FINAL MEMORANDUM

TO: Ray Alvarado — September 26, 2002

FROM: Boyle Engineering Corporation

SUBJECT: **CDSS Daily Yampa Model – Task 5 Full Basin Daily Yampa Model**

Objective

The objective of Task 5 was to create a daily model of the entire Yampa River, in accordance with recommendations out of Task 4. The daily model was to be based on the State's current monthly Yampa River model, which consists of the Phase IIIb product with modifications of Wyoming's uses on the Little Snake River, as of December 2001. Study period for the daily model was set at 1975 through 1996, compared with the monthly model's period of 1909 through 1996. The State provided Boyle Engineering Corporation (Boyle) with the command, time series, and hand-edited files necessary to create the monthly model. Boyle generated the monthly input data set and ran the model in baseflow mode to obtain the Monthly Baseflow file (ym2001Fx.xbm), then modified command files to create a daily model input data set. Results of the subsequent simulation were reviewed and compared with both the monthly simulation and historical data. The simulation, review, and analysis were confined to the Calculated data set.

Approach

The Daily Pattern approach was recommended for developing a daily model of the entire Yampa River Basin in the **CDSS Daily Yampa Model – Task 2 Pilot Study** memorandum. Procedures for developing the daily model were detailed in **CDSS Daily Yampa Model - Task 4 Recommendation for Full Basin Model** memorandum (Task 4 Memorandum). The Daily Pattern approach allows StateMod to calculate each day's baseflow by disaggregating monthly baseflows using the daily pattern of flow at selected historical gages. These "pattern gages" need to be representative of baseflow throughout the Yampa River basin. Selection of the "pattern gages" is discussed in the Task 4 Memorandum.

Monthly Calculated demands were disaggregated to daily demands by connecting the midpoints of the monthly data. Reservoir targets were disaggregated by connecting the end points of monthly data. Instream flow demands were disaggregated by setting them to the average daily value. Daily return flow fractions generated in Task 1 were used, and because daily baseflows were created from monthly, there was no daily baseflow run.

This memorandum describes the methods used to fill the missing monthly and daily gage data needed for the StateMod input files, and the subsequent model calibration efforts. Detailed documentation of the creation of the daily model input files is in **CDSS Daily Yampa Model – Task 6 Daily Model Documentation** memorandum (Task 6 memorandum).

Gage Filling

As discussed in the Task 4 Memorandum, the Daily Pattern approach was recommended for developing a daily model of the entire Yampa River Basin. The Daily Pattern approach requires that the daily pattern data are available throughout the simulation period. There are six gages with complete daily records for the study period of 1975-1996. These are:

- USGS 09239500 – Yampa River at Steamboat Springs, CO
- USGS 09245000 – Elkhead Creek near Elkhead, CO
- USGS 09251000 – Yampa River near Maybell, CO
- USGS 09523000 – Little Snake River near Slater, CO
- USGS 09255000 – Slater Fork near Slater, CO
- USGS 09260000 – Little Snake River near Lily, CO

Additionally, USGS Stations 09238900 – Fish Creek at Upper Station and 09241000 – Elk River at Clark have records for most of the study period. Records for the Fish Creek gage are complete, except for the winter (non-irrigation season) records for water years 1975-1981 and all of 1982. Records for the Elk River gage are complete through 1991; there are no records for water years 1992-1996. Prior to using these gages as pattern gages for the daily model it was necessary to fill the missing records.

Pattern gages recommended in Task 4 are shown in Table 1 and Figure 2.

Table 1
Recommended Pattern Gages

Basin subdivision	Recommended Pattern Gage
Yampa basin above Stagecoach Reservoir	09239500 Yampa River at Steamboat Springs
Yampa basin from gage 09244410 Yampa River near Hayden to Stagecoach Reservoir, excluding Fish Creek and Elk River basins	09239500 Yampa River at Steamboat Springs
Fish Creek basin	09238900 Fish Creek at Upper Station
Elk River basin	09241000 Elk River at Clark,
Mainstem Yampa River below gage 09244410 Yampa River near Hayden	09251000 Yampa River near Maybell
Elkhead Creek	09245000 Elkhead Creek near Elkhead
Fortification Creek	09245000 Elkhead Creek near Elkhead
East Fork Williams Fork	09253000 Little Snake River near Slater
Williams Fork basin excluding East Fork Williams Fork	09251000 Yampa River near Maybell
Mainstem Little Snake River	09253000 Little Snake River near Slater
Slater Creek	09255000 Slater Fork near Slater
Willow Creek	09255000 Slater Fork near Slater

Monthly linear and log relationships were evaluated for the Fish Creek and Elk River gages versus the USGS 09239500 – Yampa River at Steamboat Springs and USGS 09525300 – Little Snake River near Slater. These independent gages were selected for review based upon the correlations reported in the Mixed Station Model's Summary Information file output (*ym2001F.sum*) from the State's ym2001 model (see discussion in the Task 4 Memorandum). The results of each regression relationship are shown in Table 2 and Table 3 below.

The best relationship based upon the predicted r^2 value for each scenario is shaded in the tables. Although the linear model of Fish Creek versus Yampa at Steamboat Springs shows good r^2 values, the linear model occasionally predicted negative flow values for Fish Creek. The monthly log model based upon Fish Creek versus Yampa at Steamboat Springs was the second choice. This is the same monthly regression model used in Phase IIIa. The best monthly model for the Elk River gage was the log model versus Little Snake near Slater. **TSTool** was then used to fill the monthly missing data and ultimately the missing daily data for the pattern gages needed in the Historical Streamflow File (*ym2001D.rid*). Details on the creation of this file can be found in the Task 6 memorandum.

Table 2
R-square Values for USGS 09238900 - Fish Creek at Upper Station

	Independent Gage			
	Yampa at Steamboat Springs		Little Snake near Slater	
	Linear	Log	Linear	Log
January	0.6389	0.5532	0.3261	0.3606
February	0.4587	0.3085	0.1930	0.1693
March	0.7376	0.6408	0.6529	0.5907
April	0.4962	0.4767	0.7855	0.8100
May	0.5543	0.5701	0.3253	0.2438
June	0.8710	0.7961	0.7891	0.7483
July	0.9465	0.9375	0.8892	0.9338
August	0.7600	0.7119	0.7017	0.6996
September	0.8471	0.6854	0.6167	0.6223
October	0.8757	0.8064	0.7305	0.6691
November	0.8568	0.8155	0.7009	0.6920
December	0.7817	0.6633	0.5365	0.5951

Table 3
R-square Values for USGS 09241000 – Elk River at Clark

	Independent Gage			
	Yampa at Steamboat Springs		Little Snake near Slater	
	Linear	Log	Linear	Log
January	0.5018	0.4284	0.5511	0.5604
February	0.4657	0.3785	0.4832	0.4746
March	0.4688	0.6090	0.7848	0.7650
April	0.6859	0.6519	0.7907	0.8395
May	0.8076	0.8183	0.9197	0.9091
June	0.9031	0.9367	0.9113	0.9365
July	0.8847	0.9149	0.9434	0.9576
August	0.7959	0.8190	0.8514	0.8774
September	0.6856	0.7262	0.7115	0.7818
October	0.7314	0.7947	0.8836	0.8998
November	0.6971	0.6573	0.7873	0.7914
December	0.5468	0.5304	0.6692	0.6476

Calibration

Results of the preliminary model were presented to the State on February 21, 2002. These results were generally acceptable. However, it was requested that we investigate three items for potentially improving the calibration. These were:

- Explore alternate pattern gages for Bear River at Toponas, Willow Creek near Dixon, and Little Snake River at Lily. This includes changing the pattern gage or filling the missing daily data for the gage in question and using it as a pattern gage.

- Implement the **TSTool** command "statemodMax()" to develop the monthly Calculated demand file. This command compares two StateMod time series and generates a single time series consisting of the maximum of each. This new feature can be used to create a headgate demand that is the greater of the historical diversion for the month, and a calculated diversion based on crop irrigation water requirement (IWR) and average historical efficiency. The resulting demand is higher than the historical diversion, because if water had been available, the user would have diverted it, up to the amount of his water right. Furthermore, using "statemodMax()" in the Yampa model would automate the inclusion of winter diversions. For non-irrigation months, **Tstool** would select the historical diversion over the irrigation requirement-based demand of zero. Until now, replacement files were hand-created for winter users, combining Calculated demand during the irrigation season with historical diversions during the non-irrigation season.

- Investigate the "daily decrementing" approach to diversion demands, whereby demand on the first day of the month is set to the total monthly demand. On the second day, the monthly demand has been decremented by the first day's diversion, and so on through the month. With this approach, diversions are limited on any given day either by available supply or water right. This also requires that reservoir releases be limited to the average daily irrigation water requirement (IWR) divided by a specified efficiency, supplied as an input parameter in the operational right file.

Alternate Pattern Gages

Bear River near Toponas

The Task 4 Memorandum suggested using Fish Creek as an alternate pattern gage for base flow nodes above Steamboat Springs. Figure 1 shows the four full years of concurrent daily data for Bear River and Fish Creek. This figure illustrates that the two gages have dissimilar patterns, most likely because both gages are heavily influenced by reservoirs immediately upstream. Therefore, it was decided not to use the Fish Creek gage as the pattern gage for the Bear River gage and other baseflow nodes.

Another option for improving the Bear River gage would be to fill the missing data and use it as the pattern gage for the Bear River gage and Stillwater Reservoir baseflow nodes. Records for the Bear River gage end in September 1986 and it is necessary to fill both the monthly and daily data for the remaining study period (1987-1996). The results of the Mixed Station Model's Summary Information file output (*ym2001F.sum*) were reviewed for the Bear River gage. This information indicated that the Yampa River at Steamboat Springs would likely provide the best-fit gage for regression. As with the previous gage filling efforts, monthly linear and log relationships were evaluated for filling the monthly data. The best relationship based upon the predicted r^2 value for each scenario is shaded in Table 4.

Table 4
R-square Values for USGS 09236000 – Bear River near Toponas

	Independent Gage Yampa at Steamboat Springs Linear	Independent Gage Yampa at Steamboat Springs Log
January	0.5769	0.5984
February	0.5279	0.5553
March	0.4005	0.4138
April	0.2666	0.2371
May	0.5408	0.4596
June	0.7358	0.7970
July	0.8155	0.7841
August	0.8127	0.8423
September	0.1424	0.2068
October	0.2468	0.2492
November	0.6498	0.7170
December	0.6185	0.6171

Given that the predictive relationships are not consistently good, and that the contributing flow in this reach is small, it was decided not to pursue improving the calibration of this gage.

Willow Creek near Dixon

Since only four years of daily flow data (1992-1996) need to be filled for the Willow Creek near Dixon gage, it was decided to fill this gage and use it as its own pattern. The Little Snake River near Slater and Slater Fork near Slater were selected for use in filling the Willow Creek gage. The results of the monthly regressions are shown in Table 5.

