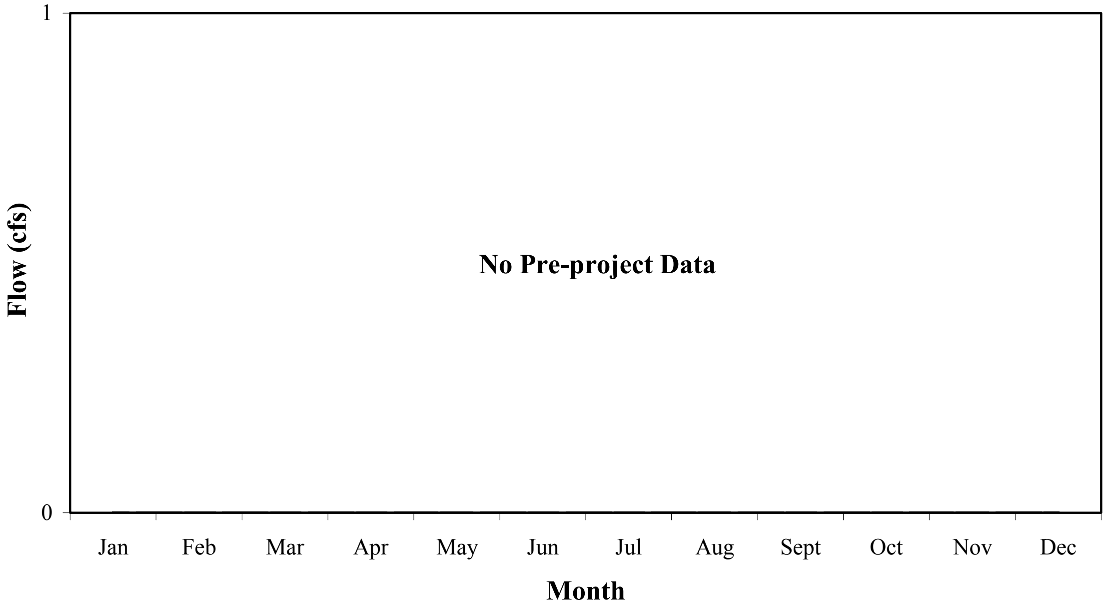


Figure 2.2-7. Daily flow exceedence curve for Lewis River above Merwin Dam near Amboy (USGS Gage 14219500: pre-project from 10/1/10 to 4/30/31).



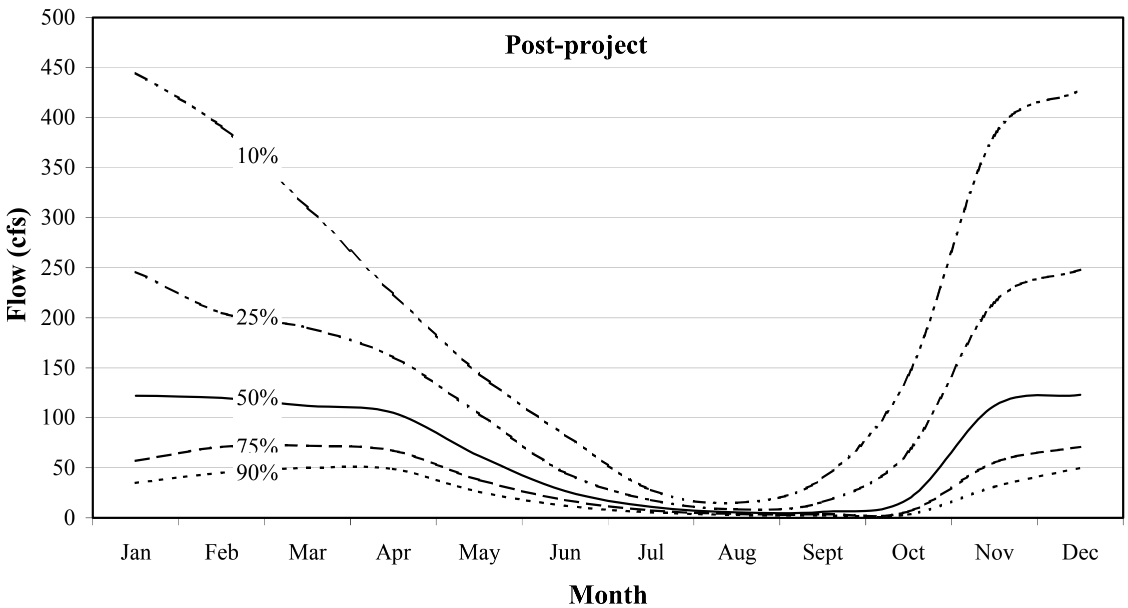


Figure 2.2-8. Daily flow exceedence curve for Speelyai Creek upstream of diversion near Cougar (USGS Gage 14219800, from 6/1/59 to 9/30/98).

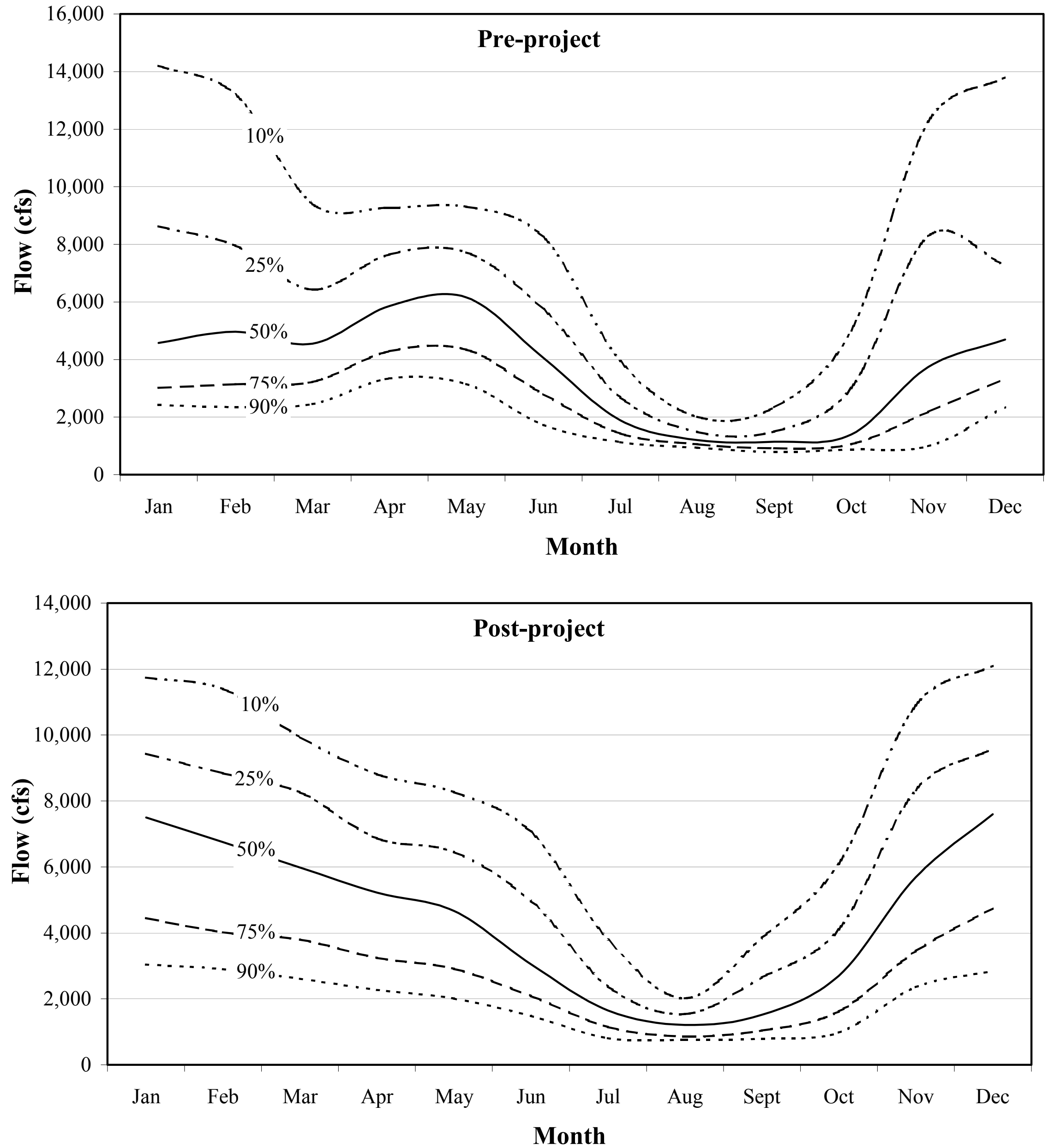


Figure 2.2-9. Daily flow exceedence curve for Lewis River at Ariel (below Merwin Dam, USGS Gage 14220500). Pre-project is from 1909 through 1930 and post-project is from 1932 through 1998. Daily flow from 1910 through 1923 was estimated based on Lewis River flow at USGS Gage 14219500 near Amboy.

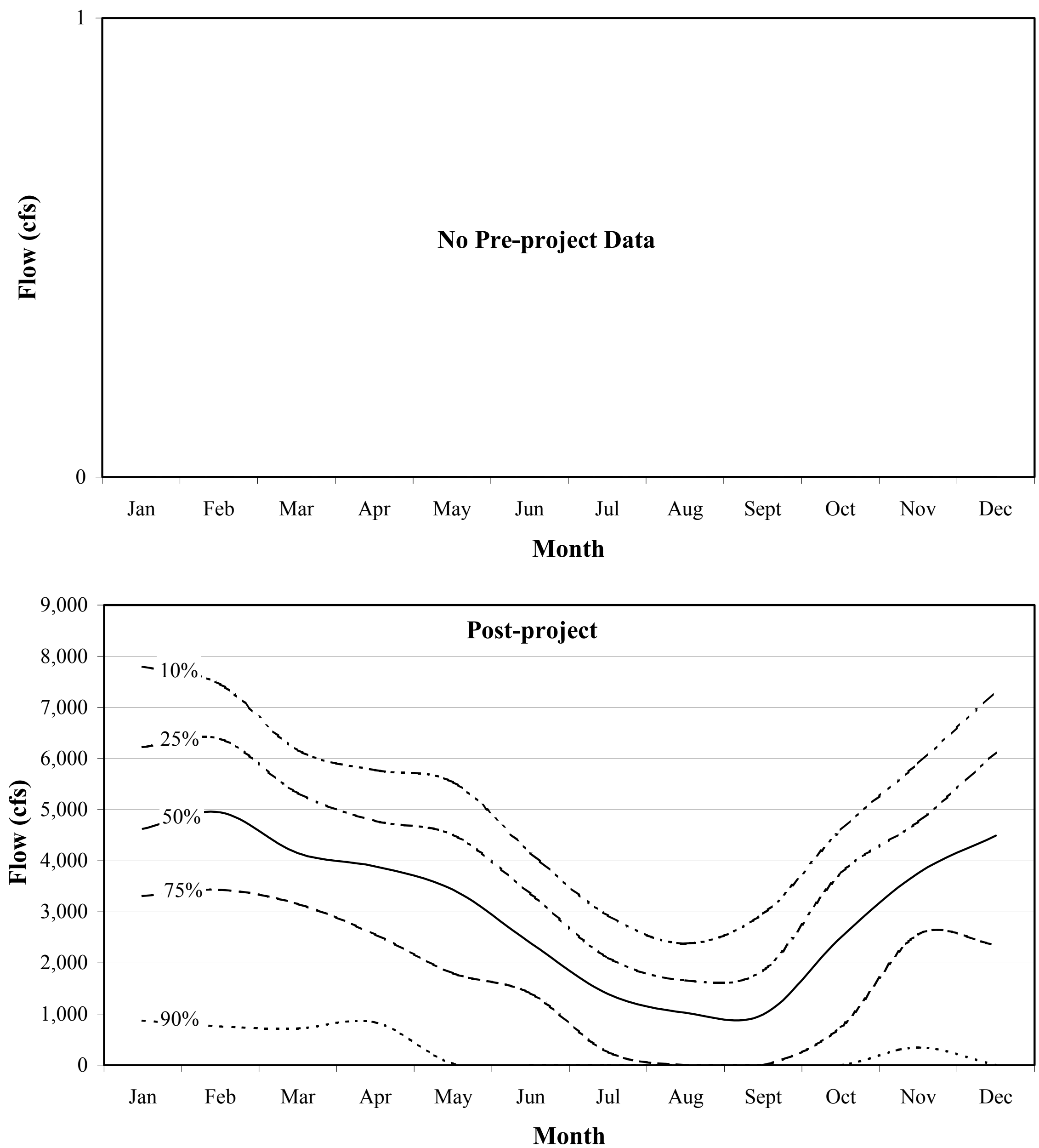


Figure 2.2-10. Daily flow exceedence curves for Swift No. 2 canal (discharge from Swift No. 1 turbines, from 1/1/89 to 12/19/00).

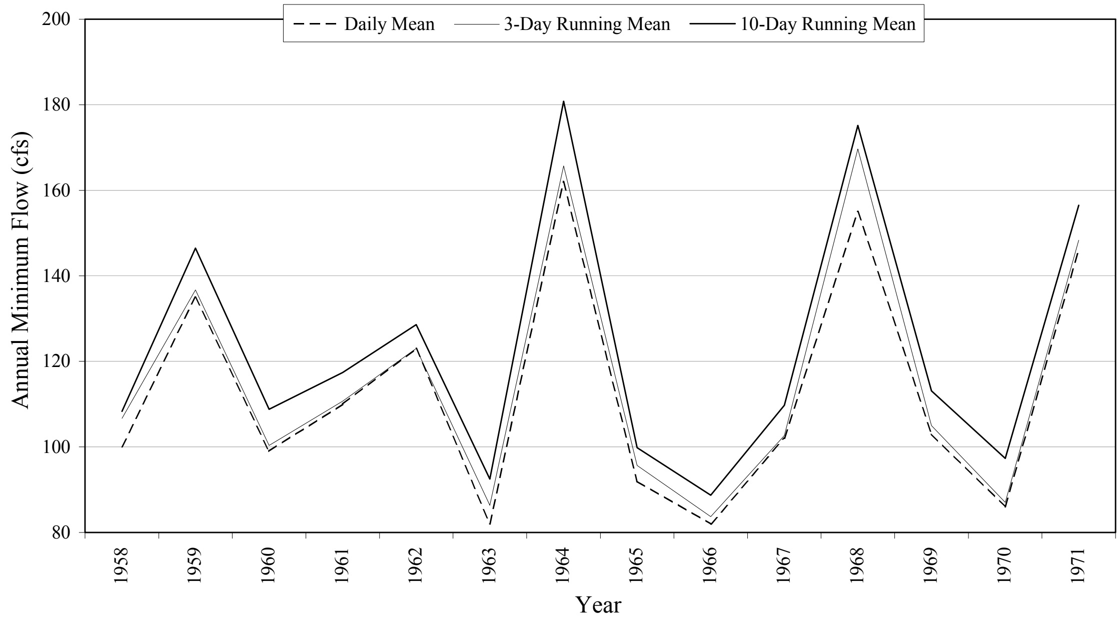


Figure 2.2-11. Base flow for Lewis River near Trout Lake (RM 73.3, USGS Gage 14213200).