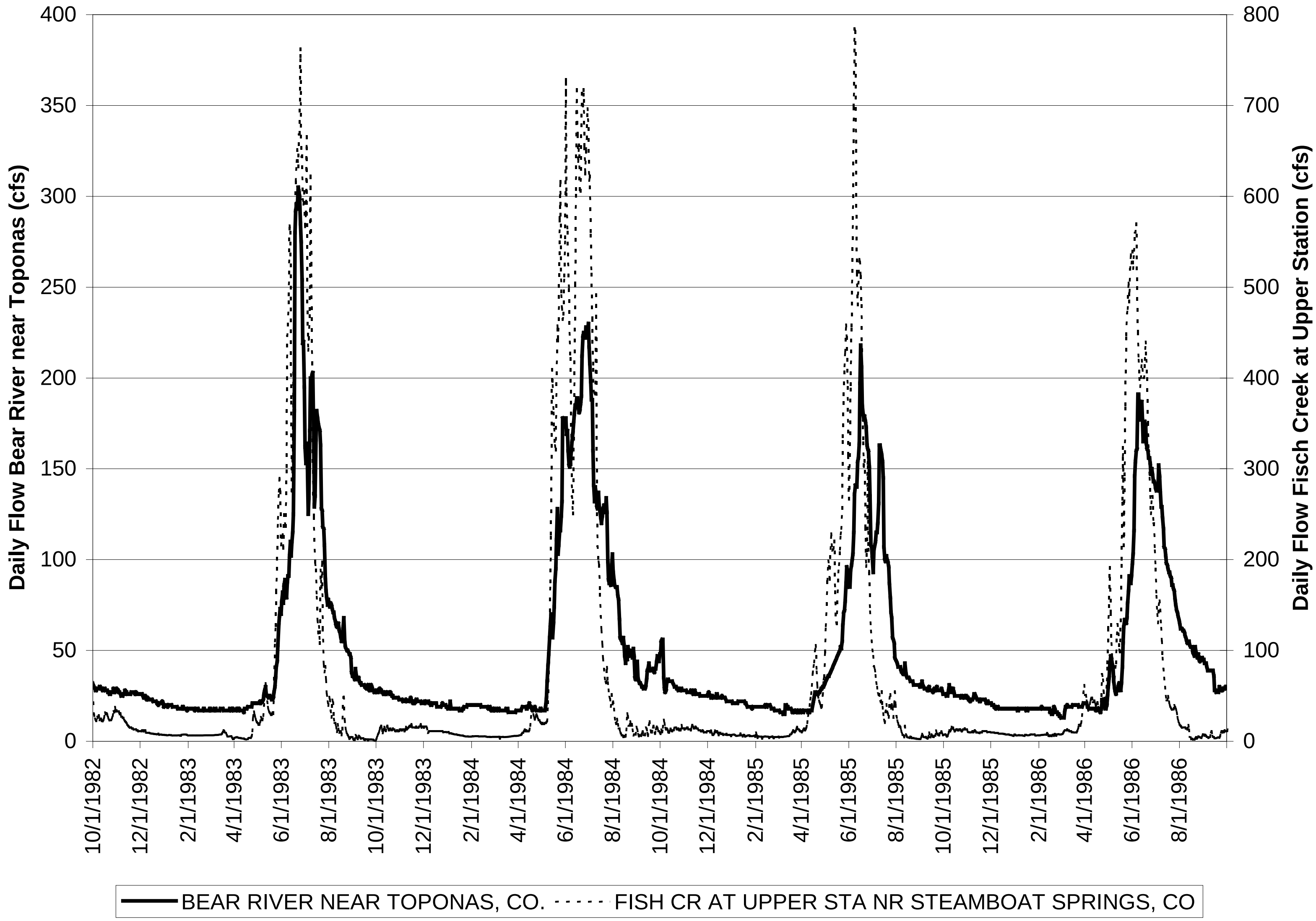

Figure 1 – Comparison of Concurrent Daily Flow Records for Bear River near Toponas and Fish Creek at Upper Station

Table 5
R-square Values for USGS 09258000 – Willow Creek near Dixon

	Independent Gage			
	Little Snake near Slater		Slater Fork near Slater	
	Linear	Log	Linear	Log
January	0.5906	0.4757	0.6560	0.6073
February	0.2531	0.2857	0.4964	0.5207
March	0.4937	0.5242	0.7250	0.6612
April	0.4908	0.4147	0.6937	0.6023
May	0.6961	0.7319	0.8077	0.8409
June	0.9236	0.9156	0.9234	0.9551
July	0.9537	0.9077	0.9649	0.8594
August	0.5657	0.4712	0.4741	0.4325
September	0.7832	0.6861	0.8674	0.7102
October	0.7301	0.7518	0.8775	0.8491
November	0.5959	0.5642	0.8357	0.7706
December	0.5728	0.5248	0.7284	0.6642

Based upon these results, missing monthly data for Willow Creek was filled by regressing it with monthly data for Slater Fork near Slater. The monthly and daily filling commands were added to the **TSTool** *rid.cmd* file and the *crunidy* variable in the *make.cmd* changed to 09235800 for the three baseflow nodes on Willow Creek (540554, 09235800, and 540591).

Little Snake River near Lily

The daily flow records are complete for USGS 09260000 Litle Snake River near Lily, CO. These records were added to the **.rid* file and the *crunidy* variable changed to 09260000 for this node. There are no other baseflow nodes in the immediate vicinity of this node that require changing the pattern gage to 09260000.

StatemodMax()

Calculating a demand that can be used to calibrate to historical diversions and used under a "what if" scenario is extremely difficult. During calibration, it is appropriate in many basins to use historical diversions and average efficiencies. But for future modeling, particularly in water-short situations, the historical diversion and consumption may not represent the full need for water. The approach taken by the State’s monthly model struck a balance by computing each month’s demand for each structure, using the month's historical IWR and average efficiency for that structure. The efficiency was computed for each irrigation season month, based on the structure's diversion history and historical monthly IWR. Because flood irrigation systems typically cannot exceed an efficiency of 60 percent, this value was capped at 60 percent; if calculated efficiency exceeds 60 percent, the crop is probably not being fully supplied, and no more than 60 percent of the diversion is being consumed.

On average, this approach produced good results, although it is recognized that in wet periods (when lower than average efficiency prevails), the "Average Calculated Demand" is less than historical diversions. These periods are offset, however, by dry periods (when higher than average efficiency prevails) in which Average Calculated Demand is greater than historical diversions. Furthermore, because efficiency is assumed never to exceed the practical limit of 60 percent, the approach results in higher-than-historical headgate demands during periods of short supply.

Upon review of the preliminary calibration results, the State suggested that future demand in the Yampa monthly model be computed as the greater of historical diversions and the Average Calculated Demand (contents of the **H.ddm* and **C.ddm* files, developed the traditional way), using **TSTool's** StatemodMax() function. This would simplify handling winter diversions and perhaps provide more realistic demands during wet periods. The total average annual demand for the historical, Average Calculated, and statemodMax() Calculated datasets is shown in Table 6. Average Calculated demand is higher than Historical, because it represents greater demand during historically water-short periods. The StateModMax() demands are higher than both the historical and the Average Calculated because it represents a greater demand during both historically water-rich and water-short periods.

Table 6
Comparison of Total Average Annual Demand (acre-feet)

Dataset	Demand (acre-feet)	Difference from Historical (acre-feet)
Historical	494,314	NA
Average Calculated	508,297	13,983
statemodMax() Calculated	585,343	91,029

Use of StatemodMax()demands was determined inappropriate for the Yampa model for several reasons:

1. Applying the average efficiency to the StatemodMax()-generated demand series would overestimate consumptive use in the basin. When relatively large amounts of water were diverted historically, the system operated with less than average efficiency, which would not be reflected in the model. Unless the Yampa model was revised to include variable efficiencies, it did not make sense to estimate demand in this manner.

2. The approach might be reasonable without the variable efficiency option in a basin where efficiencies do not vary significantly from one year to the next. This is not the case in the Yampa basin

3. Any advantage gained in the process of creating demand files that include winter diverters is more than offset by the error in estimating consumptive use.

In summary, the StatemodMax() command, although appropriate in certain applications, should be considered in the future only if the model is allowed to operate using variable efficiencies.

Daily Decrementing

A preliminary data set implementing the "daily decrementing" option was prepared. This procedure was developed for the Rio Grande Basin and is particularly applicable to systems where users might divert significant quantities of water using flood rights, for relatively few days in a month. With the "daily decrementing" option, demand on the first day of the month is set to the total monthly demand. On the second day, the monthly demand has been decremented by the first day's diversion, and so on through the month. With this approach, diversions early in the month are limited on any given day either by available supply or water right. Later in the month, the decremented demand can limit the amount diverted. This approach requires that reservoir releases be limited to the average daily irrigation water requirement (IWR) divided by a specified efficiency, supplied as an input parameter in the operational right file.

The daily decrementing approach was evaluated in the Yampa basin by DWR personnel, who concluded that this approach too generally satisfies demands early in the month, resulting in no diversion later in the month. This occurs because most of the Yampa River basin is not water short. Because these results were found to be unreasonable for most diverters in most years in this basin, the option was not implemented.

Calibration Results

Results of the Calculated Daily calibration are included in Appendix A. The Calculated Daily simulation is considered good, as based on a comparison of the following:

- Historical monthly flows as compared to the simulated monthly (monthly model) and simulated monthly (daily model) for all the seventeen gages in operation during the study period;
- Historical daily flows as compared to the simulated daily flows for 1977, 1983, and 1988 (representing dry, wet, and average years, respectively); and
- Historical monthly diversions as compared to the simulated daily demand and supply for 1977, 1983, and 1988 for Nickell Ditch and Maybell Canal.

Monthly Gage Flows

A comparison of Historical and Simulated gage flows is shown in Table 7 and in Figures 4 through 22. (Figures are located in Appendix A). As is expected, the simulated gages are not significantly different from the observed values. Average annual differences between gaged and simulated streamflows are less than one percent, with the exceptions being the Fortification Creek gage and Slater Fork near Slater gage. Here, the differences are less than 1.5 percent.

Table 7
Comparison Between Historical and Simulated Average Annual Streamflow Volumes
Daily Calculated Data Set (C) (Acre-Feet/Year) 1975-1996

				Delta (Historical – Simulated)	
Gage ID	**Gage Name**	**Historical**	**Simulated**	**Volume**	**Percent**
09236000	BEAR RIVER NEAR TOPO_FLO	29,640	29,461	179	0.6%
09237500	YAMPA RIVER BELOW ST_FLO	58,412	58,565	-152	-0.3%
09238900	FISH CR AT UPPER STA_FLO	45,061	44,944	117	0.3%
09239500	YAMPA RIVER AT STEAM_FLO	323,541	323,199	341	0.1%
09241000	ELK RIVER AT CLARK, _FLO	231,455	231,502	-48	0.0%
09244410	YAMPA RIVER BELOW DI_FLO	834,590	834,852	-262	0.0%
09245000	ELKHEAD CREEK NEAR E_FLO	42,335	42,335	0	0.0%
09245500	NORTH FORK ELKHEAD C_FLO		15,103		
09246920	FORTIFICATION CREEK _FLO	7,959	8,070	-111	-1.4%
09247600	YAMPA RIVER BELOW CR_FLO	886,533	884,524	2,008	0.2%
09249000	EAST FORK OF WILLIAM_FLO		80,567		
09249200	SOUTH FORK OF WILLIA_FLO	28,080	28,086	-6	0.0%
09249750	WILLIAMS FORK AT MOU_FLO	151,034	151,026	8	0.0%
09251000	YAMPA RIVER NEAR MAY_FLO	1,137,502	1,135,056	2,447	0.2%
09253000	LITTLE SNAKE RIVER N_FLO	166,989	167,138	-148	-0.1%
09255000	SLATER FORK NEAR SLA_FLO	60,938	61,718	-781	-1.3%
09258000	WILLOW CREEK NEAR DI_FLO	7,932	7,909	24	0.3%
09260000	LITTLE SNAKE RIVER N_FLO	412,111	413,606	-1,495	-0.4%
09260050	YAMPA RIVER AT DEERL_FLO	1,559,913	1,557,364	2,549	0.2%

Daily Gage Flows

Historical daily gaged flows were compared to simulated daily flows for 1977, 1983, and 1988 (representing dry, wet, and average years, respectively). The results are graphically presented in Figures 23-34 (1977), 35-46 (1983) and 47-59 (1988). Each of these figures shows that the Daily Yampa model simulates the historical gage flows well. When only one line appears on a graph, it indicates that the Historical and Simulated results are the same at the scale presented. This typically occurs when the pattern gage is the gage itself, or on the same tributary or stem as the gage being reviewed. For example, this can be seen in the figures for Yampa River at Steamboat Springs and Yampa River below Diversion near Hayden. When the pattern gage is more distant from the gage being evaluated, greater differences are seen. This can be seen when looking at Bear River near Toponas (pattern gage is Yampa River at Steamboat Springs) or South Fork of Williams Creek (pattern gage is Yampa River near Maybell).

Daily Diversions

A comparison of average annual historical diversion and simulated diversion is shown in Table 8. The average annual difference between historical and simulated diversions is approximately 2.4

percent. This compares well with the differences seen in the original Calculated calibration results. The disparity is partly due to the difference between historical diversions and Calculated demand.

Historical monthly diversions were compared to the Calculated daily demand and simulated diversion for the Nickell and Maybell ditches for 1977, 1983, and 1988. The results are graphically presented in Figures 60-65. Each of these figures shows that the Daily Yampa model does a good job simulating Calculated daily demand, as limited by water supply. June of 1977 at the Nickell Ditch illustrates that using the average monthly demand rate each day would result in total June diversions below the monthly Calculated demand. When supply peaks in mid-June, the average demand would limit the diversion, which would be further limited by water supply in the last few days of June. With the "midpont-to-midpoint" method of disaggregating demand, the model can divert more water when supply peaks in mid-June, which offsets the late-month deficit with respect to Calculated demand. Because the peak disaggregated daily demand often exceeds average monthly demand, the mid-point to mid-point method of disaggregating monthly flows to daily is considered an improvement over using the monthly average demand rate each day.

Table 8
Comparison Between Average Annual Historical Diversion and Simulated Diversion Volumes
Daily Calculated Data Set (C) (acre-feet/year) 1975-1996

				Delta (Historical - Simulated)	
Structure ID	**Structure Name**	**Historical Diversion**	**Simulated Diversion**	**Volume**	**Percent**
440509	WILSON DITCH	1,092	1,078	14	1.3%
440511	WISCONSIN DITCH	2,436	2,745	-309	-12.7%
440514	WOOLEY & JOHNSON D	542	533	9	1.7%
440517	YAMPA VAL STOCK BR CO D	1,062	1,556	-494	-46.5%
440518	YELLOW JACKET DITCH NO 1	287	215	72	25.1%
440519	YELLOW JACKET DITCH NO 2	200	171	29	14.5%
440522	CRAIG STATION D & PL	10,201	10,201	0	0.0%
440524	AQ DITCH 1	226	195	31	13.7%
440527	AIR LINE IRR D	607	598	9	1.5%
440533	ANDERSON DITCH	219	147	72	32.9%
440538	AVERILL DITCH	203	104	99	48.8%
440541	BAILEY DITCH	778	771	7	0.9%
440570	CARD DITCH	1,285	1,236	49	3.8%
440572	CARRIGAN-AVERILL D	174	69	105	60.3%
440573	CATARACT DITCH	813	552	261	32.1%
440581	CRAIG WATER SUPPLY PL	1,652	1,652	0	0.0%
440583	CROSS MTN PUMP - GROUNDS	2,794	2,825	-31	-1.1%
440584	CROSS MTN PUMP NO 1 & 2	2,543	2,635	-92	-3.6%
440585	CRYSTAL CK DITCH	443	428	15	3.4%
440586	D D & E DITCH	1,817	2,342	-525	-28.9%
440587	D D FERGUSON D NO 2	1,272	1,469	-197	-15.5%
440589	DEEP CUT IRR D	5,907	5,743	164	2.8%

Table 8
Comparison Between Average Annual Historical Diversion and Simulated Diversion Volumes
Daily Calculated Data Set (C) (acre-feet/year) 1975-1996

				Delta (Historical - Simulated)	
Structure ID	**Structure Name**	**Historical Diversion**	**Simulated Diversion**	**Volume**	**Percent**
440590	DEER CK & MORAPOS D	1,197	921	276	23.1%
440593	DENNISON & MARTIN D	301	250	51	16.9%
440601	DUNSTON DITCH	803	794	9	1.1%
440607	EGRY MESA DITCH	2,740	2,626	114	4.2%
440611	ELK TRAIL DITCH	842	296	546	64.8%
440612	ELKHORN IRR DITCH	624	407	217	34.8%
440613	ELLGEN DITCH	264	446	-182	-68.9%
440614	ELLIS & KITCHENS D	246	203	43	17.5%
440628	GIBBONS WILSON JORDAN D	361	281	80	22.2%
440635	GRIESER DITCH	407	398	9	2.2%
440638	HADDEN BASE DITCH	297	202	95	32.0%
440644	HARPER DITCH 1	307	509	-202	-65.8%
440645	HARPER DITCH 2	268	257	11	4.1%
440647	HAUGHEY IRR DITCH	773	582	191	24.7%
440650	HIGHLINE MESA BAKER D	69	246	-177	-256.5%
440651	HIGHLAND DITCH	1,498	1,656	-158	-10.5%
440652	HIGHLAND AKA HIGHLINE D	729	743	-14	-1.9%
440660	J A MARTIN DITCH	304	340	-36	-11.8%
440661	J P MORIN DITCH	472	457	15	3.2%
440670	J W KELLOGG D 2	251	313	-62	-24.7%
440675	JUNIPER MTN TUNNEL	3,375	3,657	-282	-8.4%
440677	K DIAMOND DITCH	2,164	2,089	75	3.5%
440681	LAMB IRR DITCH	312	233	79	25.3%
440687	LILY PARK PUMP NO 1	2,804	2,648	156	5.6%
440688	LITTLE BEAR DITCH	1,718	1,321	397	23.1%
440691	M DITCH	795	939	-144	-18.1%
440692	MARTIN CK DITCH	2,064	1,771	293	14.2%
440694	MAYBELL CANAL	14,603	14,558	45	0.3%
440695	MAYBELL MILL PIPELINE	224	222	2	0.9%
440698	MCDONALD DITCH	284	263	21	7.4%
440699	MCKINLAY DITCH NO 1	816	858	-42	-5.1%
440700	MCKINLAY DITCH NO 2	1,310	1,306	4	0.3%
440702	MCINTYRE DITCH	2,242	2,097	145	6.5%
440706	MILK CK DITCH	813	824	-11	-1.4%
440711	MOCK DITCH	906	930	-24	-2.6%
440716	MULLEN DITCH	186	320	-134	-72.0%

Table 8
Comparison Between Average Annual Historical Diversion and Simulated Diversion Volumes
Daily Calculated Data Set (C) (acre-feet/year) 1975-1996

				Delta (Historical - Simulated)	
Structure ID	**Structure Name**	**Historical Diversion**	**Simulated Diversion**	**Volume**	**Percent**
440723	NICHOLS DITCH NO 1	922	923	-1	-0.1%
440724	NORVELL DITCH	1,779	1,913	-134	-7.5%
440729	PATRICK SWEENEY D	1,926	1,932	-6	-0.3%
440731	PECK IRRIG D	947	1,001	-54	-5.7%
440735	PINE CK DITCH	649	552	97	14.9%
440740	RATCLIFF DITCH	622	591	31	5.0%
440747	ROBY D AKA ROBY D NO 1	183	143	40	21.9%
440748	ROBY DITCH NO 2	198	163	35	17.7%
440749	ROUND BOTTOM D NO 1	228	244	-16	-7.0%
440750	ROUND BOTTOM D NO 2	291	289	2	0.7%
440751	ROUND BOTTOM DITCH	619	670	-51	-8.2%
440763	SMITH DITCH	1,049	1,204	-155	-14.8%
440765	SOUTH SIDE DITCH	792	808	-16	-2.0%
440770	STARR IRRIG DITCH	213	205	8	3.8%
440778	SUNBEAM DITCH	1,672	1,651	21	1.3%
440785	TIPTON IRR DITCH	731	666	65	8.9%
440786	TISDEL D NO 2	1,747	1,703	44	2.5%
440790	UTLEY DITCH	927	889	38	4.1%
440801	CROSS MTN PUMP - GUESS	1,325	1,253	72	5.4%
440806	ELLGEN NO 2 DITCH	286	315	-29	-10.1%
440812	HART DITCH	327	193	134	41.0%
440814	HIGHLINE DITCH	466	547	-81	-17.4%
440820	LOWRY SEELEY PUMP	1,195	1,190	5	0.4%
440821	MACK DITCH	328	380	-52	-15.9%
440828	MOCK DITCH NO 3	423	426	-3	-0.7%
440830	OLD SWEENEY DITCH	1,478	1,448	30	2.0%
440863	HENRY SWEENEY DITCH	1,616	1,630	-14	-0.9%
440998	DRY COTTONWOOD DITCH	410	349	61	14.9%
441122	VAUGHN PUMP	1,002	669	333	33.2%
442214	WISE DITCH ALT PT	235	407	-172	-73.2%
540507	BEELER DITCH	1,089	909	180	16.5%
540531	HEELEY DITCH	2,491	2,808	-317	-12.7%
540532	HOME SUPPLY DITCH	1,120	977	143	12.8%
540543	LUCHINGER DITCH	916	775	141	15.4%
540548	MORGAN & BEELER D	1,256	1,060	196	15.6%
540549	MORGAN SLATER DITCH	749	881	-132	-17.6%

Table 8
Comparison Between Average Annual Historical Diversion and Simulated Diversion Volumes
Daily Calculated Data Set (C) (acre-feet/year) 1975-1996