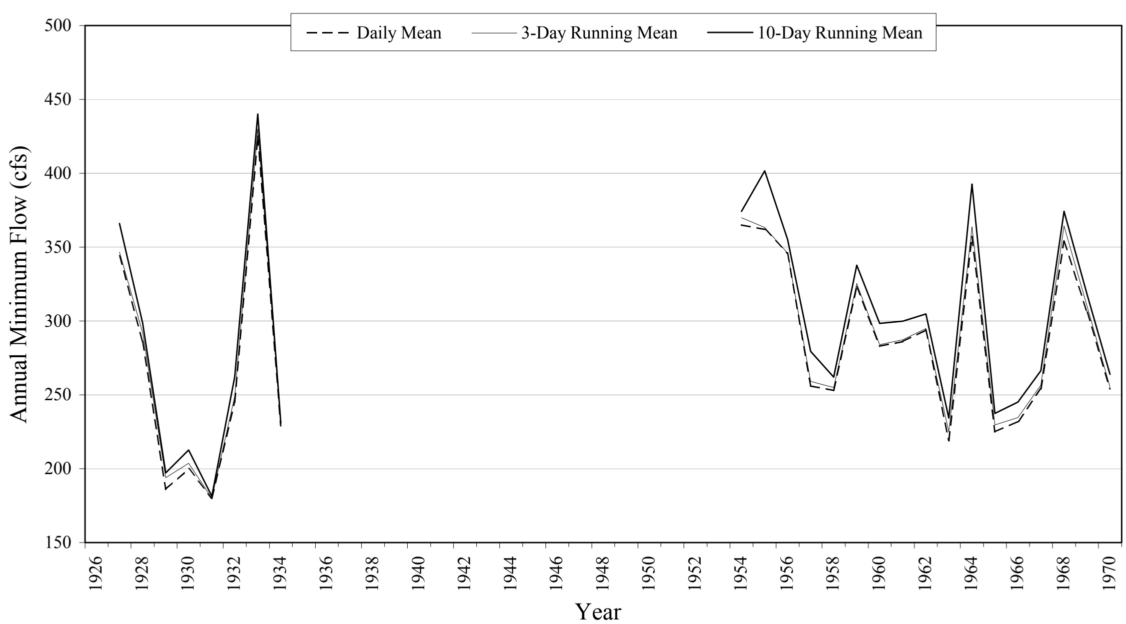


Figure 2.2-12. Base flow for Lewis River above Muddy River (RM 62, USGS Gage 14216000).

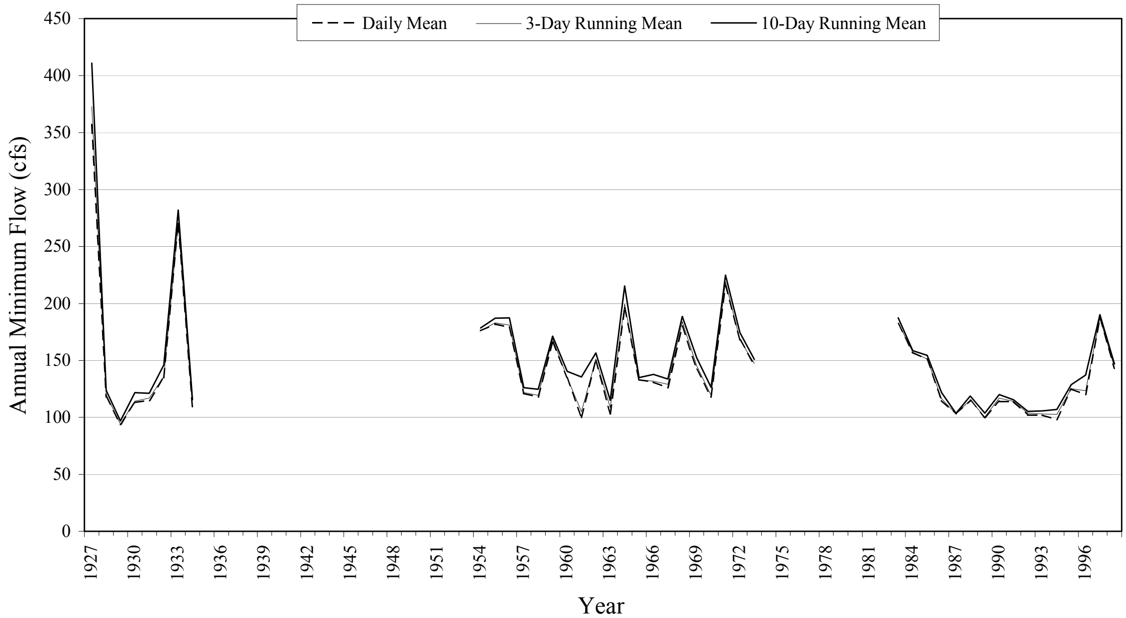


Figure 2.2-13. Base flow for Muddy River below Clear Creek (USGS Gage 14216500).

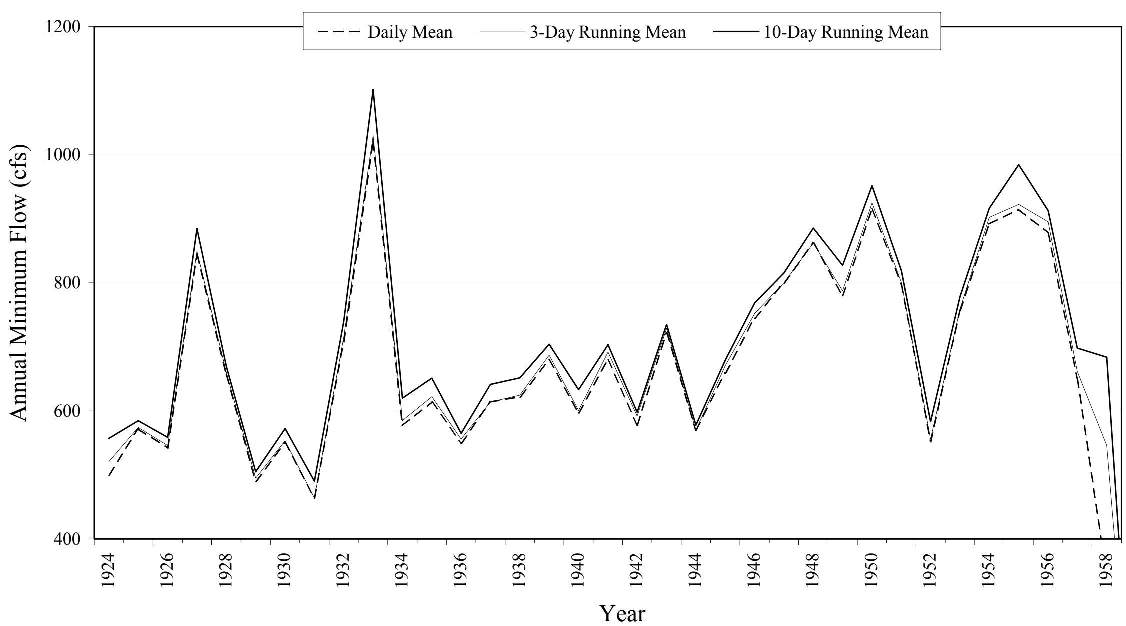


Figure 2.2-14. Base flow for Lewis River near Cougar (RM 46.8, USGS Gage 14218000).
Note: only the pre-project flow record was used to compute baseflows due to the inconsistent recording of low flows after Swift was constructed.

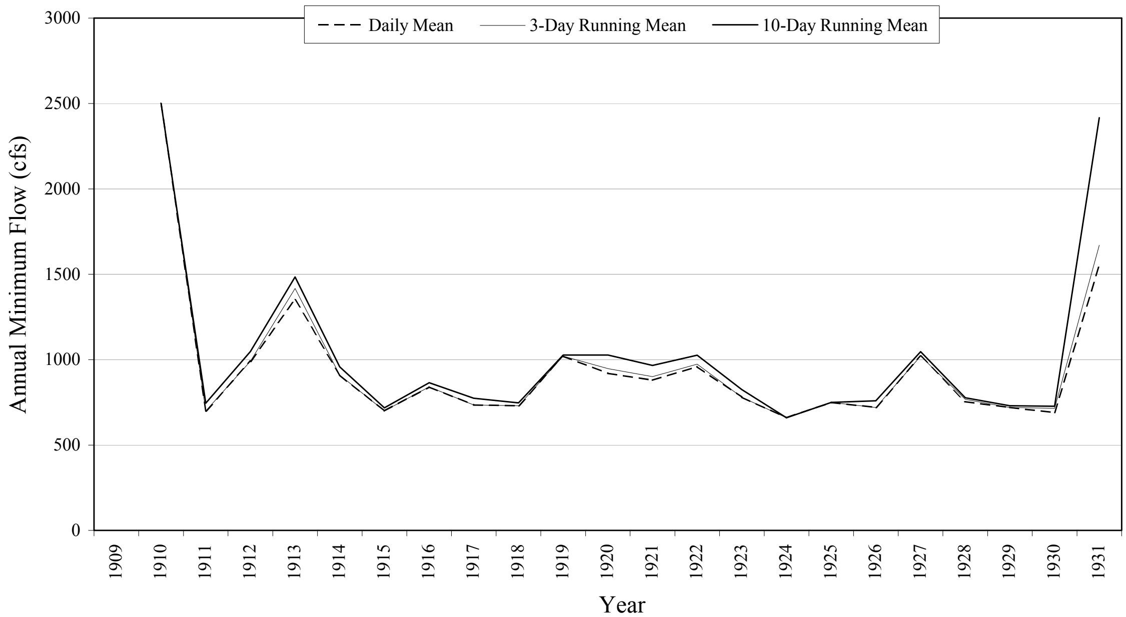


Figure 2.2-15. Base flow for Lewis River near Amboy (RM 30.9, USGS Gage 14219500).

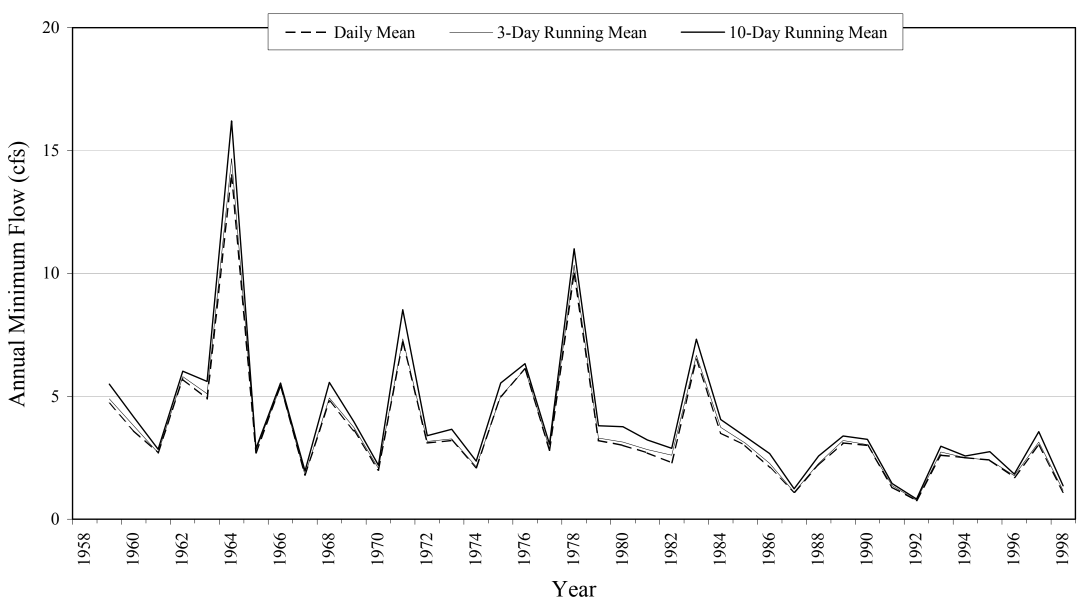


Figure 2.2-16. Base flow for Speelyai Creek above diversion (USGS Gage 14219800).

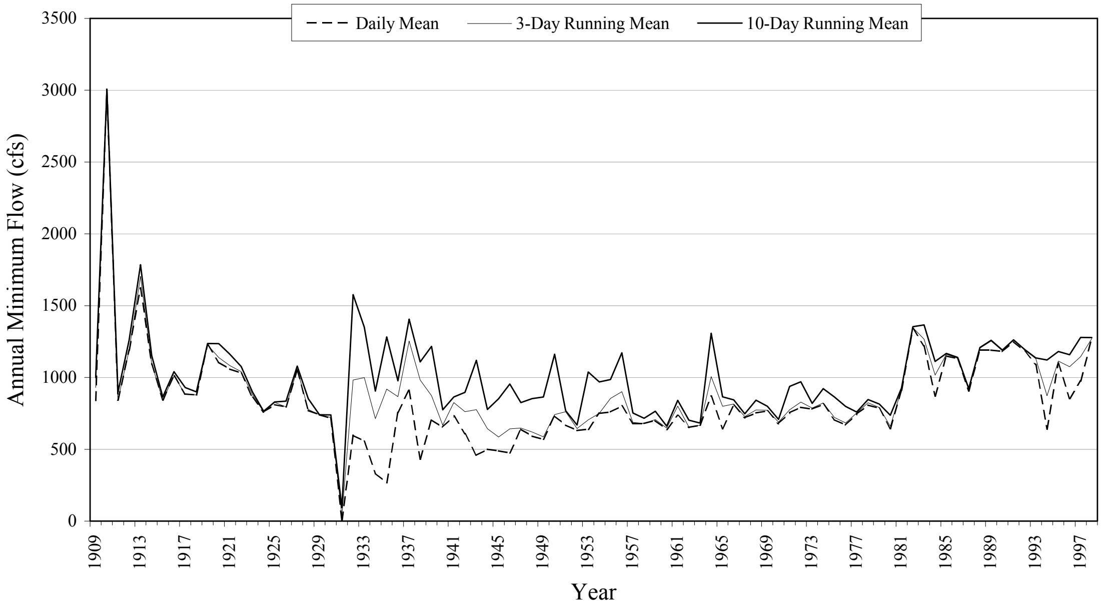


Figure 2.2-17. Base flow for Lewis River below Merwin Dam at Ariel (RM 19, USGS Gage 14220500).