				Delta (Historical - Simulated)	
Structure ID	**Structure Name**	**Historical Diversion**	**Simulated Diversion**	**Volume**	**Percent**
540554	PERKINS FOX DITCH	474	538	-64	-13.5%
540555	PERKINS IRR DITCH	892	1,248	-356	-39.9%
540564	SALISBURY DITCH	662	553	109	16.5%
540568	SLATER FORK DITCH	925	850	75	8.1%
540570	SLATER PARK DITCH NO 1	563	514	49	8.7%
540571	SLATER PARK DITCH NO 2	301	187	114	37.9%
540572	SLATER PARK DITCH NO 3	348	172	176	50.6%
540574	SLATER PARK DITCH NO 5	617	377	240	38.9%
540583	TROWEL DITCH	3,150	3,248	-98	-3.1%
540591	WILLOW CK DITCH	1,929	1,977	-48	-2.5%
540592	WILSON DITCH	420	365	55	13.1%
540594	WOODBURY DITCH	772	1,054	-282	-36.5%
550504	ESCALANTA PUMP 2	813	838	-25	-3.1%
550506	MAJORS PUMP NO 2	2,035	2,066	-31	-1.5%
550507	NINE MILE IRR DITCH	894	873	21	2.3%
550508	NINE MILE IRR PL	753	701	52	6.9%
550513	VISINTAINER DITCH	677	651	26	3.8%
550519	RINKER PUMP D	628	638	-10	-1.6%
550537	LEFEVRE NO 1 PUMP	1,488	1,350	138	9.3%
570508	BROCK DITCH	1,979	2,039	-60	-3.0%
570510	CARY DITCH CO DITCH	3,226	3,124	102	3.2%
570512	COLO UTILITIES D & PL	4,919	4,919	0	0.0%
570513	CONNELL DITCH	343	362	-19	-5.5%
570517	DAVID M CHAPMAN DITCH	697	695	2	0.3%
570519	DENNIS & BLEWITT D	960	1,025	-65	-6.8%
570524	EAST SIDE DITCH	499	517	-18	-3.6%
570525	EAST SIDE DITCH 2	624	851	-227	-36.4%
570535	ERWIN IRRIGATING DITCH	515	485	30	5.8%
570539	GIBRALTAR DITCH	7,765	7,364	401	5.2%
570544	HIGHLAND DITCH	924	929	-5	-0.5%
570545	HOMESTEAD DITCH	1,031	1,063	-32	-3.1%
570555	LAST CHANCE DITCH	882	854	28	3.2%
570561	MALE MOORE CO DITCH	523	469	54	10.3%
570563	MARSHALL ROBERTS DITCH	3,923	3,927	-4	-0.1%
570576	ORNO DITCH	544	559	-15	-2.8%
570579	R E CLARK DITCH	817	887	-70	-8.6%

Table 8
Comparison Between Average Annual Historical Diversion and Simulated Diversion Volumes
Daily Calculated Data Set (C) (acre-feet/year) 1975-1996

Structure ID	Structure Name	Historical Diversion	Simulated Diversion	Delta (Historical - Simulated) Volume	Delta (Historical - Simulated) Percent
570584	SADDLE MOUNTAIN DITCH	603	617	-14	-2.3%
570592	SHELTON DITCH	7,599	7,042	557	7.3%
570608	TROUT CREEK DITCH 3	904	893	11	1.2%
570609	TROUT CREEK DITCH 2	335	324	11	3.3%
570611	WALKER IRRIG DITCH	5,609	5,590	19	0.3%
570622	WILLIAMS IRRIG DITCH	2,603	2,592	11	0.4%
570623	WILLIAMS PARK DITCH	775	862	-87	-11.2%
570635	KOLL DITCH	1,080	1,075	5	0.5%
574629	RICH DITCH	1,470	1,469	1	0.1%
580500	ACTON D	1,676	1,558	118	7.0%
580506	ALLEN BASIN SUPPLY D	266	229	37	13.9%
580508	ALPHA DITCH	1,119	1,035	84	7.5%
580530	BAXTER DITCH	2,129	2,209	-80	-3.8%
580532	BEAVER CREEK D	364	356	8	2.2%
580539	BIG MESA DITCH	4,340	3,855	485	11.2%
580541	BIRD DITCH	1,694	1,650	44	2.6%
580549	BORLAND VAIL DITCH	299	557	-258	-86.3%
580556	BRINKER CREEK DITCH	316	282	34	10.8%
580559	BROOKS DITCH	644	648	-4	-0.6%
580561	BRUMBACK DITCH	404	388	16	4.0%
580564	BUCKINGHAM MANDALL D	2,332	2,463	-131	-5.6%
580568	BURNETT DITCH	1,297	1,349	-52	-4.0%
580569	BURNT MESA D	303	264	39	12.9%
580574	C R BROWN MOFFAT COAL D	326	315	11	3.4%
580577	CAMPBELL DITCH	1,031	1,029	2	0.2%
580582	CHARLES & A LEIGHTON D	444	398	46	10.4%
580583	CHARLES H KEMMER D	232	249	-17	-7.3%
580588	CLARK & BURKE DITCH	655	649	6	0.9%
580589	COAL CREEK DITCH	497	441	56	11.3%
580590	COLEMAN DITCH	141	271	-130	-92.2%
580591	COLLINS DITCH	838	828	10	1.2%
580599	CULLEN DITCH 2	882	822	60	6.8%
580604	DAY DITCH	175	306	-131	-74.9%
580612	DEVER D	568	546	22	3.9%
580618	DUQUETTE DITCH	1,683	1,613	70	4.2%
580622	EGERIA DITCH	1,588	1,562	26	1.6%

Table 8
Comparison Between Average Annual Historical Diversion and Simulated Diversion Volumes
Daily Calculated Data Set (C) (acre-feet/year) 1975-1996

				Delta (Historical - Simulated)	
Structure ID	**Structure Name**	**Historical Diversion**	**Simulated Diversion**	**Volume**	**Percent**
580623	EKHART DITCH	1,129	1,129	0	0.0%
580626	ELK VALLEY DITCH CO. D.	2,596	2,553	43	1.7%
580627	ENTERPRISE DITCH	2,363	2,149	214	9.1%
580628	EXCELSIOR DITCH	376	353	23	6.1%
580633	FELIX BORGHI DITCH	1,203	1,166	37	3.1%
580634	FERGUSON DITCH	893	858	35	3.9%
580640	FIRST CHANCE DITCH	531	502	29	5.5%
580642	FISH CR MUN WATER INTAKE	1,990	1,990	0	0.0%
580643	FIX DITCH	1,510	1,588	-78	-5.2%
580649	FRANZ DITCH	1,721	1,675	46	2.7%
580662	GRAHAM & BENNETT D	1,549	1,537	12	0.8%
580663	GREER DITCH	410	409	1	0.2%
580665	GUIDO DITCH	303	280	23	7.6%
580684	HERNAGE & KOLBE DITCH	1,048	1,042	6	0.6%
580685	HIGH MESA IRR D	366	439	-73	-19.9%
580687	HIGHLINE BEAVER DITCH	386	369	17	4.4%
580694	HOOVER JACQUES DITCH	2,270	2,190	80	3.5%
580695	HOT SPGS CR HIGHLINE D	630	623	7	1.1%
580714	KELLER DITCH	2,100	2,096	4	0.2%
580717	KINNEY DITCH	1,008	980	28	2.8%
580721	L L WILSON D	464	462	2	0.4%
580722	LAFON DITCH	412	431	-19	-4.6%
580728	LARSON DITCH	665	634	31	4.7%
580730	LATERAL A DITCH	588	760	-172	-29.3%
580731	LAUGHLIN DITCH	270	317	-47	-17.4%
580738	LINDSEY DITCH	1,259	1,500	-241	-19.1%
580749	LOWER PLEASANT VALLEY D	584	553	31	5.3%
580756	LYON DITCH 2	455	438	17	3.7%
580763	MANDALL DITCH	4,590	4,376	214	4.7%
580767	MAYFLOWER DITCH	397	364	33	8.3%
580777	MILL DITCH 1	482	481	1	0.2%
580782	MOODY DITCH	275	236	39	14.2%
580783	MORIN DITCH	2,647	2,612	35	1.3%
580791	MUDDY DITCH 1	306	280	26	8.5%
580798	NICKELL DITCH	916	995	-79	-8.6%
580801	NORTH HUNT CREEK DITCH	332	374	-42	-12.7%

Table 8
Comparison Between Average Annual Historical Diversion and Simulated Diversion Volumes
Daily Calculated Data Set (C) (acre-feet/year) 1975-1996

Structure ID	Structure Name	Historical Diversion	Simulated Diversion	Delta (Historical - Simulated) Volume	Percent
580805	OAK CREEK DITCH	748	719	29	3.9%
580807	OAK DALE DITCH	588	580	8	1.4%
580808	OAKTON DITCH	1,081	1,113	-32	-3.0%
580809	OLD CABIN DITCH	228	265	-37	-16.2%
580811	OLIGARCHY DITCH	228	259	-31	-13.6%
580813	PALISADE DITCH	504	500	4	0.8%
580821	PENNSYLVANIA DITCH	1,579	1,509	70	4.4%
580826	PONY CREEK D	341	333	8	2.3%
580830	PRIEST DITCH	251	182	69	27.5%
580844	SAGE HEN DITCH	416	435	-19	-4.6%
580847	SAND CREEK DITCH	337	389	-52	-15.4%
580863	SIMON DITCH	1,878	1,997	-119	-6.3%
580866	SNOW BANK DITCH	756	718	38	5.0%
580868	SODA CREEK DITCH	1,886	1,847	39	2.1%
580872	SOUTH SIDE DITCH	667	668	-1	-0.1%
580879	STAFFORD DITCH	2,370	2,347	23	1.0%
580895	SUNNYSIDE DITCH 1	925	902	23	2.5%
580897	SUTTLE DITCH	2,963	2,962	1	0.0%
580908	TRULL MORIN DITCH	470	465	5	1.1%
580914	UNION DITCH	1,293	871	422	32.6%
580915	UPPER ELK RIVER D CO. D	1,008	1,004	4	0.4%
580916	UPPER PLEASANT VALLEY D	1,179	1,236	-57	-4.8%
580917	VAIL SAVAGE DITCH	420	507	-87	-20.7%
580920	WALTON CREEK DITCH	9,739	9,107	632	6.5%
580922	WEISKOPF DITCH	611	582	29	4.7%
580924	WELCH & MONSON D	227	237	-10	-4.4%
580928	WHEELER BROS DITCH	510	488	22	4.3%
580933	WHIPPLE DITCH	521	529	-8	-1.5%
580939	WINDSOR DITCH	432	432	0	0.0%
580943	WOODCHUCK D SODA CK HG	242	552	-310	-128.1%
580944	WOOLERY DITCH	2,095	2,089	6	0.3%
580945	WOOLEY DITCH	1,190	1,168	22	1.8%
580980	GABIOUD DITCH	467	408	59	12.6%
581021	LEE IRRIGATION D	928	885	43	4.6%
581035	NORTH SIDE DITCH	587	561	26	4.4%
581074	ROSSI HIGHLINE DITCH	513	465	48	9.4%

Table 8
Comparison Between Average Annual Historical Diversion and Simulated Diversion Volumes
Daily Calculated Data Set (C) (acre-feet/year) 1975-1996

Structure ID	Structure Name	Historical Diversion	Simulated Diversion	Delta (Historical - Simulated) Volume	Delta (Historical - Simulated) Percent
581085	MILL CREEK DITCH	483	612	-129	-26.7%
581583	STAGECOACH HYDROELECTRIC	14,814	14,696	118	0.8%
582374	STEAMBOAT SKI SNOW PL	156	156	0	0.0%
584630	Dome_Creek_Ditch	321	228	93	29.0%
584684	SARVIS DITCH	813	792	21	2.6%
584685	STILLWATER DITCH	4,548	4,352	196	4.3%
584686	Stillwater_Colo	1,710	1,625	85	5.0%
990528	Cheyenne_City	10,093	10,093	0	0.0%
990533	Wyoming_Irrig1	32,155	31,448	707	2.2%
990534	Wyoming_Irrig2	32,155	30,824	1,331	4.1%
990535	Wyoming_Irrig3	7,905	7,667	238	3.0%
990536	Wyoming_Irrig4	194	192	2	1.0%
990537	Wyoming_M&I	361	345	16	4.4%
990538	New_Wyo_Ag	0	0	0	0.0%
44_ADY012	ADY012_ElkheadCreek	1,828	1,549	279	15.3%
44_ADY013	ADY013_YampaRbelCraig	5,092	5,078	14	0.3%
44_ADY014	ADY014_EFkWilliamsFork	6,316	6,262	54	0.9%
44_ADY015	ADY015_SFkWilliamsFork	2,889	2,889	0	0.0%
44_ADY016	ADY016_WilliamsFork	4,330	4,320	10	0.2%
44_ADY017	ADY017_MilkCrabvGSpring	1,832	1,193	639	34.9%
44_ADY018	ADY018_MilkCreek	4,086	3,988	98	2.4%
44_ADY019	ADY019_YampaRnrMaybell	2,892	2,891	1	0.0%
44_ADY025	ADY025_YampaR@DeerLodge	2,346	2,336	10	0.4%
44_AMY001	44_AMY001_YampaRbelCraig	742	742	0	0.0%
44_FDP001	44_FDP_WD_44	0	0	0	0.0%
44_WSA	44_WSA_EDFdemand	0	0	0	0.0%
54_ADY020	ADY020_LSnakeRnrSlater	5,832	4,925	907	15.6%
54_ADY021	ADY021_LSnakeRabvSlater	3,002	2,649	353	11.8%
54_ADY022	ADY022_SlaterCreek	7,085	5,508	1,577	22.3%
54_ADY023	ADY023_LSnakeabvDryGlch	15,120	13,380	1,740	11.5%
55_ADY024	ADY024_LSnakeRnrLily	1,929	1,892	37	1.9%
55_ADY026	ADY026_YampaR@GreenR	255	254	1	0.4%
55_AMY003	55_AMY003_LSnakeRnrLily	13	13	0	0.0%
55_FDP001	Fu_Dev_55	0	0	0	0.0%
56_ADY027	ADY027_GreenRiver	7,894	7,894	0	0.0%
56_FDP001	Fu_Dev_56	0	0	0	0.0%

Table 8
Comparison Between Average Annual Historical Diversion and Simulated Diversion Volumes
Daily Calculated Data Set (C) (acre-feet/year) 1975-1996

				Delta (Historical - Simulated)	
Structure ID	**Structure Name**	**Historical Diversion**	**Simulated Diversion**	**Volume**	**Percent**
57_ADY009	ADY009_TroutCreek	1,419	1,417	2	0.1%
57_ADY010	ADY010_YampaRnrHayden	497	497	0	0.0%
57_ADY011	ADY011_YampaRabvElkhead	1,453	1,450	3	0.2%
57_AMY001	57_AMY001_YampaRabCraig	484	484	0	0.0%
57_FDP001	Fu_Dev_57	0	0	0	0.0%
57_NAG01	Nu_Ag_Dev	0	0	0	0.0%
57_NMID01	Nu_Fu_M&I	0	0	0	0.0%
57_NPWR01	Nu_Fu_Pwr	0	0	0	0.0%
58_ADY001	ADY001_UpperBearRiver	877	875	2	0.2%
58_ADY002	ADY002_ChimneyCreek	2,853	2,770	83	2.9%
58_ADY003	ADY003_BearRabvHuntCk	2,643	2,640	3	0.1%
58_ADY004	ADY004_BearRabvStagecoa	1,981	1,979	2	0.1%
58_ADY005	ADY005_YampaRabvSteambt	3,486	3,481	5	0.1%
58_ADY006	ADY006_ElkRivernrClark	1,826	1,817	9	0.5%
58_ADY007	ADY007_MiddleElkRiver	3,183	3,174	9	0.3%
58_ADY008	ADY008_LowerElkRiver	2,015	2,008	7	0.3%
58_AMY001	58_AMY001_Yampa@Steamboa	1,342	1,342	0	0.0%
58_FDP001	Fu_Dev_58	0	0	0	0.0%
	TOTAL	**494,314**	**482,376**	**11,938**	**2.4%**

Water Balance

Table 9 summarizes the water balance for the Yampa River basin. There are small differences in inflow and outflow on an annual basis. On average, the delta between inflow and outflow is approximately 5 acre-feet, indicating that the model correctly conserves mass.

Comments

StatemodMax()

Care must be taken when using the **TSTool** command “statemodMax()”. As shown in Table 6, the Calculated demand created using the statemodMax() command can result in a much larger demand than one would assume. In this basin, it is not compatible with an average efficiency model. Because there is no "standard" approach to estimating demands, it is recommended that a user recognize the limitations of any approach selected, and develop a demand that is consistent with natural and operating characteristics of the basin, as well as the need of a particular "what if". As described previously, the Average Calculate demand, not the StatemodMax() approach was estimated to best serve the current needs of the State for the Yampa model and has been implemented.

General

StateMod is highly flexible and allows several different approaches to daily operation. The user may supply daily input for some or all the variables, or may choose to disaggregate monthly values to daily by various means. The user must have a good understanding of the basin in order to choose the appropriate method. As an example, it was found that the "daily decrementing" approach to developing daily demands was unsuitable for the Daily Yampa model. However, in other basins, particularly water-short basins such as the Rio Grande, the model may produce much better results.

The current version of StateMod, and its associated tools (DMI Utilities and Mixed-Station Model), makes it much simpler for the user to convert a monthly model to a daily model, without the burden of developing a daily model from daily data.

Boyle has found that for the Yampa River Basin, careful selection of pattern gages takes precedence over the selection of method to develop the daily demand pattern.

Table 9
Water Balance Summary
Daily Calculated Data Set (C) (acre-feet/year) 1975-1996

Year	Stream Inflow	Diversions	Return Flows	Reservoir Evaporation	Reservoir Change in Storage	Stream Outflow	Total Inflows	Total Outflows	Total Inflow - Total Outflow	CU (1)
	(+)	(-)	(+)	(-)	(-)	(-)	N/A	N/A	N/A	N/A
1975	2,203,257	423,466	287,470	9,491	25,749	2,032,020	2,490,727	2,490,725	2	136,065
1976	1,484,619	432,158	306,050	9,630	(2,758)	1,351,633	1,790,669	1,790,664	5	137,546
1977	705,395	428,618	313,793	9,529	(4,999)	586,035	1,019,188	1,019,183	5	125,367
1978	2,597,858	473,587	333,440	9,644	7,738	2,440,319	2,931,298	2,931,288	10	148,665
1979	2,289,797	460,999	321,832	10,564	5,017	2,135,045	2,611,629	2,611,624	4	149,494
1980	2,239,262	457,825	330,957	10,547	677	2,101,171	2,570,219	2,570,219	(1)	139,372
1981	1,054,682	411,467	291,885	10,797	2,933	921,367	1,346,567	1,346,564	3	130,546
1982	2,433,589	422,557	297,127	10,911	9,468	2,287,774	2,730,716	2,730,709	7	139,471
1983	3,018,456	361,235	245,606	11,007	(146)	2,891,964	3,264,063	3,264,060	3	124,304
1984	3,739,508	364,551	258,572	11,005	152	3,622,370	3,998,081	3,998,078	2	120,501
1985	2,810,317	435,302	303,024	11,000	(1,426)	2,668,464	3,113,341	3,113,339	2	142,158
1986	3,064,674	456,744	326,157	10,974	1,416	2,921,692	3,390,831	3,390,826	5	144,024
1987	1,476,717	491,724	345,676	10,935	(5,208)	1,324,942	1,822,393	1,822,392	1	152,425
1988	1,737,416	585,231	430,687	10,839	(1,160)	1,573,191	2,168,104	2,168,100	3	168,897
1989	1,176,319	590,416	433,129	11,821	25,757	981,452	1,609,448	1,609,445	4	170,629
1990	1,271,881	560,463	406,173	11,878	610	1,105,095	1,678,054	1,678,045	9	166,122
1991	1,478,559	516,316	371,494	11,990	3,569	1,318,169	1,850,053	1,850,045	8	157,748
1992	1,100,150	516,370	378,986	11,942	(5,803)	956,624	1,479,136	1,479,133	3	151,083
1993	2,270,210	583,563	422,515	11,862	(2,058)	2,099,357	2,692,725	2,692,724	0	172,669
1994	1,218,939	581,598	430,270	11,667	(7,966)	1,063,902	1,649,209	1,649,201	8	164,260
1995	2,658,365	465,049	329,415	11,973	19,337	2,491,405	2,987,780	2,987,764	16	148,419
1996	2,649,426	584,811	431,084	12,055	(4,631)	2,488,266	3,080,510	3,080,502	9	167,194
Ave	2,030,882	482,002	345,243	11,003	3,012	1,880,103	2,376,125	2,376,119	5	148,043