The timing of base flows for each of the study gages was plotted as magnitude of flow vs. the day(s) of the year that flow occurred (Figures 2.2-18 through 2.2-24). Base flows occur during September and October at most gages, at the end of the drier summer months. There are some slight variations in timing at different gages; the Speelyai Creek gage has some base flows that spread into August, and some of the gages in the upper watershed have a few baseflows in November.

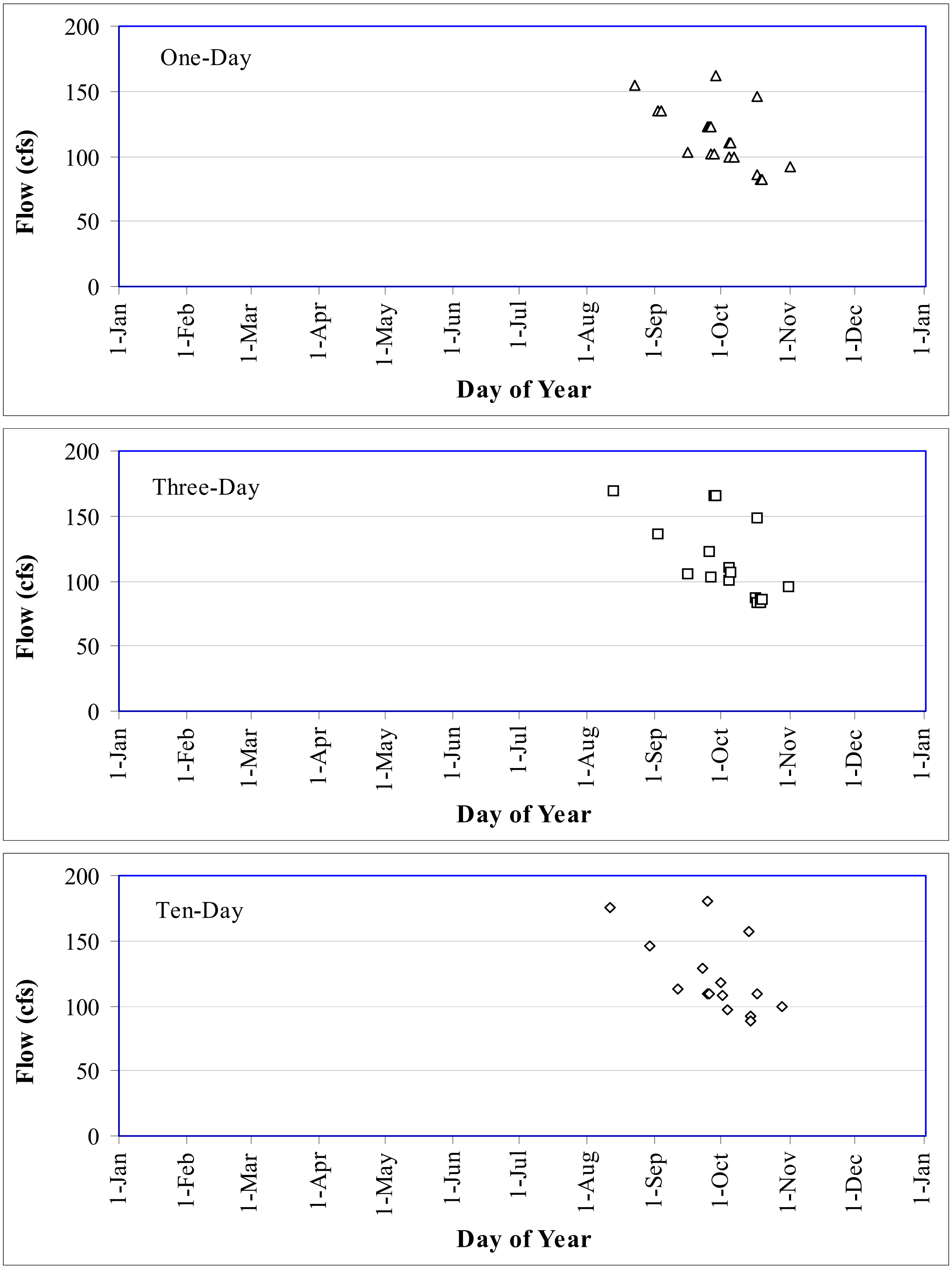


Figure 2.2-18. Base flow timing for Lewis River near Trout Lake (USGS Gage 14213200). Base flows were estimated annual minimum of daily average flow, 3-day running average flow, and 10-day running average flow.

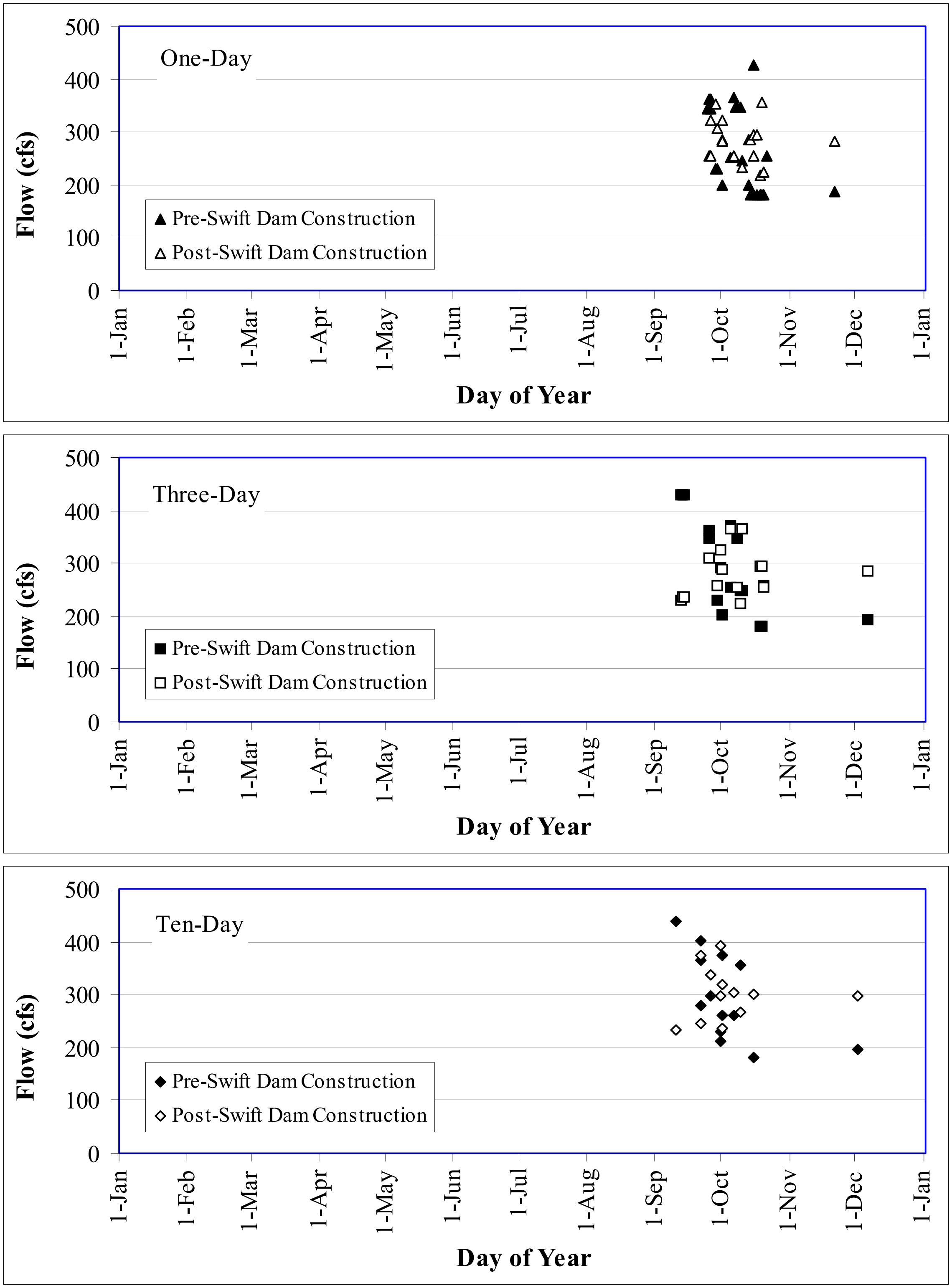


Figure 2.2-19. Base flow timing for Lewis River above Muddy River (USGS Gage 14216000). Base flows were estimated annual minimum of daily average flow, 3-day running average flow, and 10-day running average flow.

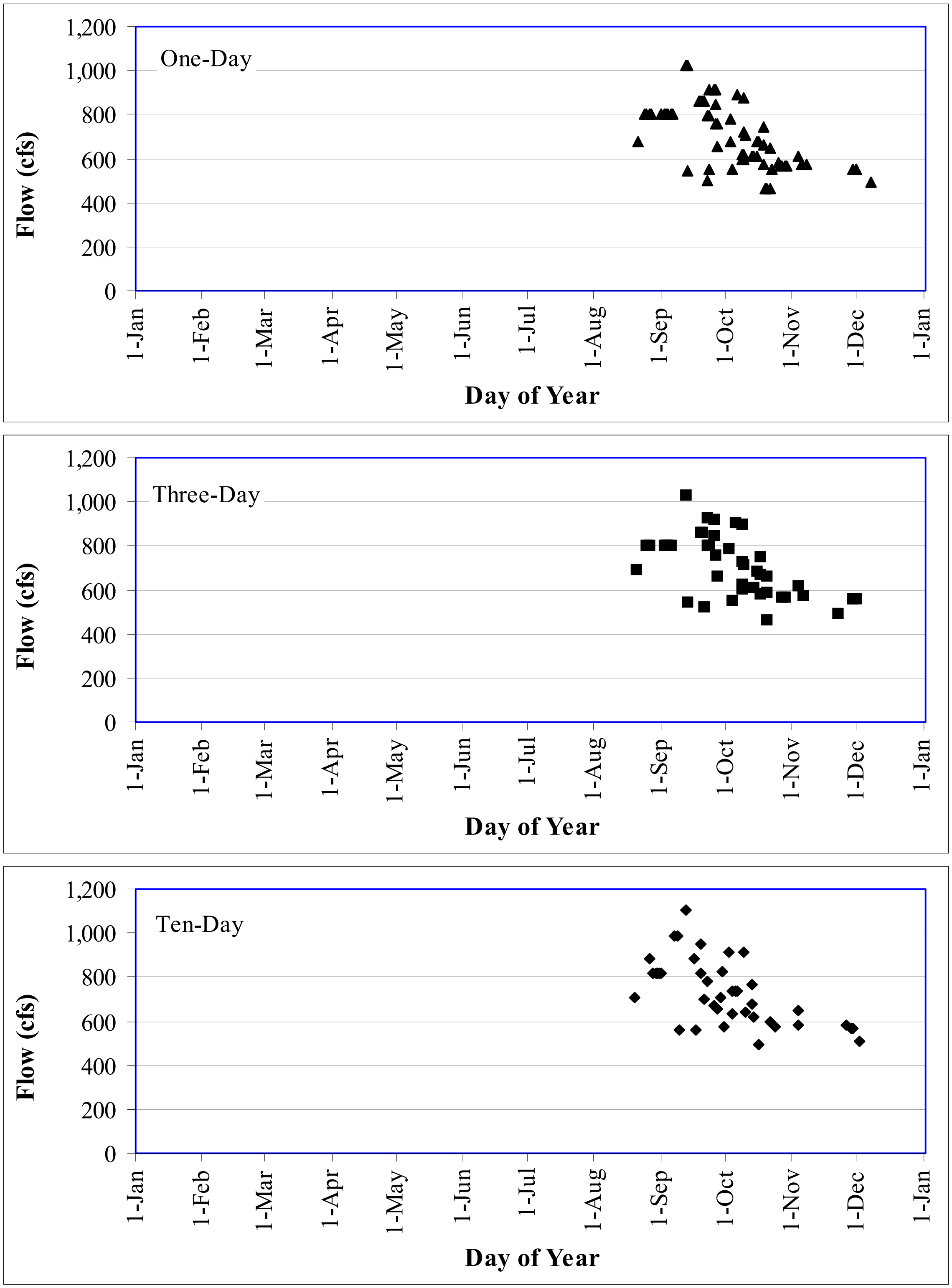


Figure 2.2-20. Base flow timing for Lewis River near Cougar (USGS Gage 14218000). Base flows were estimated annual minimum of daily average flow, 3-day running average flow, and 10-day running average flow.

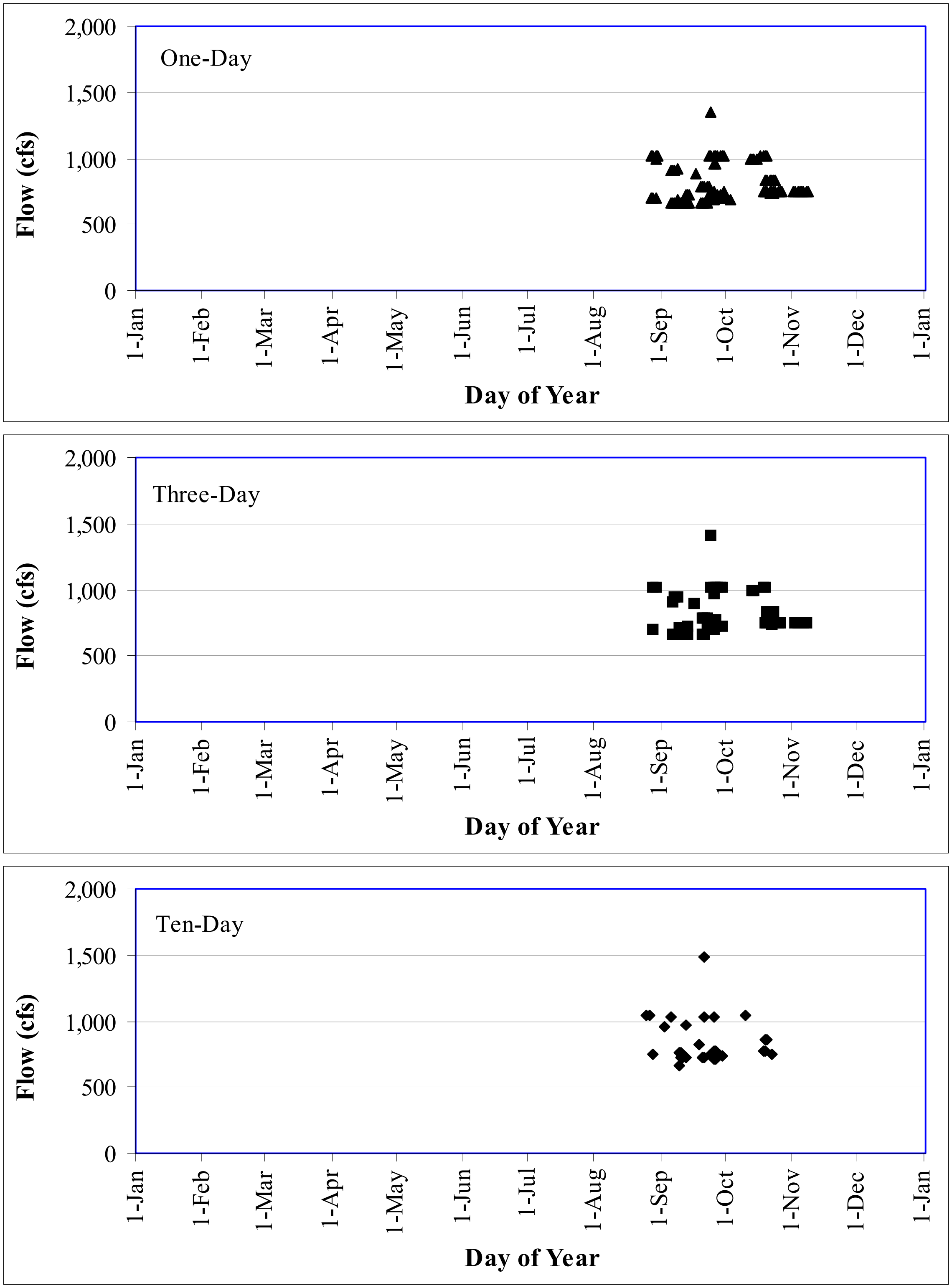


Figure 2.2-21. Base flow timing for Lewis River near Amboy (USGS Gage 14219500). Base flows were estimated annual minimum of daily average flow, 3-day running average flow, and 10-day running average flow.