1) Consumptive Use (CU) = Diversion * Efficiency + Reservoir Evaporation

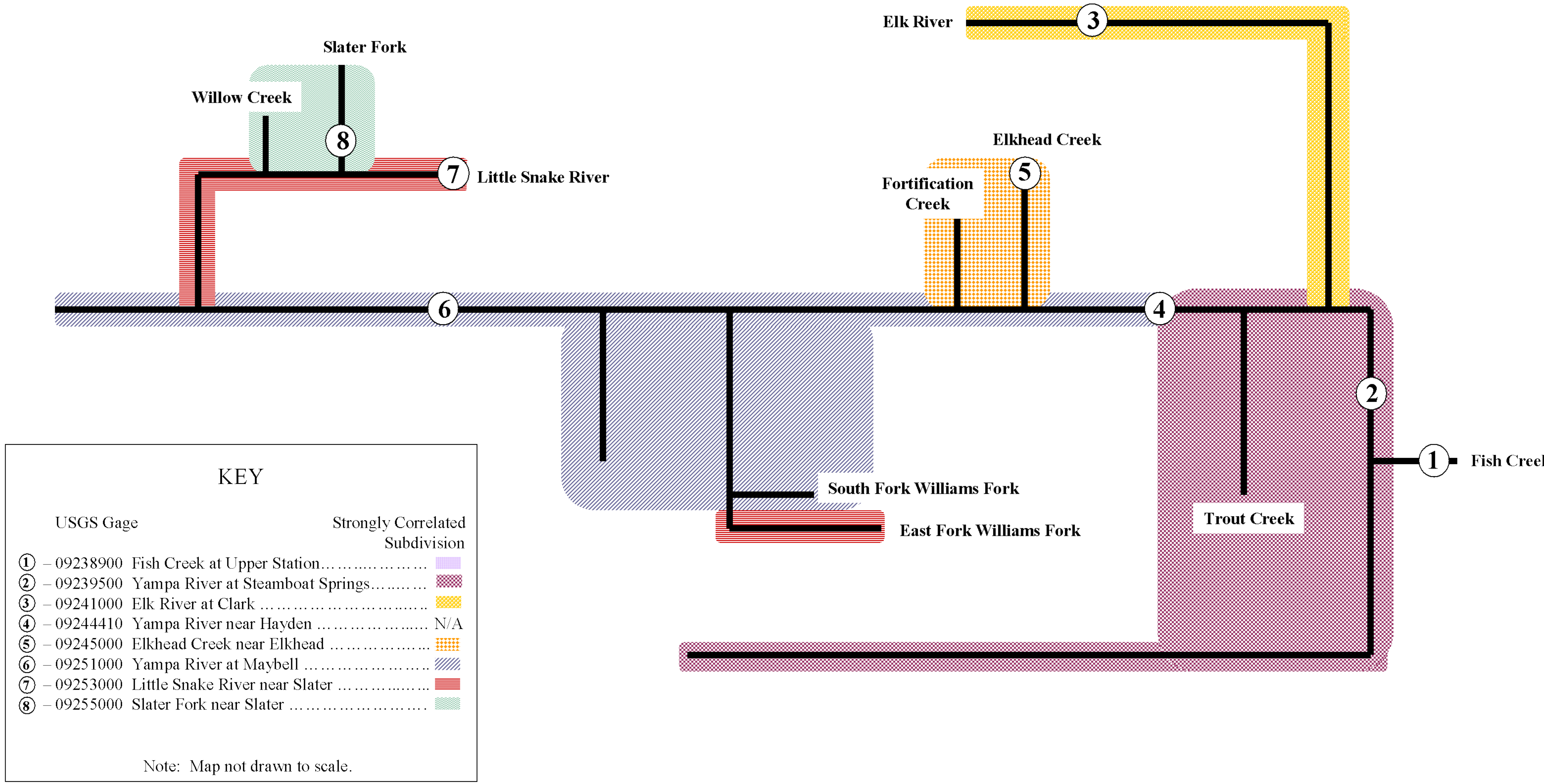

Figure 2 – Initial Application of Daily Pattern Gages

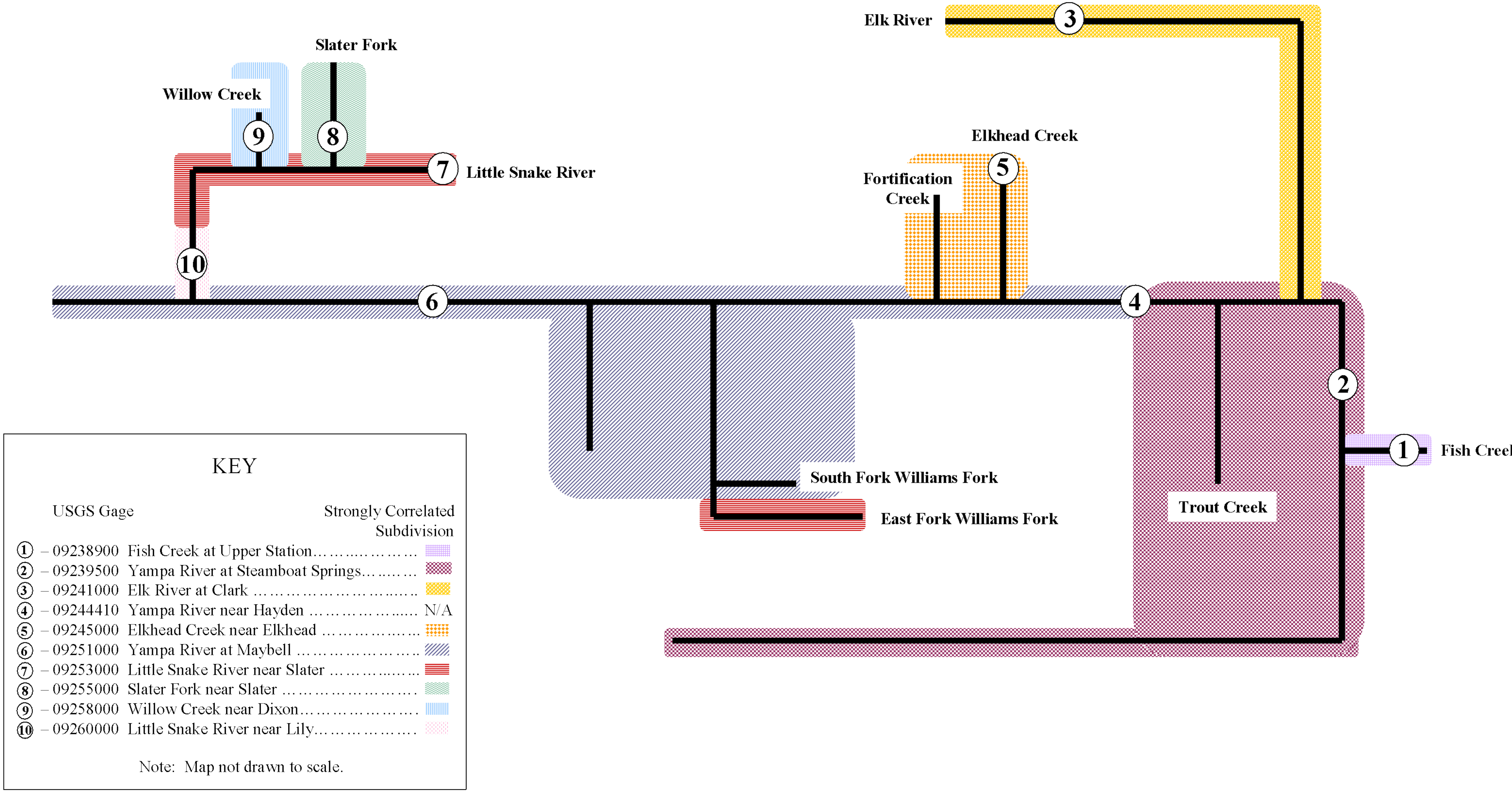

Figure 3 – Final Application of Daily Pattern Gages

Appendix A

Calibration Results

Historical versus Simulated Monthly Flows

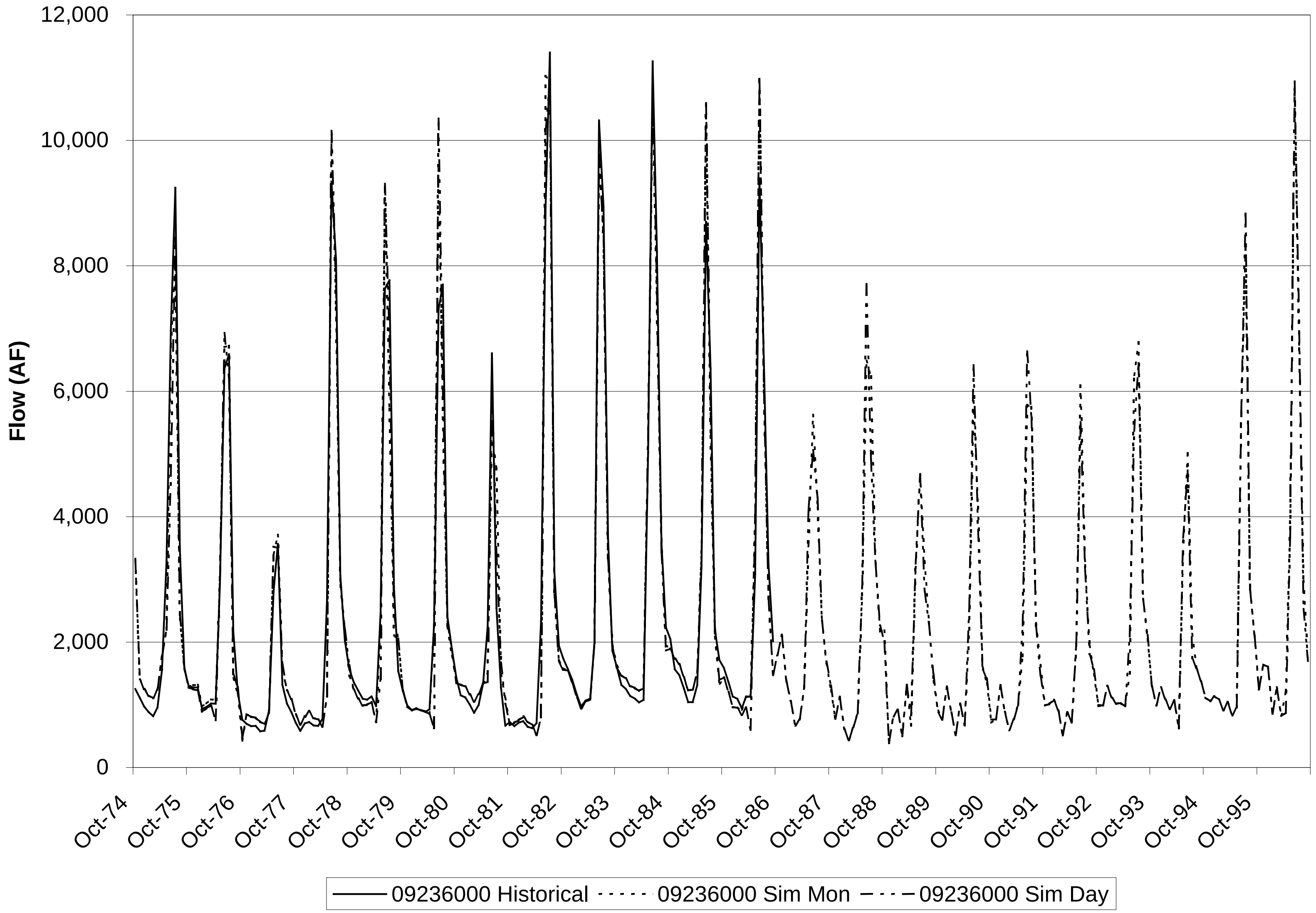

Figure 4 - Historical versus Simulated Monthly Flows, USGS 09236000 - Bear River near Toponas

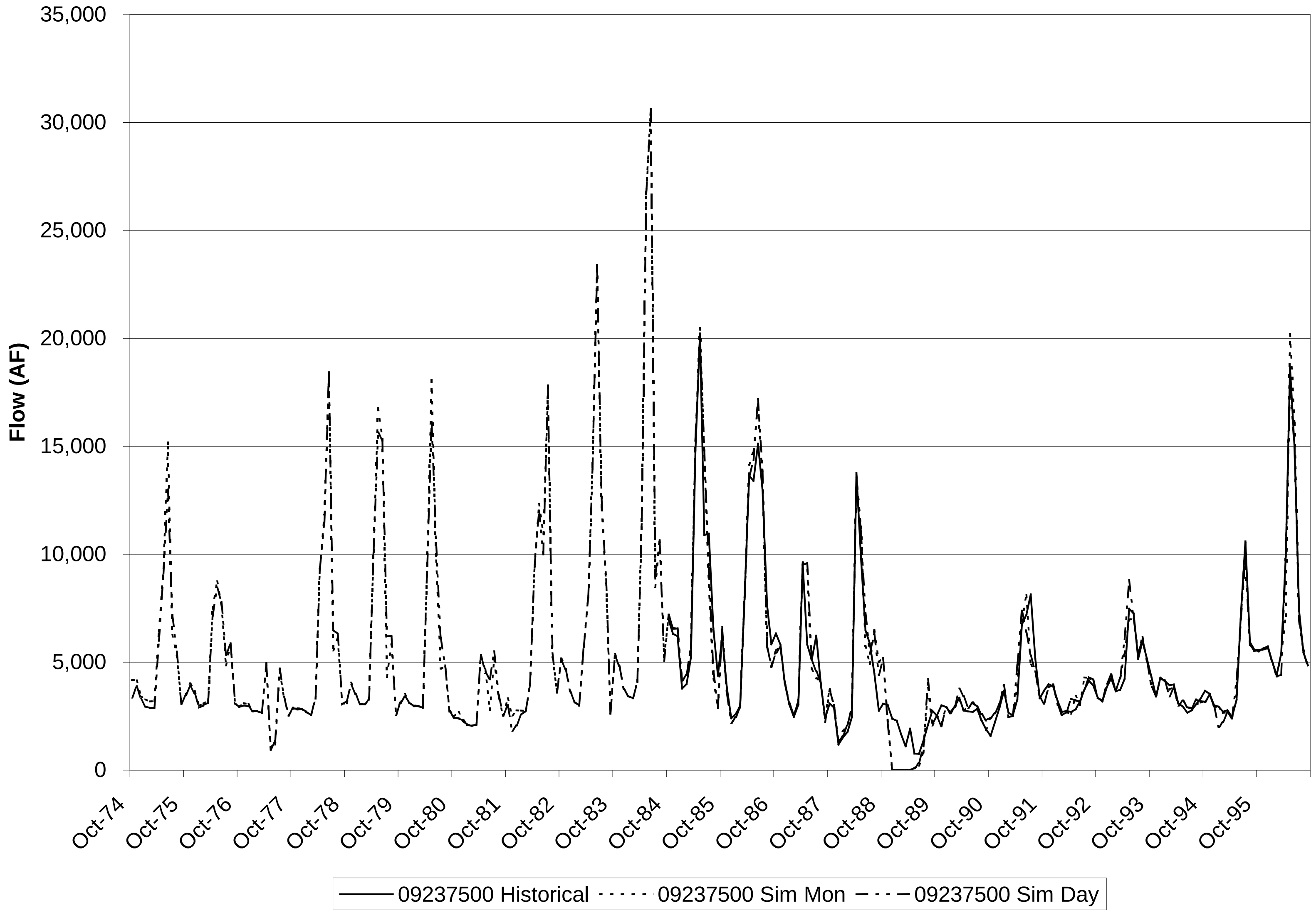

Figure 5 - Historical versus Simulated Monthly Flows, USGS, 09237500 - Yampa River below Stagecoach Reservoir

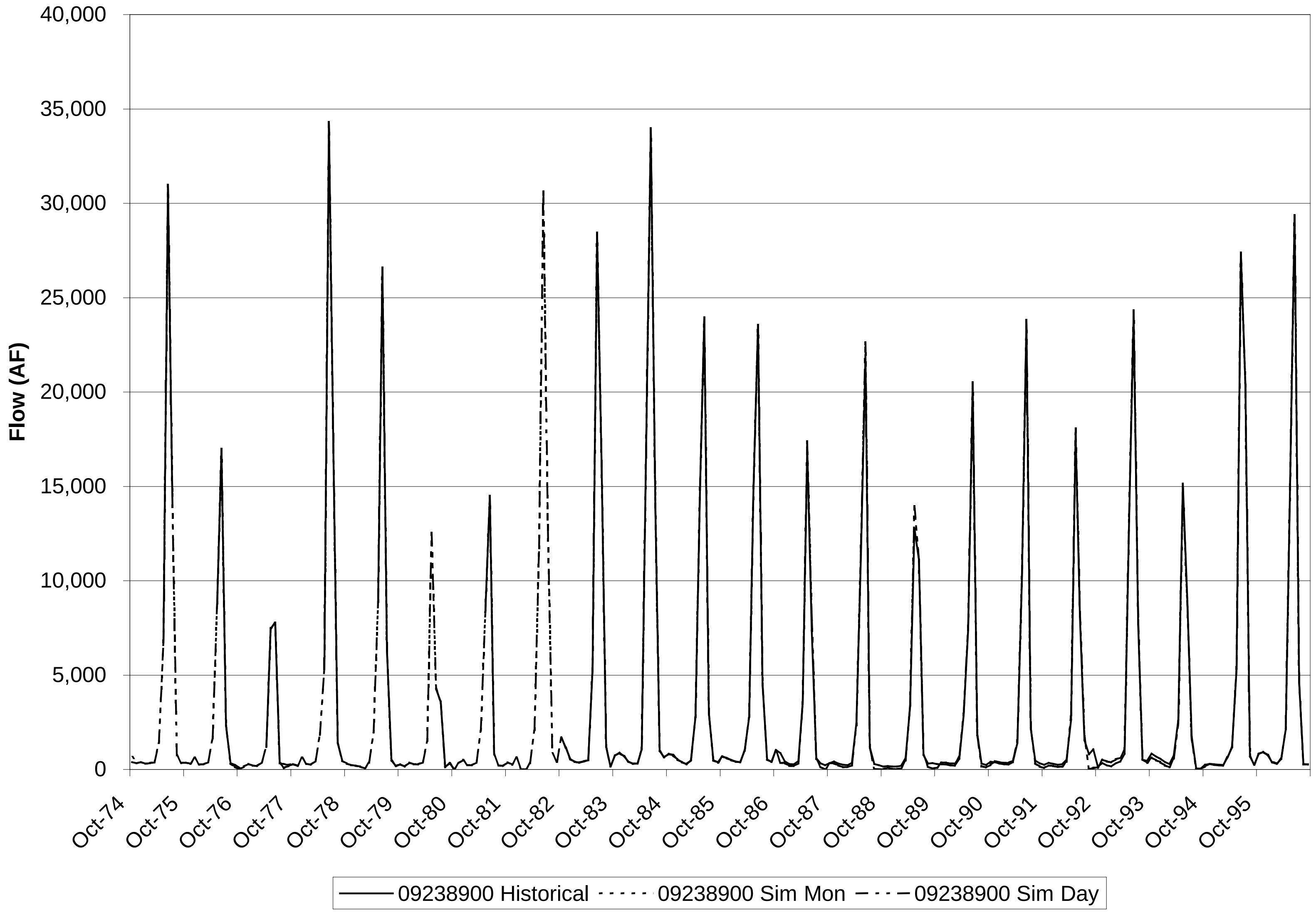

Figure 6 - Historical versus Simulated Monthly Flows, USGS 09238900 - Fish Creek at Upper Station near Steamboat Springs

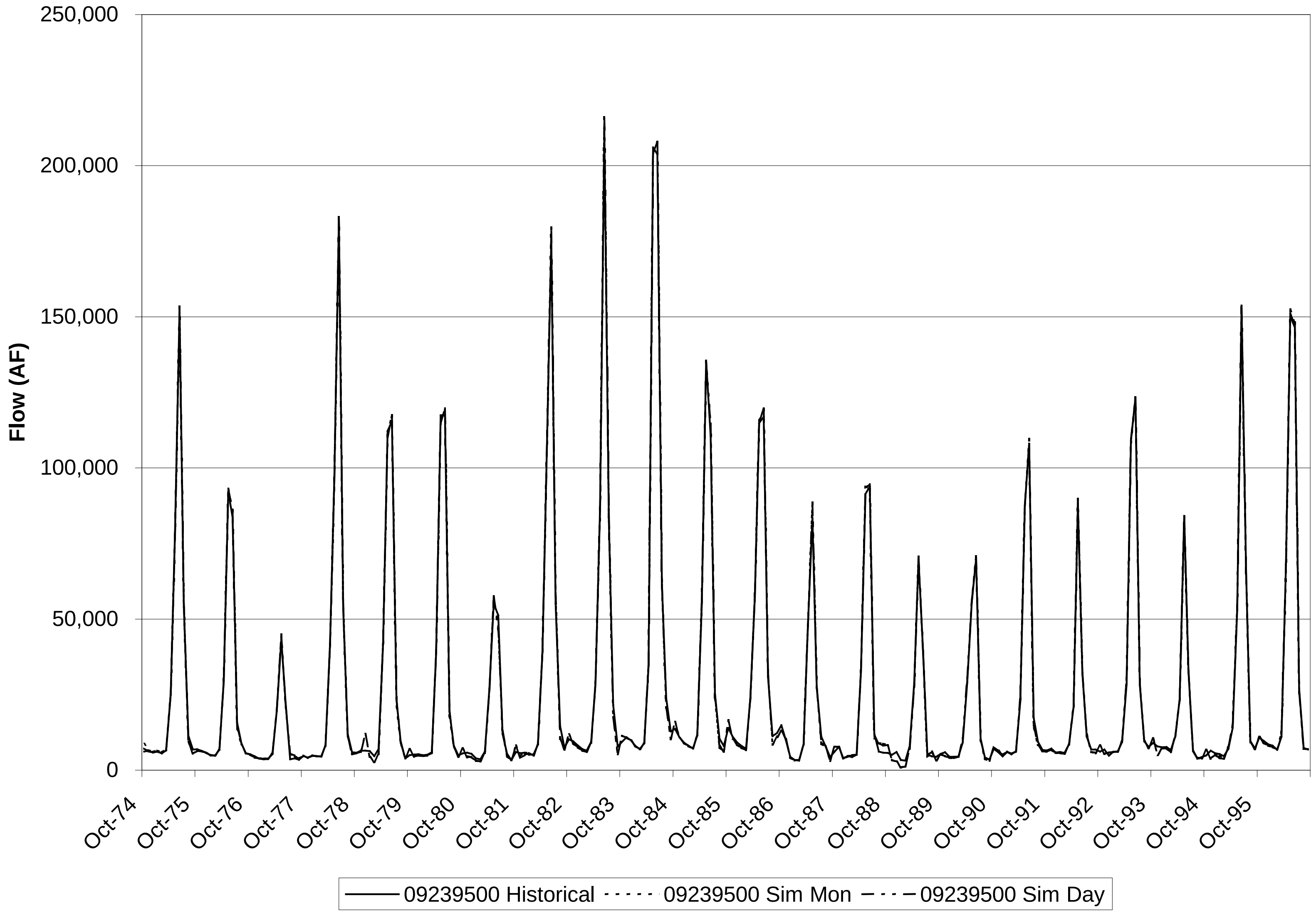

Figure 7 - Historical versus Simulated Monthly Flows, USGS 09239500 – Yampa River at Steamboat Springs