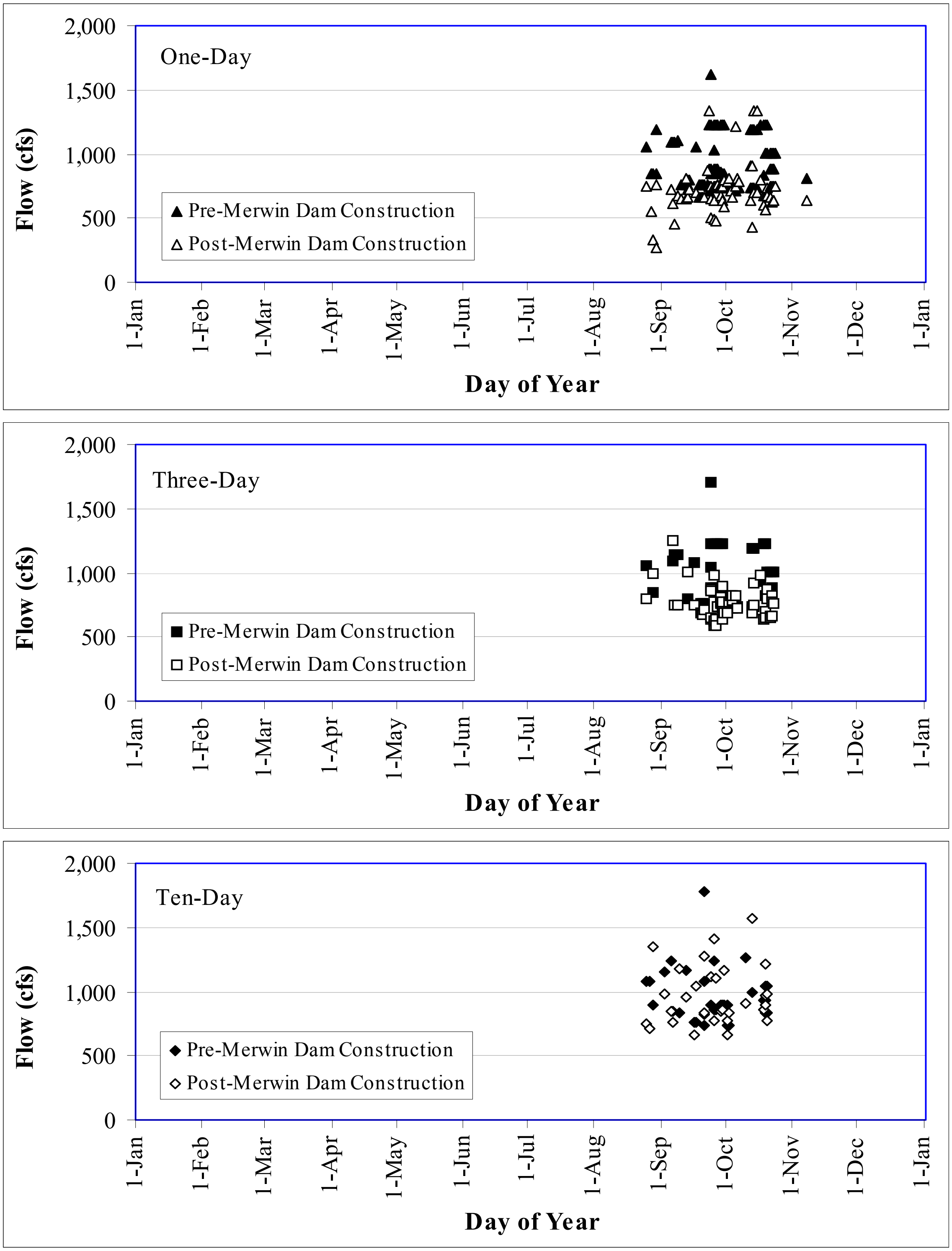


Figure 2.2-22. Base flow timing for Lewis River at Ariel (USGS Gage 14220500). Base flows were estimated annual minimum of daily average flow, 3-day running average flow, and 10-day running average flow. Peak flows for Lewis River at Ariel between 1910 and 1923 were estimated based on flood flows for Lewis River near Amboy.

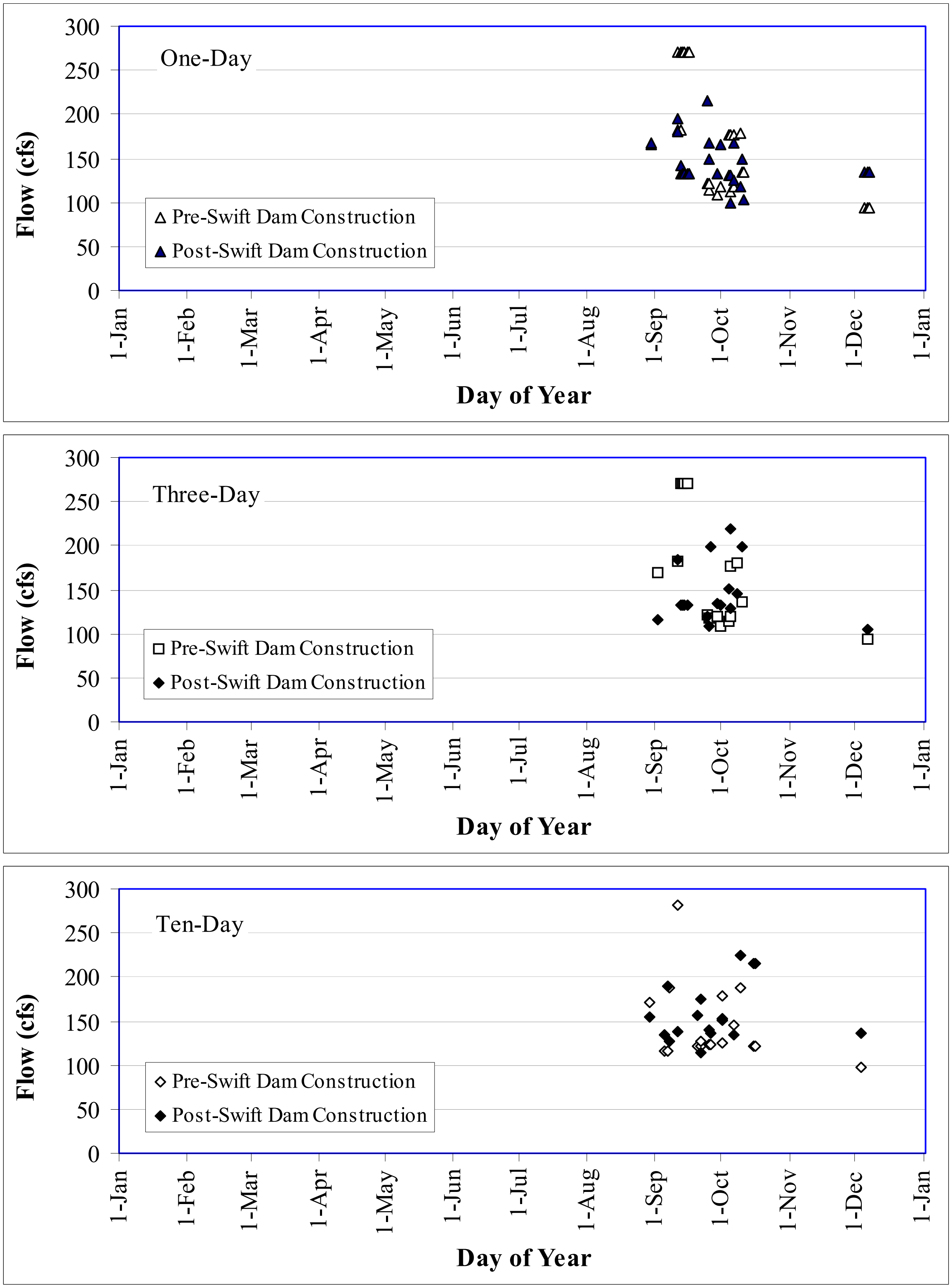


Figure 2.2-23. Base flow timing for Muddy River below Clear Creek (USGS Gage 14216500). Base flows were estimated annual minimum of daily average flow, 3-day running average flow, and 10-day running average flow.

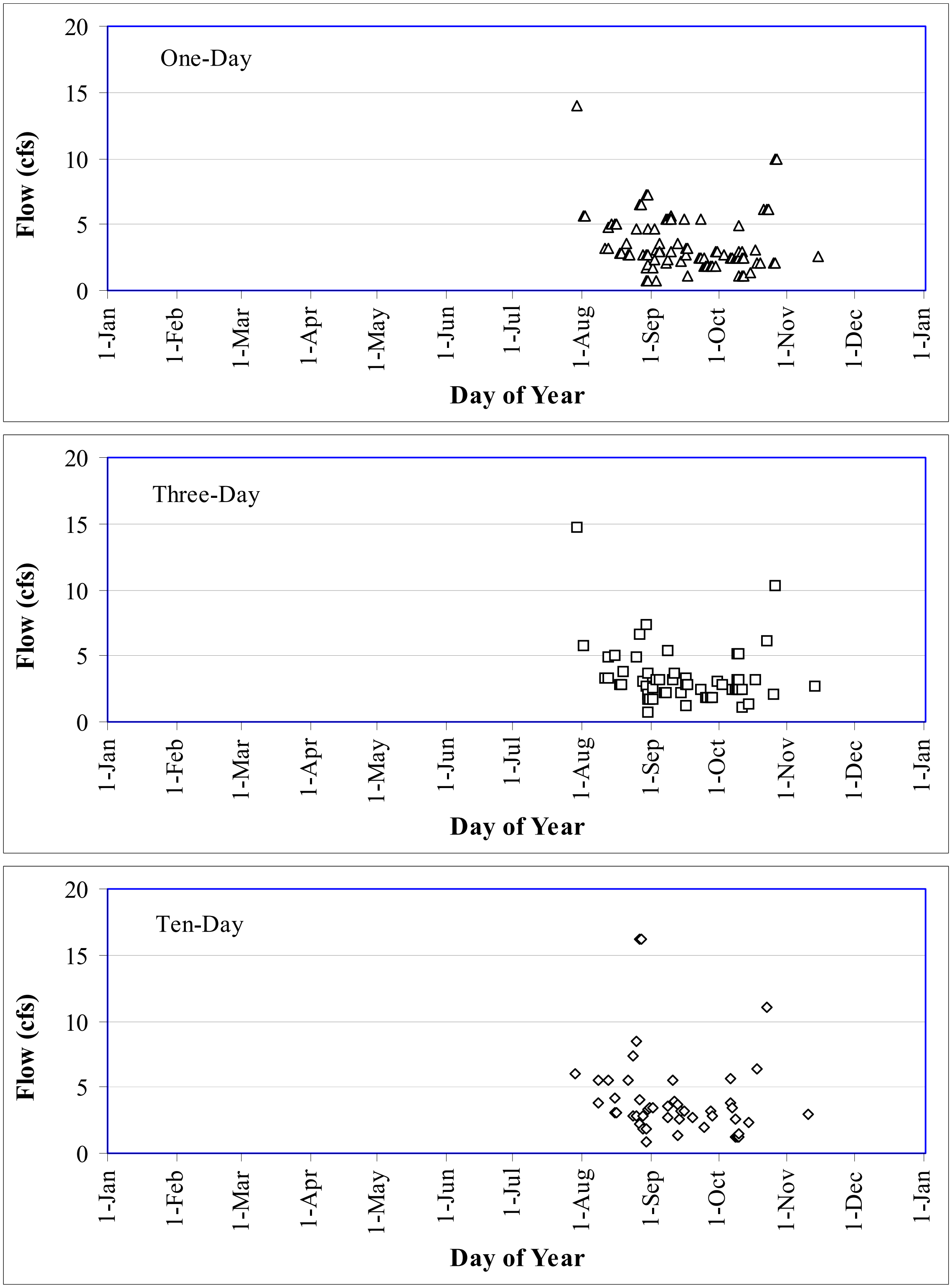


Figure 2.2-24. Base flow timing for Speelyai Creek near Cougar (USGS Gage 14219800). Base flows were estimated annual minimum of daily average flow, 3-day running average flow, and 10-day running average flow.

2.2.5.4 Peak Flow Frequency

Peak flow frequency analyses were performed on 6 streamflow gages using the HECEXE program. This program computes peak flow frequency from annual instantaneous peak flows using the accepted U.S. Water Resources method (U.S. Water Resources Council 1981). The Lewis River gage at Ariel record is being analyzed as part of the flood studies (FLD 1, Section 11.1) and is not reported here. During the early years of the Amboy gage, flows were based on a single daily stage reading made by a local observer, so the peak flow values may be somewhat lower than later continuous gage measurements.

The results of the analysis are displayed in Table 2.2-2 and Figures 2.2-25 through 2.2-27. It should be noted that development of peak flow frequencies is a statistical procedure and is very sensitive to the period of record available and the magnitude of peak flows that occurred during the analysis period. A longer data record produces more reliable results, particularly for longer recurrence interval flows like the 50-100 years. The largest recorded peak flows in the watershed occurred during December 1917, December 1933, and February 1996. Since each of the gages analyzed had a different period of record that included some, all, or none of these large floods, the results of this analysis are not directly comparable between gage sites. The purpose of the following data is to provide information on peak flow frequencies. Analysis of flood control at the project is undertaken in a separate study (FLD 1, Section 11-1).

Table 2.2-2. Peak flow frequencies.

		Station, Analysis Period, and Number of Events Analyzed in Each Period					
Chance of flow occurring in any given year	**Re-currence interval (years)**	**Lewis River near Trout Lake (14213200)**	**Lewis River above Muddy River (14216000)**	**Lewis River near Cougar (14218000)**	**Lewis River near Amboy (14219500)**	**Muddy River below Clear Creek (14216500)**	**Speelyai Creek near Cougar (14219800)**
		1958-1972	**1927-1933, 1955-1977**	**1917, 1925-1975**	**1912-1931**	**1928-1934, 1955-1997**	**1960-1997**
		14	**28**	**48**	**20**	**41**	**39**
1%	100	19,500	35,300	74,100	98,500	26,300	4,470
2%	50	16,800	30,300	61,800	87,600	22,000	4,020
5%	20	13,500	24,100	47,500	73,200	16,900	3,410
10%	10	11,100	19,600	37,900	62,100	13,600	2,940
20%	5	8,890	15,200	29,100	50,600	10,500	2,440
50%	2	5,890	9,240	18,100	33,600	6,720	1,680
80%	1.25	3,990	5,540	11,700	21,800	4,490	1,140
90%	1.11	3,280	4,220	9,430	17,200	3,710	916
95%	1.05	2,810	3,350	7,970	14,100	3,200	764
99%	1.01	2,120	2,170	5,910	9,590	2,470	538

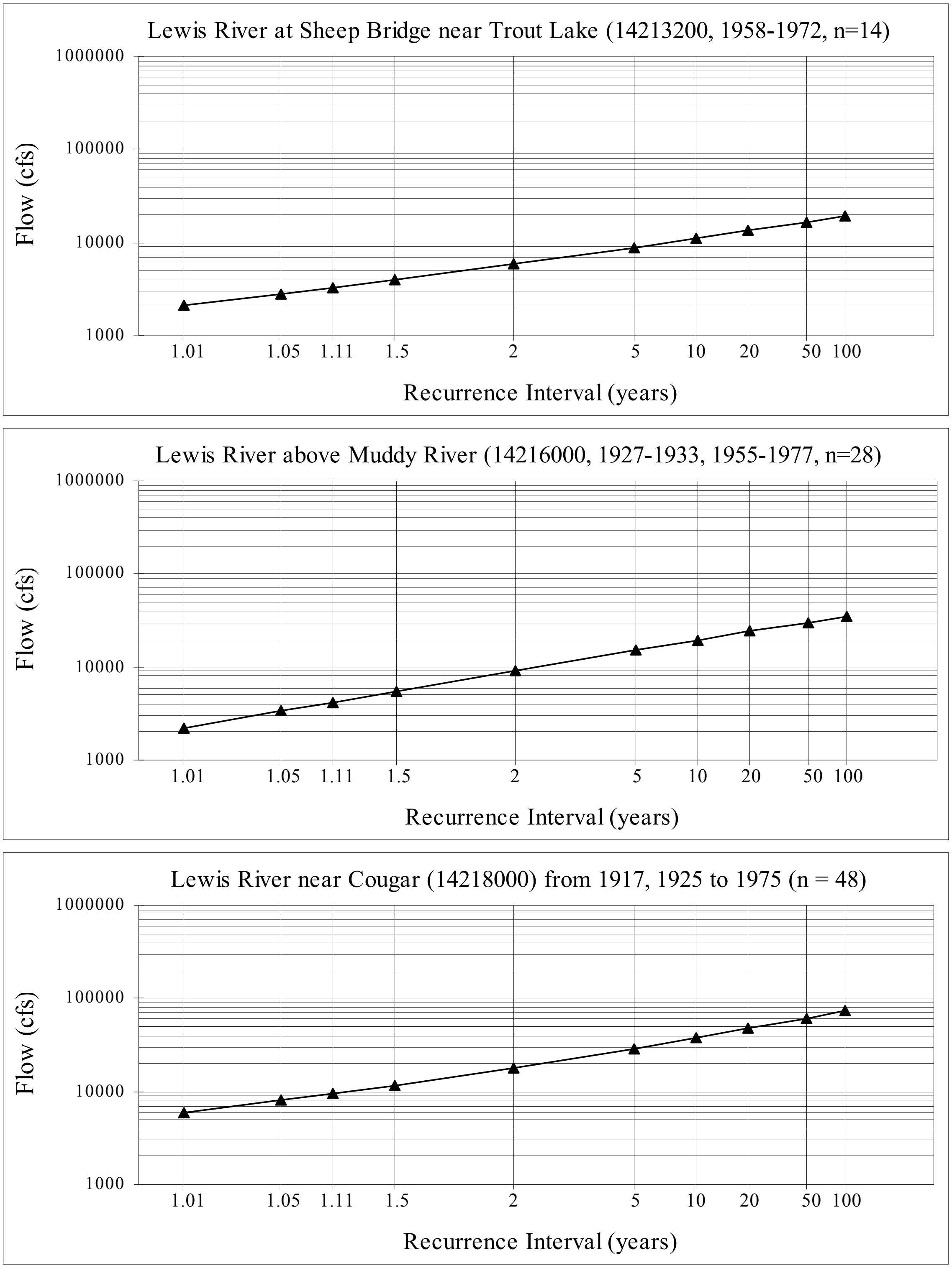


Figure 2.2-25. Peak flow hydrographs for USGS gages in the upper and middle Lewis River basin.

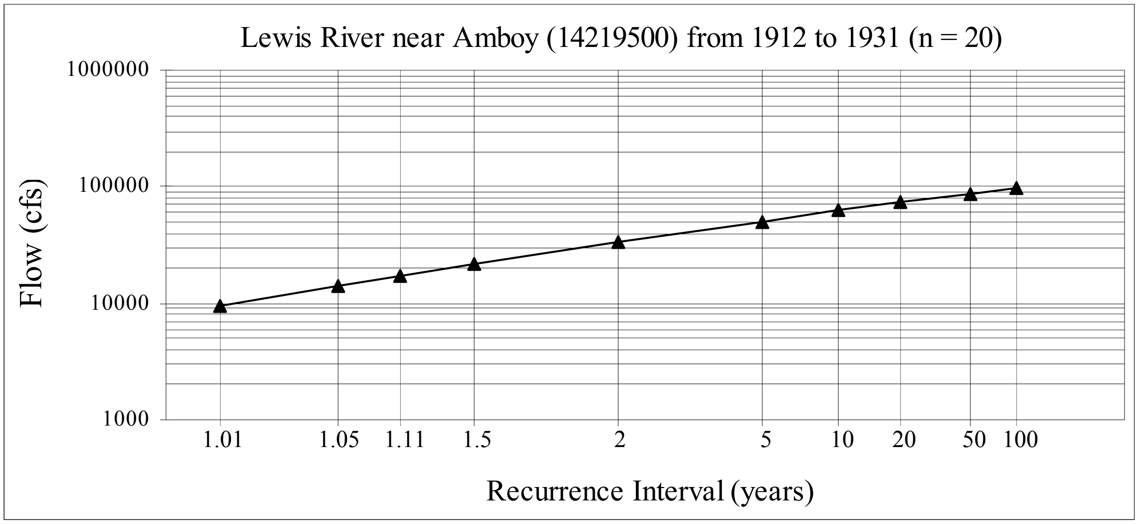
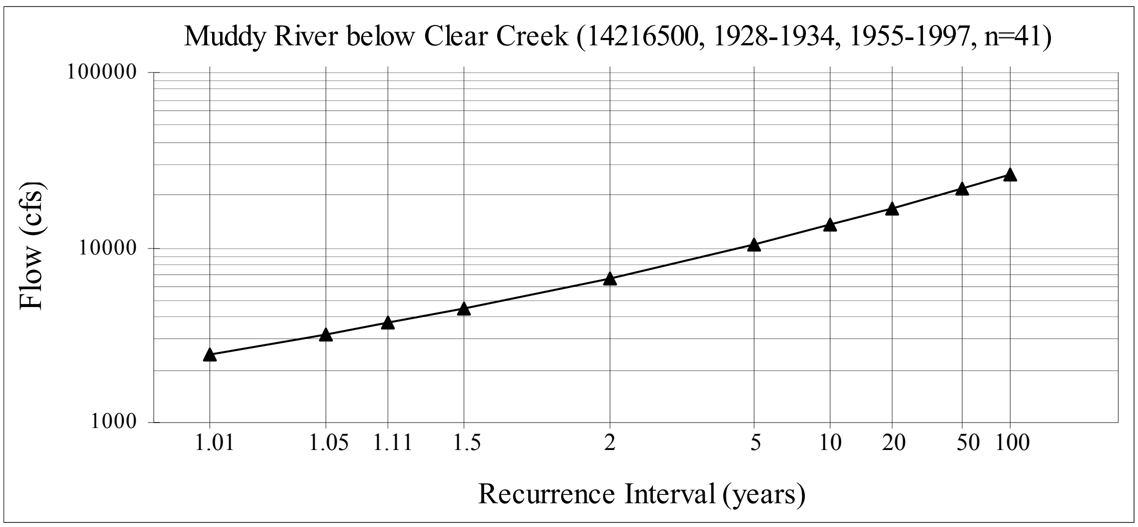


Figure 2.2-26. Peak flow hydrographs for USGS gages in the lower Lewis River basin.



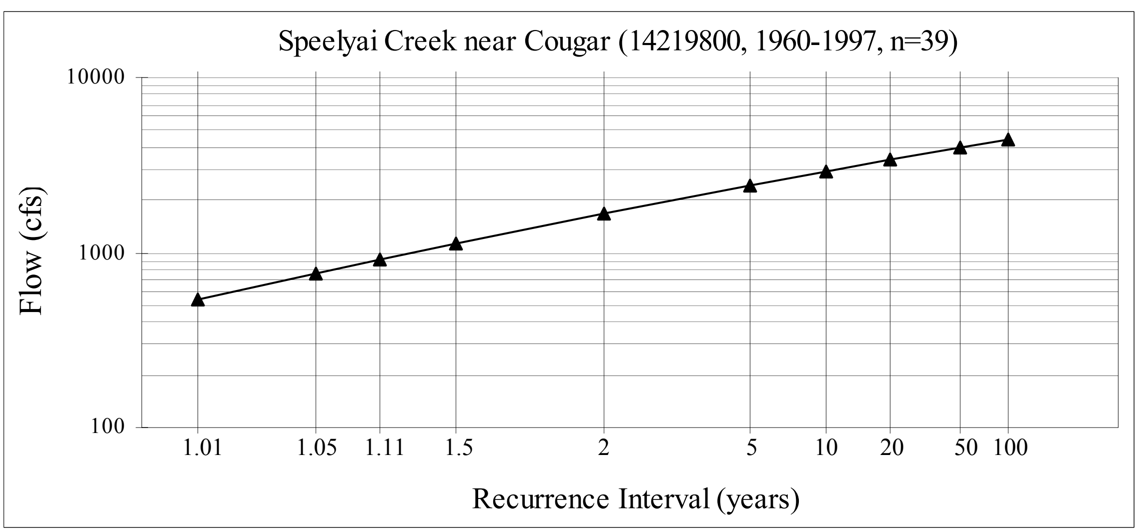


Figure 2.2-27. Peak flow hydrographs for USGS gages on tributaries in the Lewis River basin: Muddy River below Clear Creek and Speelyai Creek near Cougar.

2.2.5.5 Peak Flow Timing

The timing of peak flows at each of the gages was also analyzed. The magnitude of each annual peak was plotted versus day of the year that the flow occurred (Figures 2.2-28 through 2.2-30). The highest flows at most gages occur in the November-February time period, indicating they are the result of heavy rain or rain-on-snow events. At some gages, particularly those in the upper watershed or that have drainage areas at high elevations, many of the lower peaks occur in the March-June period, indicating the signature of snowmelt-caused high flows on those stations.

2.2.5.6 Project Spill Events

Available information on spill events at the Swift No. 1, Yale, and Merwin powerhouse tailraces was collected. Data availability was limited prior to 1989. The data were graphed to show magnitude of spill versus date at each location (Figures 2.2-31 through 2.2-33).

2.2.5.7 Comparison of Total Water Year Runoff and Precipitation

The total annual water year runoff for the Lewis River near Ariel was compared to the total annual precipitation at the Vancouver 4 NNE weather station (Figure 2.2-34). This is the closest weather station to the basin with a long period of record.

Annual precipitation ranged from 26-62 inches (66 to 157 cm), and total runoff ranged from 1.9 to 5.4 million acre-feet. Runoff generally corresponds to precipitation, with lower runoff in years with lower precipitation and visa versa. No distinct cyclic patterns of precipitation or runoff were observed; the regionally accepted drier years around 1930 and from 1985-1994 show up, as does the wetter 1995-1999 period.

The average annual runoff was regressed with annual precipitation to determine how well they correlate (Figure 2.2-35). As evidenced in the plot by water year, there was a general correlation of runoff with precipitation, but the 2 did not correlate in all years.

2.2.6 Discussion

Streams in the Lewis River watershed have flow patterns characteristic of a wet maritime climate: low flows in the late summer and early fall when little precipitation falls; and high flows during the wet winter and spring months. Streams in the upper portions of the watershed, with drainage basins at high elevations, show a marked snowmelt runoff peak in May and June that is even higher than the winter peak (i.e. Figure 2.2-3, Lewis River near Trout Lake, and Figure 2.2-5, Muddy River). The spring snowmelt peak becomes more and more muted as flows move downstream in the watershed. Lower elevation streams do not show a snowmelt peak, but have high flows from November through April in response to winter rains (i.e. Figure 2.2-8, Speelyai Creek).

Baseflows for all streams studies occur during August, September, and October when little rain falls in the area. Baseflows vary with stream size, but are generally 1/3 to 1/4 of the average annual flow (Table 2.2-3). The exception to this is Speelyai Creek, a small tributary to the Lewis River that has very low baseflows (about 14 times lower than average annual flow).

Peak flows in the watershed occur in response to winter rain and rain-on-snow events between November and April (Figures 2.2-18 through 2.2-30). In some years, the annual peak flow at upper watershed gages occurs during the spring snowmelt season, but these peaks are lower than the large rain-on-snow events. At most studied gages, the 2-year peak flow is 8-12 times higher than the mean annual flow. The exception is again Speelyai Creek, which has much higher peak flows, with the 2-year peak 30 times higher than the mean annual flow, indicating a very flashy hydrologic regime.

2.2.6.1 Effects of Project Operations on Flow Regimes

The Lewis River projects affect flow regimes in 3 reaches: the Swift bypass reach (between Swift Dam and Yale Lake); Speelyai Creek downstream of the upper diversion; and the Lewis River downstream of Lake Merwin. The effects of project operations are very different in each of these reaches.

Under current normal operating conditions, Swift Dam diverts essentially all of the flow from the Lewis River into the Swift No. 2 canal. As a result, the only flow in the Swift bypass reach is a result of inflow from tributaries, groundwater, and canal leakage. However, during high runoff conditions, when the projects are operating to control floods in the basin or during operational emergencies, water is spilled into the reach from either the Swift Dam spillway or the canal spillway. As a result of these operational regimes, flow in the Swift bypass reach is very low (5-10 cfs) most of the time. Flows downstream of Ole Creek, near the downstream end of the reach, are higher as a result of inflows from the creek. Spill events occur sporadically, but in general spills of several thousand cfs or greater occur every few years. The largest spill was 45,000 cfs during the February 1996 event. The effects of the project on flows and aquatic resources are described in more detail in the Swift Bypass Synthesis Report (WTS 4).

Under current conditions, the upper diversion on Speelyai Creek diverts all water from the upper watershed into the Speelyai canal and Yale Lake. The primary objective for diverting flows is to protect water quality at the Speelyai Hatchery water intake from the effects of high flows; the water is also used for power production at Yale Dam. Flows downstream of the upper diversion are the result of groundwater inflow, and increase downstream to an average of 15-20 cfs at the hatchery intake. Flows downstream of the diversion are fairly constant throughout the year. A detailed discussion of the effects of the upper diversion on Speelyai Creek is included in the Speelyai Creek Connectivity and Hatchery Protection Study (AQU 9).

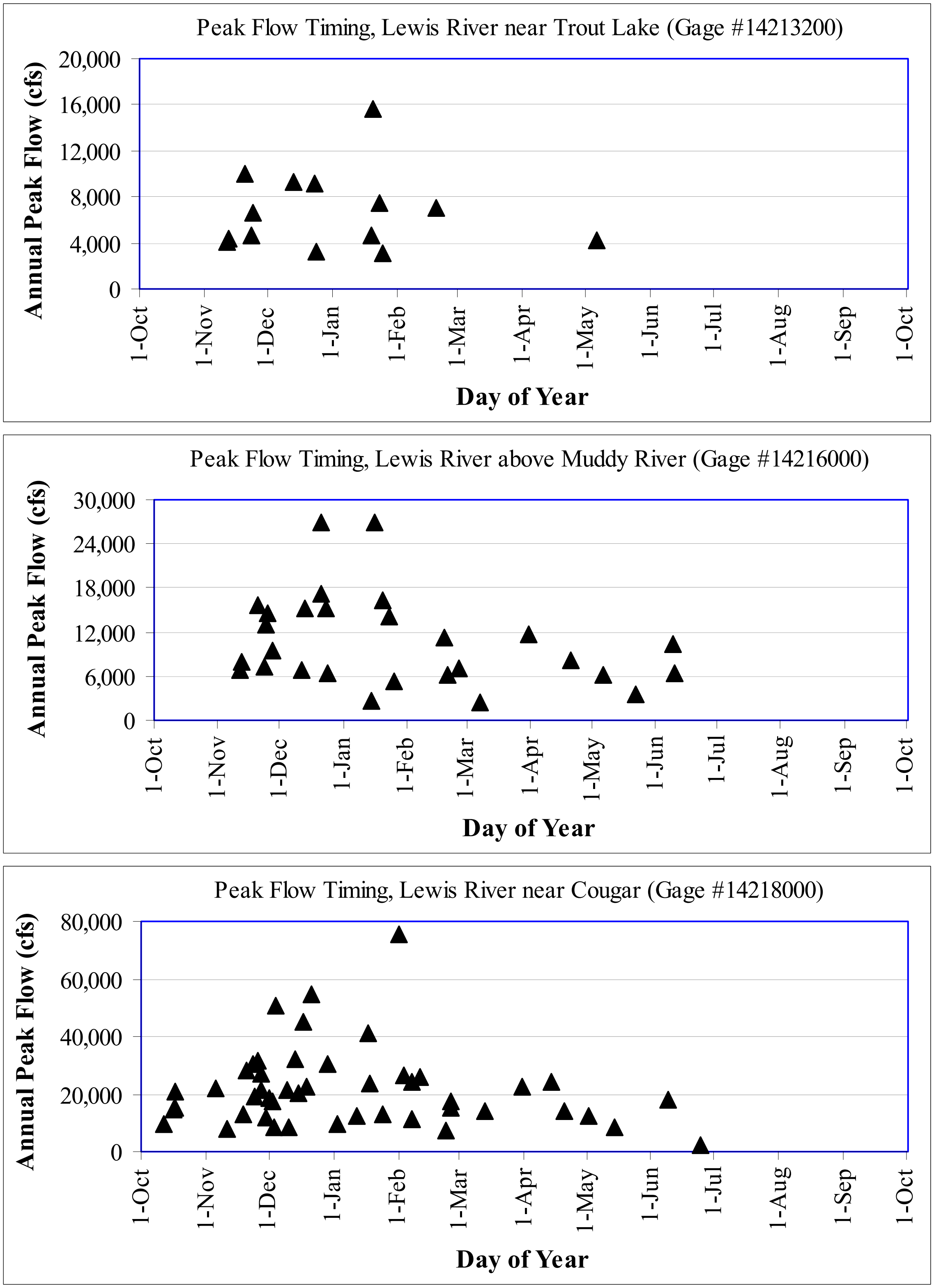


Figure 2.2-28. Peak flow timing in the upper and middle Lewis River basin.

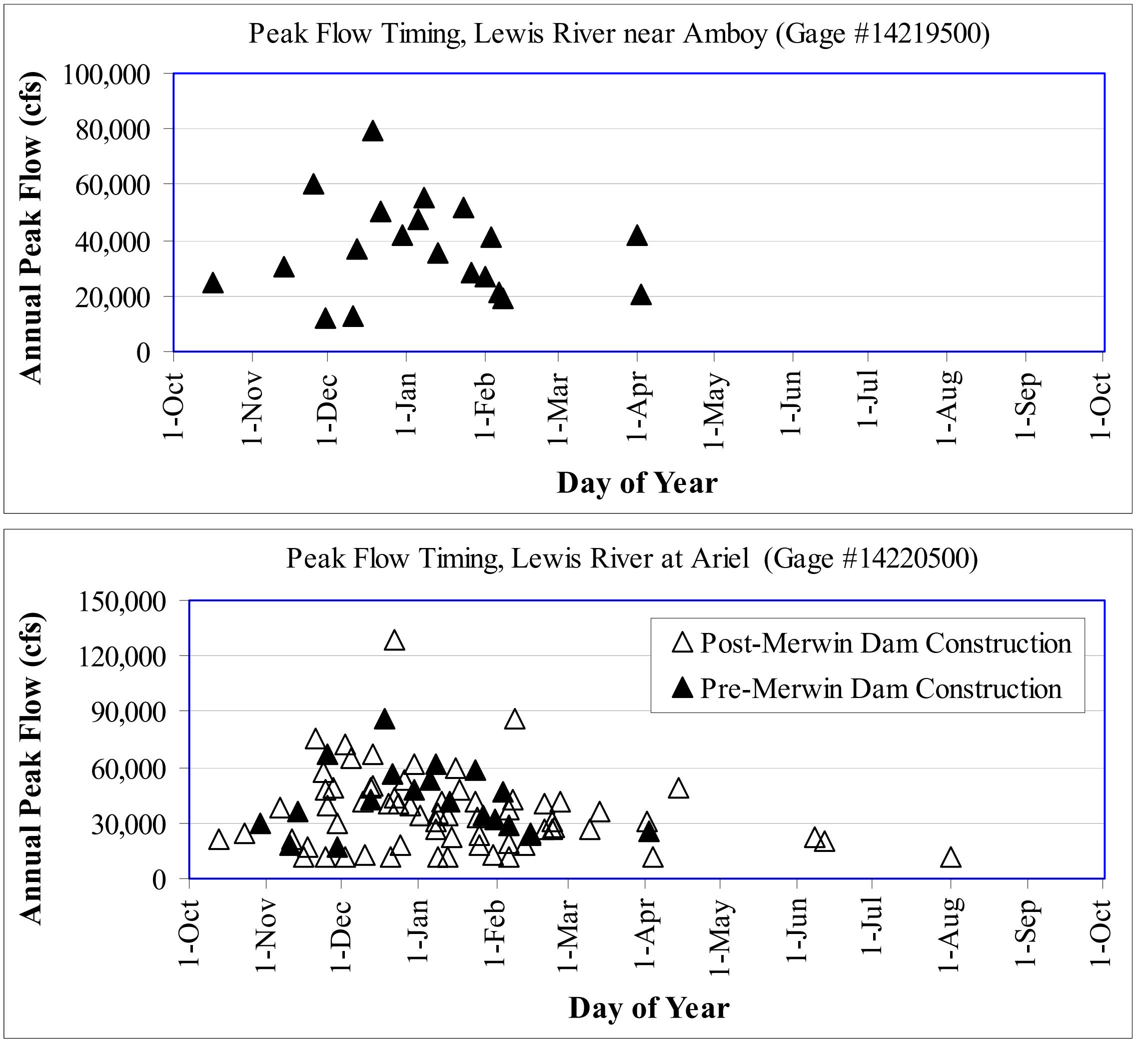


Figure 2.2-29. Peak flow timing in the lower Lewis River basin. Peak flows at Ariel prior to 1924 and 1925 were predicted from observed annual flood flow near Amboy.

Table 2.2-3. Summary of streamflow statistics for Lewis River stream gages.

Stream Gage	Annual 50% exceedence flow	Average 1-day baseflow	2-year peak flow	Baseflow: annual flow ratio	Peak: annual flow ratio
Lewis River near Trout Lake	500	113	5,890	0.23	12
Lewis River above Muddy River	917	283	9,240	0.31	10
Muddy River below Clear Creek	620	144	6,720	0.23	11
Lewis River near Cougar (pre-project)	2,185	687	18,100	0.31	8
Lewis River near Amboy	3,050	949	33,600	0.31	11
Speelyai Creek	56	4	1,680	0.07	30
Lewis River at Ariel (pre-project)	3,370	1,051	42,000	0.31	12
Lewis River at Ariel (with-project)	3,790	767	22,000	0.20	6

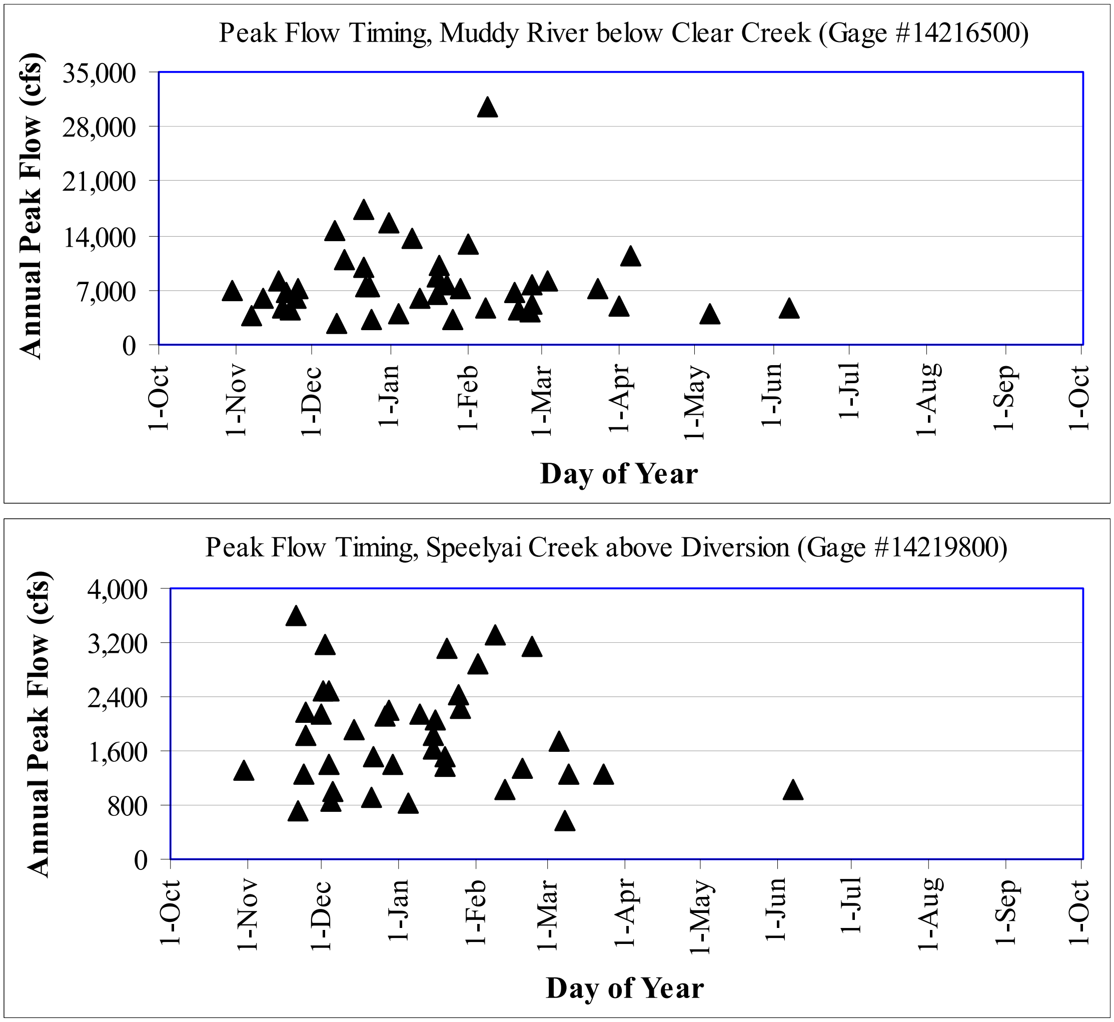


Figure 2.2-30. Peak flow timing for selected tributaries in the Lewis River basin.

Operation of the Lewis River projects in compliance with the current FERC license articles and voluntary measures to protect aquatic resources controls the flow of water in the Lewis River downstream of Merwin Dam. The projects are operated to produce power, manage peak (flood) flows, augment late summer flows, and minimize rapid water level fluctuations in the lower river. As a result of these constraints, mean flows during the late summer, fall, and winter are higher than under pre-project conditions due to flow augmentation for fish in late fall and reductions in reservoir levels for peak flow storage (Figure 2.2-9). Flows during the spring are lower than under pre-project conditions as the reservoirs are refilled for the summer recreation season. Operation of the projects has also reduced the frequency of flows in the 10,000-20,000 cfs range and changed the shape of the mid-range flow fluctuations (Figure 2.2-36). The Merwin facility has 3 units, 2 with flow capacities of 3,790 cfs and a third with a capacity of 3,890, for a total of 11,470 cfs when all 3 turbines are operating at full capacity. As a result, flows under with-project conditions have a more step-wise pattern as units are turned on or off and brought up to their full capacity and held constant. Under pre-project conditions, flow fluctuations had a spikier shape as flows increased to a peak and then decreased over the course of several days to weeks. During large peak flows, when reservoirs are filled, peak flows have a similar spike shape under pre- and with-project conditions as water is spilled at the dams. The net effect of the projects is to dampen the range of flow fluctuations (Figure 2.2-9; Table 2.2-3). High flows are lower and low flows are higher than under pre-project conditions.

2.2.7 Schedule

The Streamflow Study is complete.

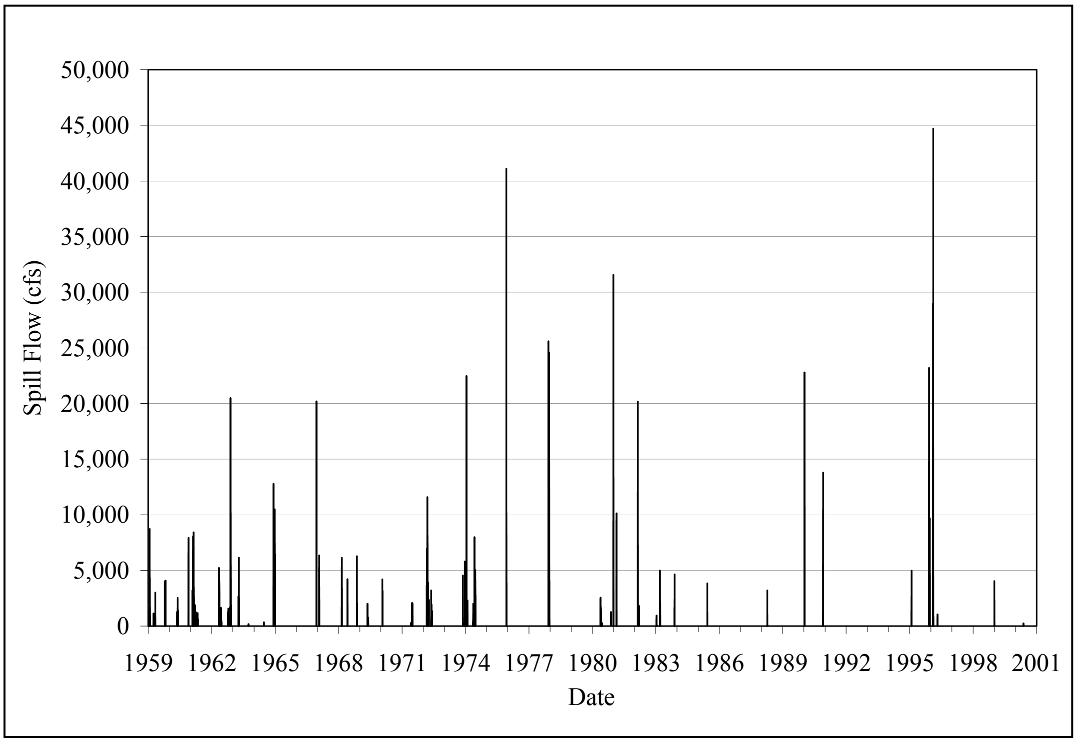


Figure 2.2-31. Spill events and magnitude (cfs) into the Swift bypass reach.

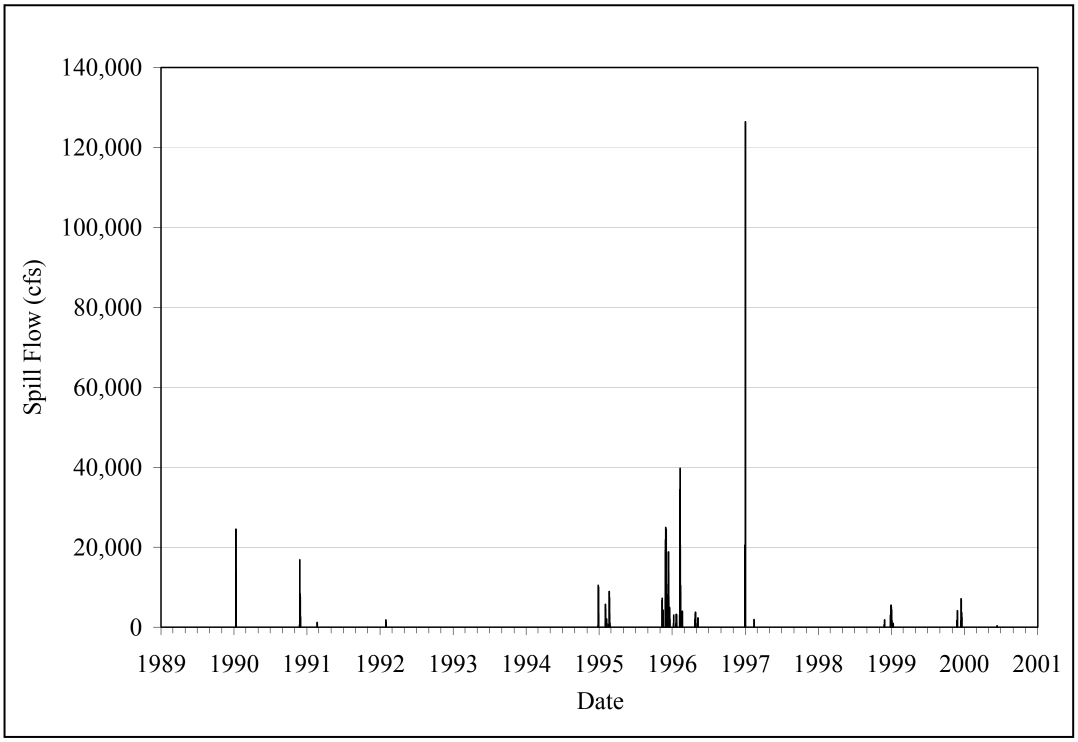


Figure 2.2-32. Spill events and magnitude (cfs) at Yale powerhouse tailrace.
Note: Data were not available prior to1989.

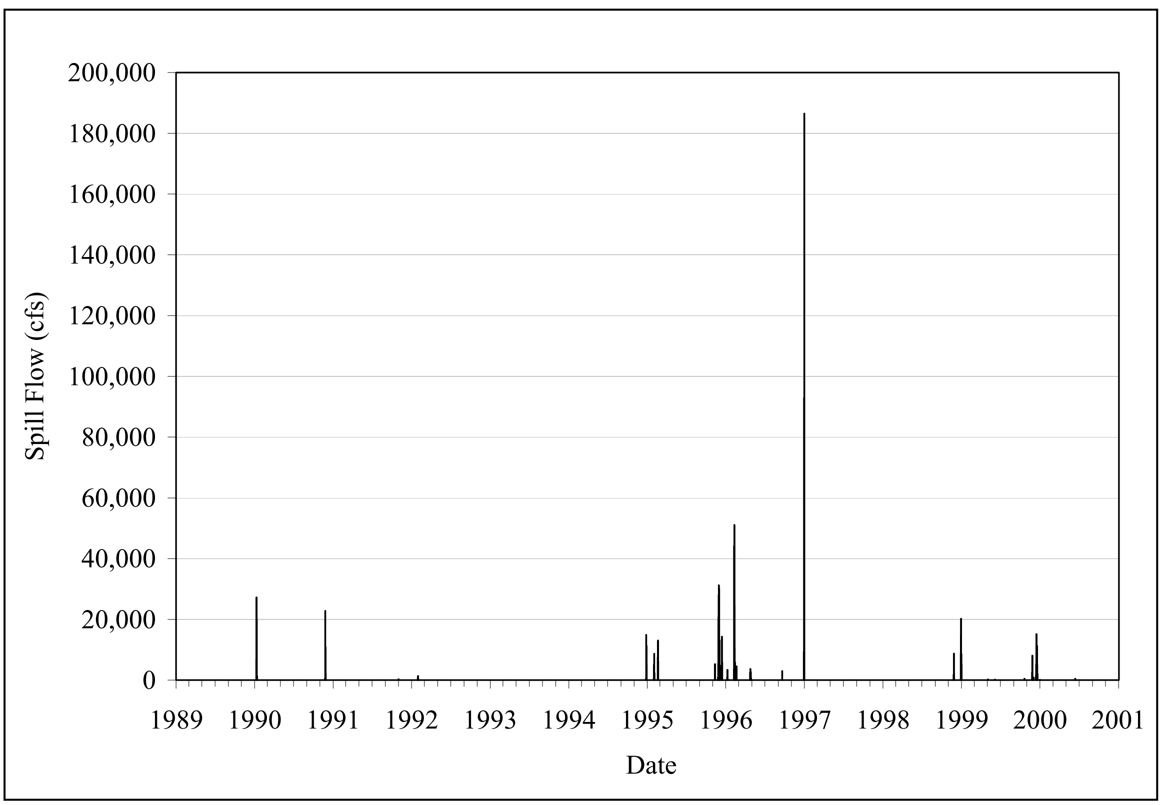


Figure 2.2-33. Spill events and magnitude (cfs) at Merwin powerhouse tailrace.
Note: Data were not available prior to 1989.

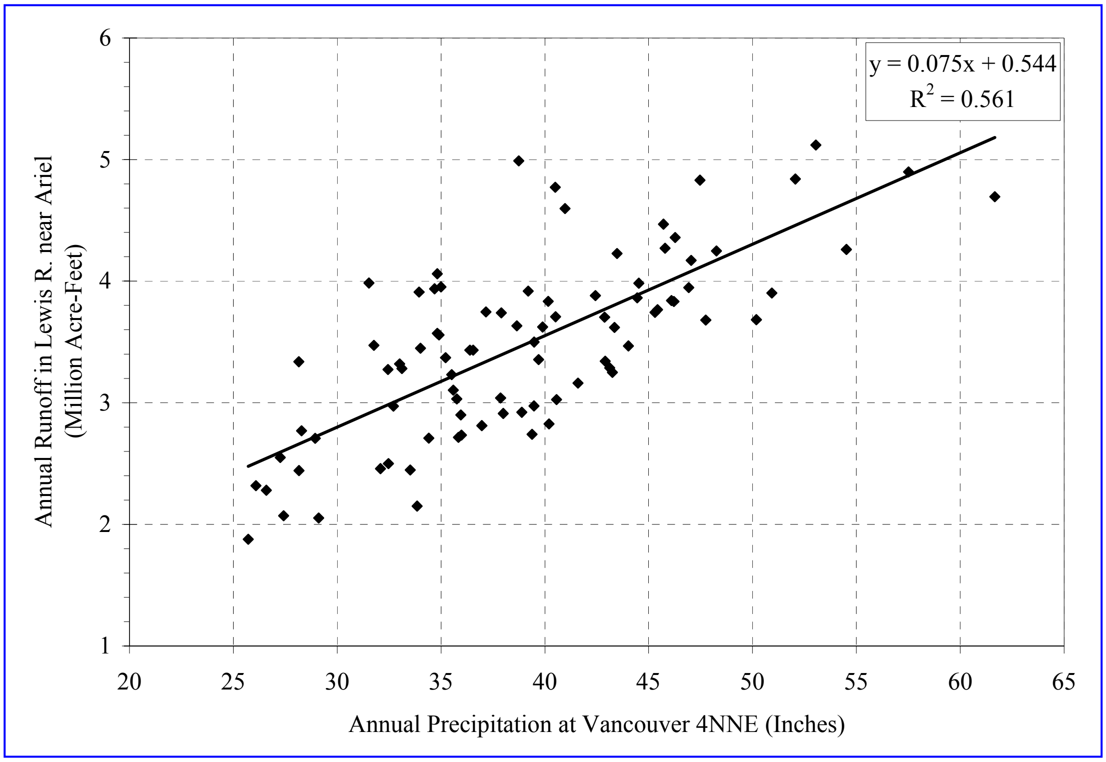


Figure 2.2-34. Annual runoff at the Lewis River near Ariel gage and annual precipitation at Vancouver 4NNE weather station.

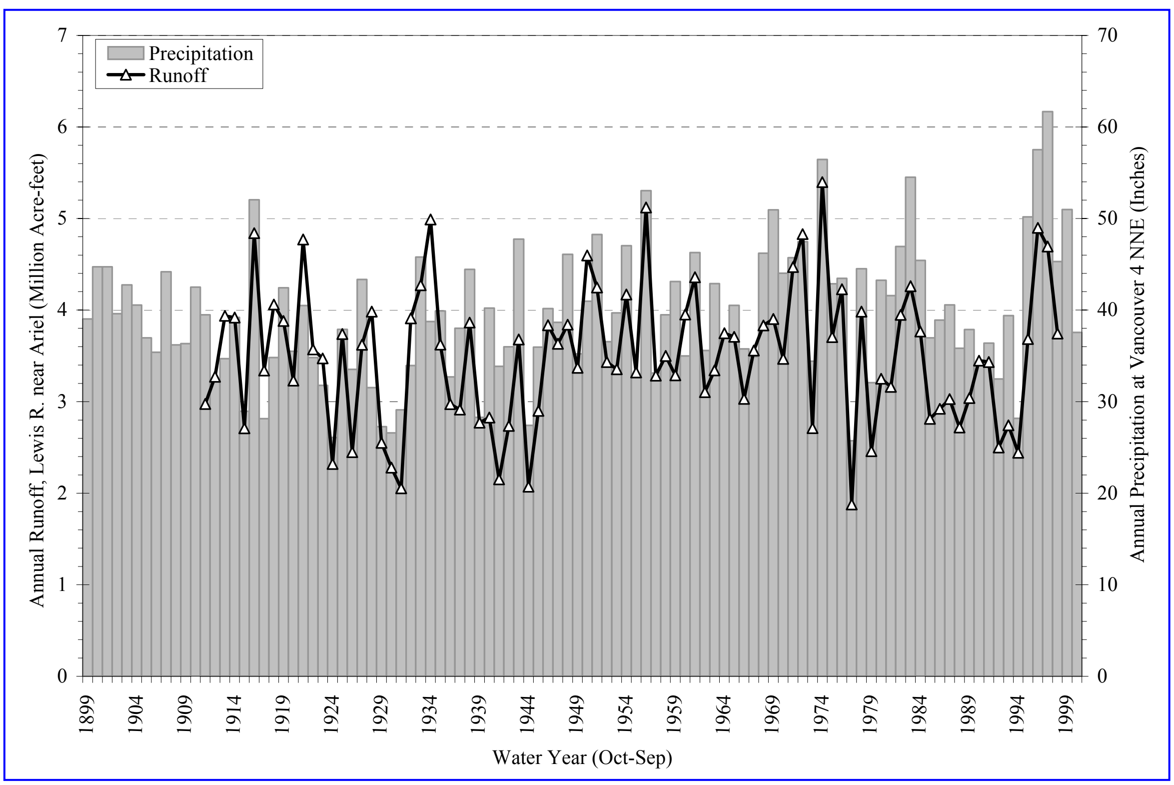
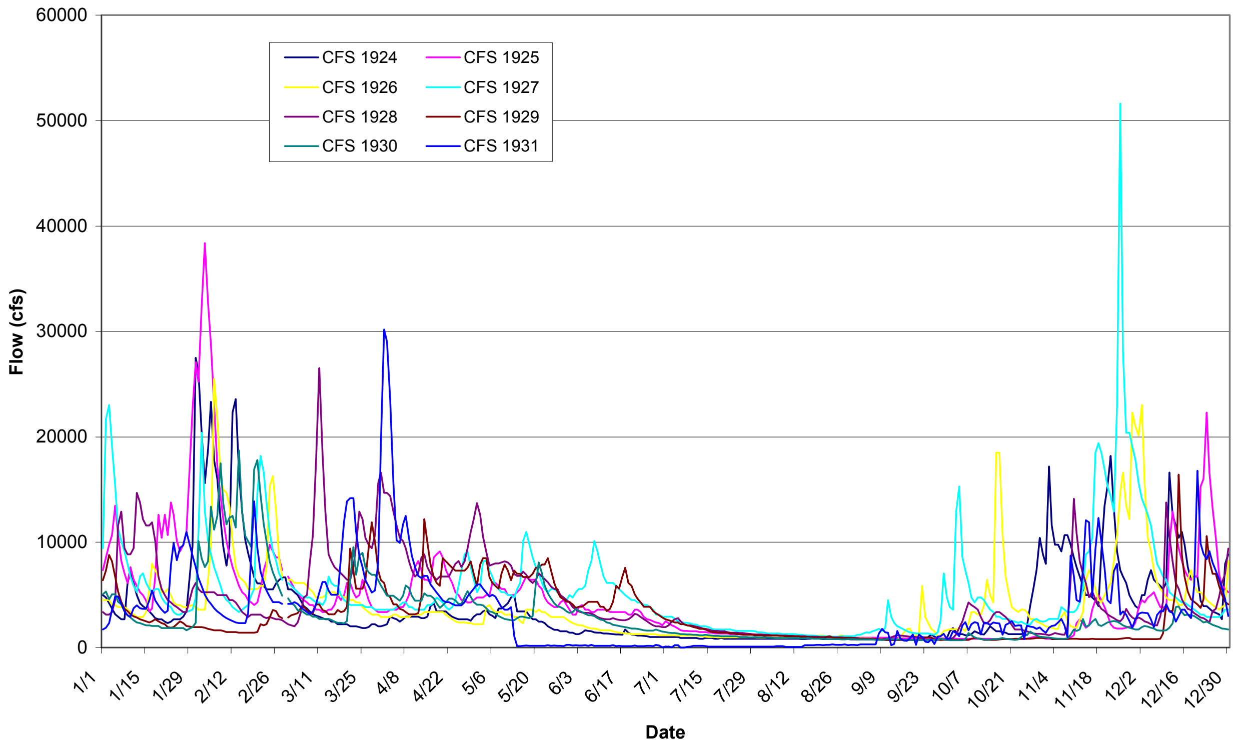


Figure 2.2-35. Regression of annual runoff vs. precipitation.



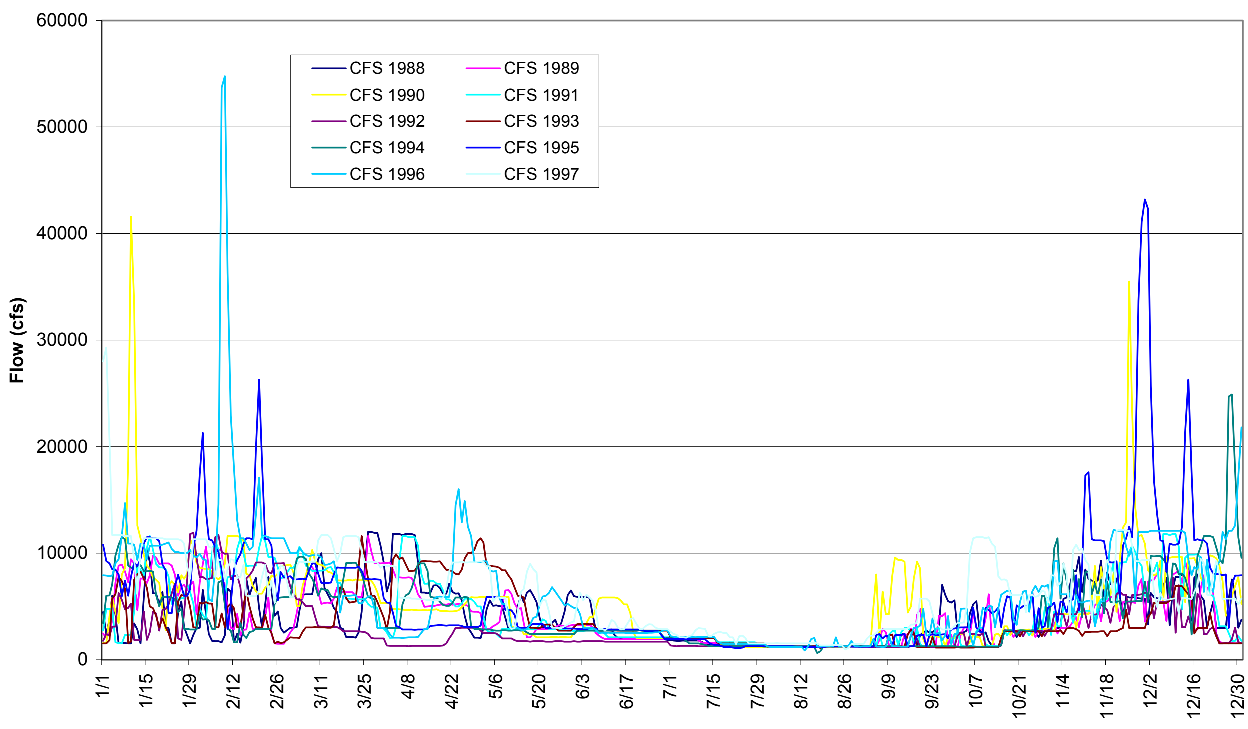


Figure 2.2-36. Mean daily flows at the Lewis River at Ariel gage (USGS 14220500) under pre-project (top graph; 1924-31) and recent with-project (bottom graph; 1988-1997) conditions. (Graphs courtesy of Jennifer Sampson, 10,000 Years Institute).

2.2.8 <u>References</u>

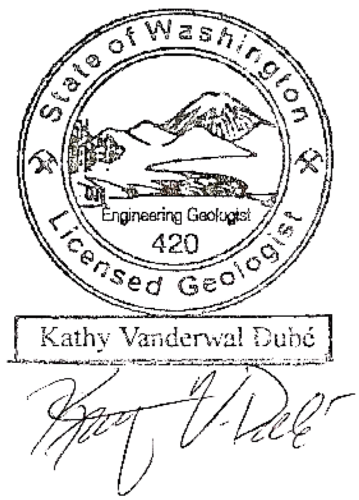
Linsley, R.K. Jr., M.A. Kohler, and J.L.H. Paulhus. 1982. Hydrology for Engineers. McGraw-Hill:New York.

Maidment, D.R. 1993. Handbook of Hydrology. McGraw-Hill:New York.

PacifiCorp and Cowlitz PUD. 1999 as amended. Study Plan Document for the Lewis River Hydroelectric Projects. Portland, OR. And Longview, WA. October 29, 1999, as amended.

U.S. Water Resources Council. 1981. Guidelines for determining flood flow frequency. Bulletin No. 17B of the Hydrology Committee.

This report was prepared by:



2.2.9 Comments and Responses on Draft Report

This section presents stakeholder comments provided on the draft report, followed by the Licensees' responses. The final column presents any follow-up comment offered by the stakeholder and in some cases, in italics, a response from the Licensees.

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
WDFW – JIM BYRNE	1	WTS 02	Ramping rate.	Where is the characterization of the ramping rates?	A discussion of ramping rates, originally intended for this study, was expanded to its own study and is reported in AQU 3.	
WDFW – KAREN KLOEMPKE N	1	WTS 02-7 – 17 Fig. 2.2-3 to 2.2-16	Flow exceedence curves.	Some of the figures have a frame around them and some don't. They should be consistent.	Comment noted.	
WDFW – JIM BYRNE	1	WTS 02-30	Diverting flows.	I thought the primary objective for diverting flows was for additional power generation at Yale.	The original water right application for the Yale diversion stated the purpose of the diversion was "to divert flood water away from State Fisheries rearing ponds" as well as power production.	Are the words in quotes referenced as the primary objective? **Licensees' Response:** *The quotation marks should not have been used for this paraphrasing. Water right permit no. 14862 states that the primary purpose is to divert flow in the interests of fish propagation and to protect hatchery water quality from the effects of high flows.*
J. Kaje – Tech.Adv. for Cowlitz Tribe	1	WTS 02-30-33, 2.2.6.1	Scope of entire section	The discussion of project effects on the flow regime is inadequate, particularly with respect to peak flow timing and base flow below Merwin. The report should include statistical analysis to support the figures. For example, Figure 2.2-22 appears to	While an in-depth analysis of pre- and with-project hydrologic conditions is possible, FERC guidelines for relicensing define existing conditions as the baseline for analysis of the	Hydrologic impacts are not a figment of the past in the way that fish passage is considered to be by some parties. Hydrologic changes are happening continuously to this day. One only needs to look at

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				indicate a clear post-project decrease in the 1-day and 3-day base flow rate at Ariel, but no statistics are provided. Also peak flow timing at Ariel is presented in Figure 2.2-29 and appears to indicate that a much higher proportion peak flows occur after Feb-15 during the post-project period. By visual inspection of the graph, it looks like the pre-project era had only one peak flow data point after Feb-15 compared to 18 between late October and mid February, whereas the post project ratio appears significantly different. Please provide a more thorough discussion of all project effects on the flow regime.	effects of the new license. A general discussion of the differences between pre-project and with-project conditions was provided, but further comparison is not required.	the CURRENT hydrologic patterns above the project area to the CURRENT hydrologic patterns below the area to recognize that fact. So, the "baseline" argument does not hold water. We have asked that a thorough assessment of project effects on downstream hydrology be performed – this has not yet happened. We suggest using the Indicators of Hydrologic Alteration methodology and associated Range of Variability Analysis (Richter et al.). Hydrologic changes are among the most fundamental, continuous impacts of dams. These should be quantified in the relicensing context. **Licensees' Response**: *Studies have been developed and performed that are consistent with the Commission's guidelines defining baseline conditions. This guidance has been affirmed by the courts in American Rivers v. FERC, 103F.3d 1007 (9th Circuit 1999) and in Confederated Tribes of the Yakama Nation v. FERC, 746 F 2d 466 (9th Circuit 1984. Accordingly, we respectfully decline to conduct further*

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
						analysis of pre-project hydrologic conditions. That being said, analyses using the Indicators of Hydrologic Alteration (IHA) methodology have been conducted. Hardin-Davis recently carried out a statistical analysis of hydrologic patterns below Merwin Dam, using the IHA. This analysis compares the past 18 years of daily flow records with and without the dams in place (without-dam flows were calculated based on recorded daily changes in reservoir volumes). The report, which includes statistics on peak and base-flow timing and magnitude, will be made available to the ARG.
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 02-30 – 33	"The net effect of the projects is to dampen the range of flow fluctuations… High flows are lower and low flows are higher than under pre-project conditions"	Interpretation of effects of the projects on flows downstream of the Merwin project is overly simplistic. By providing only the most general types of hydrological statistics, the 2001 Technical Report (TR) is not able to compare hydrologic variation before and after the projects at temporal scales relevant to processes which increase and support biological and habitat diversity. We submit figures 1 and 2 as an illustration of how the projects		**Licensees' Response**: *These figures have been included in the final report as Figure 2.2-36.*

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				suppress the multitude of peak flows between 1000 and 20,000 cfs in the reach downstream of Merwin dam. These figures were generated from daily mean flows reported by USGS on their website for the Ariel gage. These are the same data used for Figure 4.3-4 (AQU3). Figures 1 and 2 should be included side by side as Figure 2.2-36 (Figure 1 as 2.2-36a and Figure 2 as 2.2-36b) with the title "Comparison of daily mean flows at Ariel gage between 1924 and 1931, with those between 1988 and 1997." The last sentence of WTS2 Section 2.2.6.1 should be deleted, and replaced with the following text: "Figure 2.2-36 provides an illustration of how operation of the projects, even under the most recent license terms, reduce the day to day variation in flows between 1000 and 20,000 cfs in the reach downstream of Merwin dam. Where pre-project conditions provided many small floods to this reach, project operation tends to dampen peaks in this flow range, regardless of their size. As a result, the river is less often in contact with the riparian zone; that is, the connectivity of the system is diminished. Because of this fundamental change in flows, transfer		

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				of nutrients and materials between the riparian zone and the river is altered (Meyer et al. 1988; Gregory et al. 1991), changing patterns of productivity in the channel; biological diversity in the riparian zone may be reduced (Pollock et al. 1998; Pinay et al. 1990; Power et al. 1996); and riparian habitat diversity including development of wetlands and side channels is reduced Pollock et al. 1998). The fundamental process upon which habitat and biological diversity in the reach develop is the variation in flows (Pollock 1998 see also citations of Richter 1996, Richter et al. 1997). While non-project developments may have similar, localized impacts in the riparian zone, alteration of short term patterns of variation as illustrated by Figure 2.2-36, and changes in flow variation at other temporal scales, are results of project operations."		

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