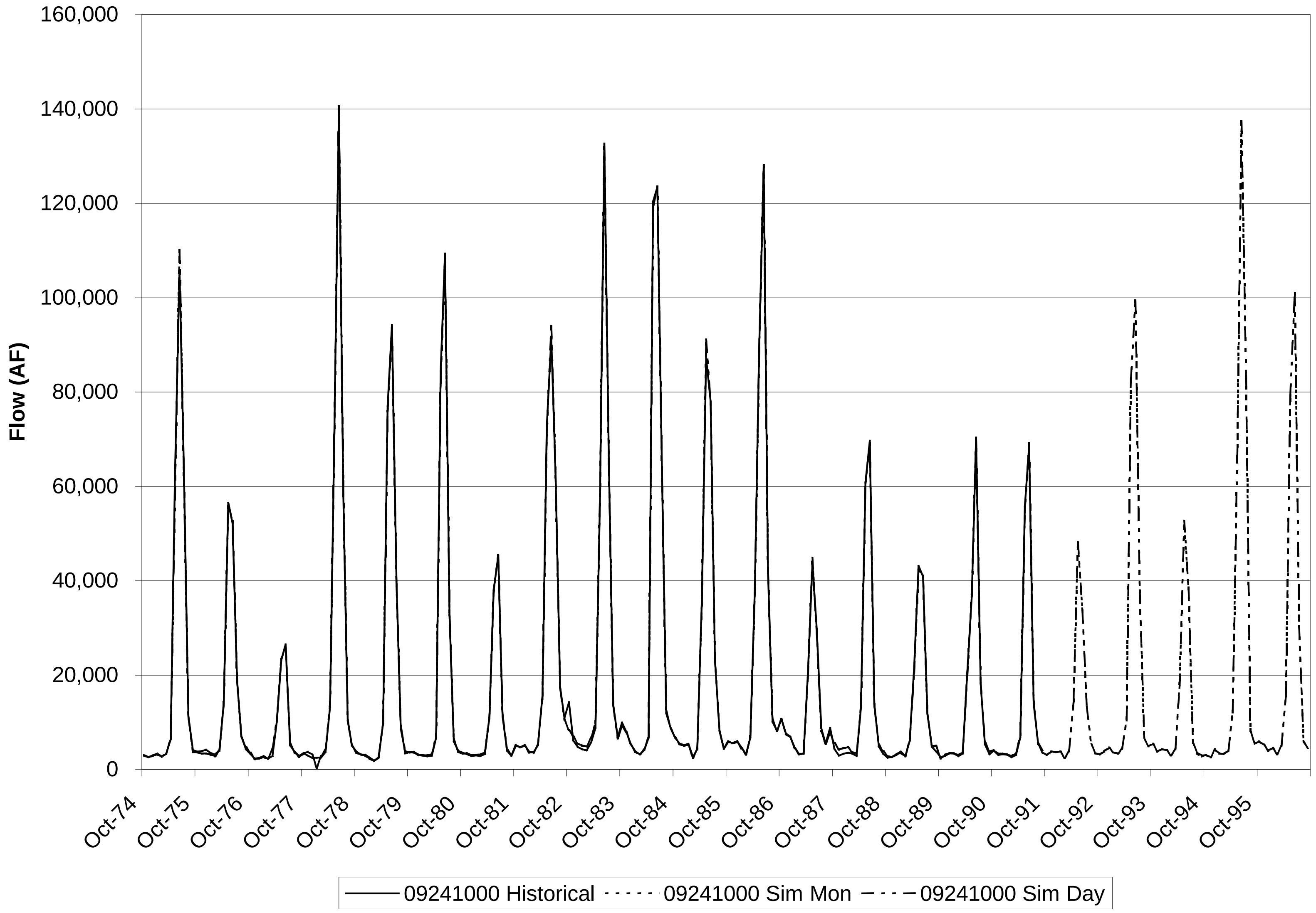

Figure 8 - Historical versus Simulated Monthly Flows, USGS 09241000 - Elk River at Clark

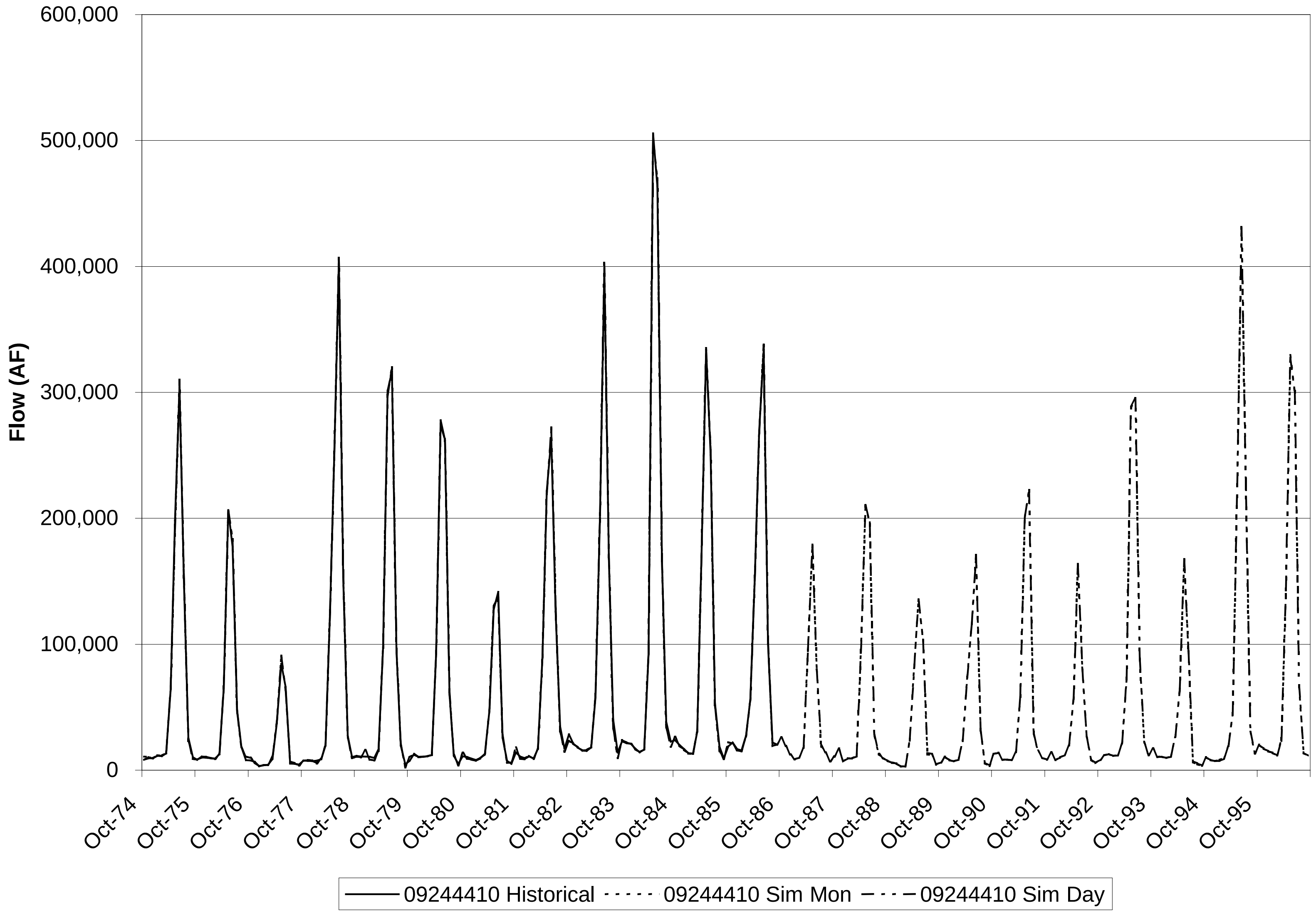

Figure 9 - Historical versus Simulated Monthly Flows, USGS 09244410 - Yampa River below diversion near Hayden

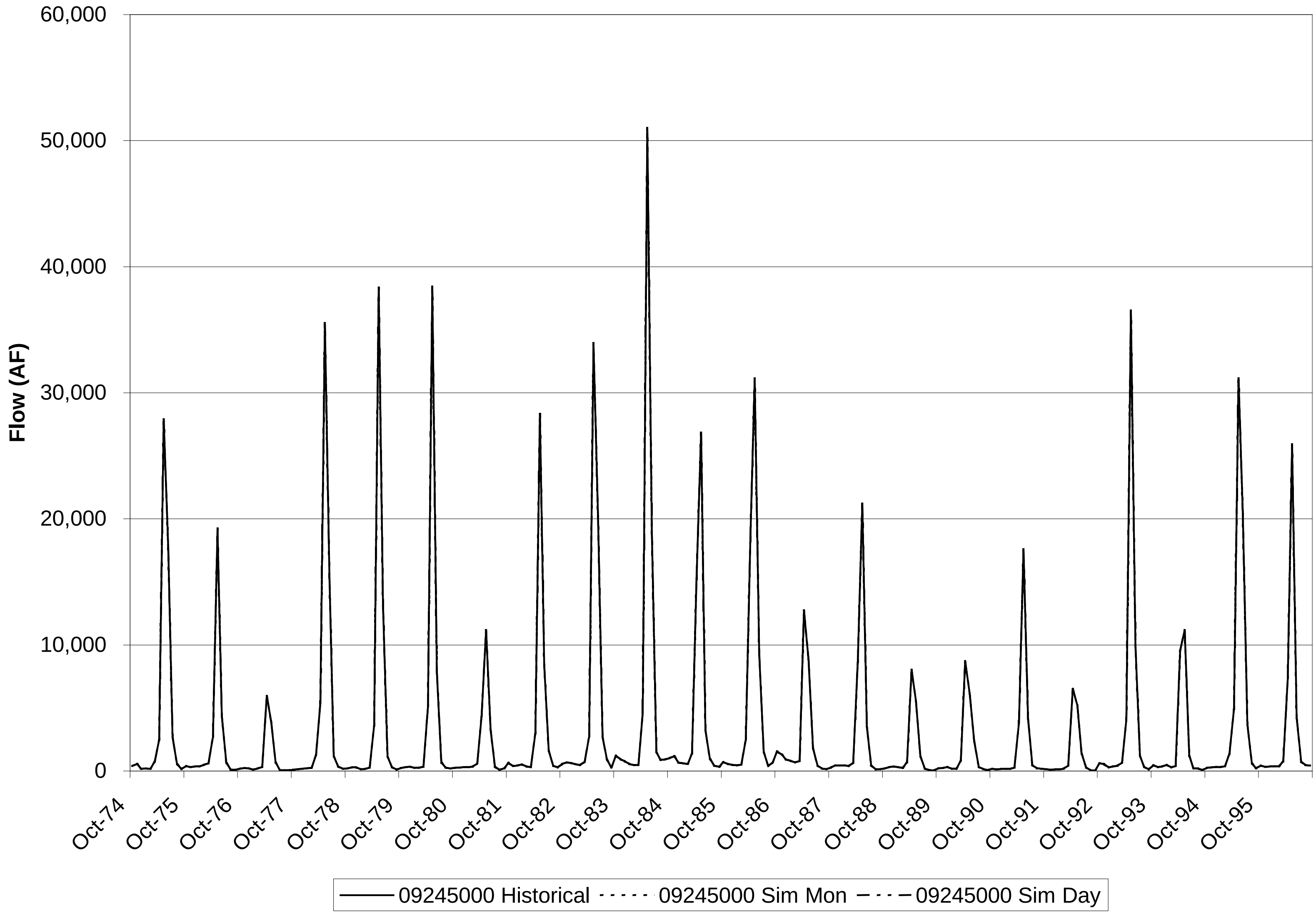

Figure 10 - Historical versus Simulated Monthly Flows, USGS 09245000 - Elkhead Creek near Elkhead

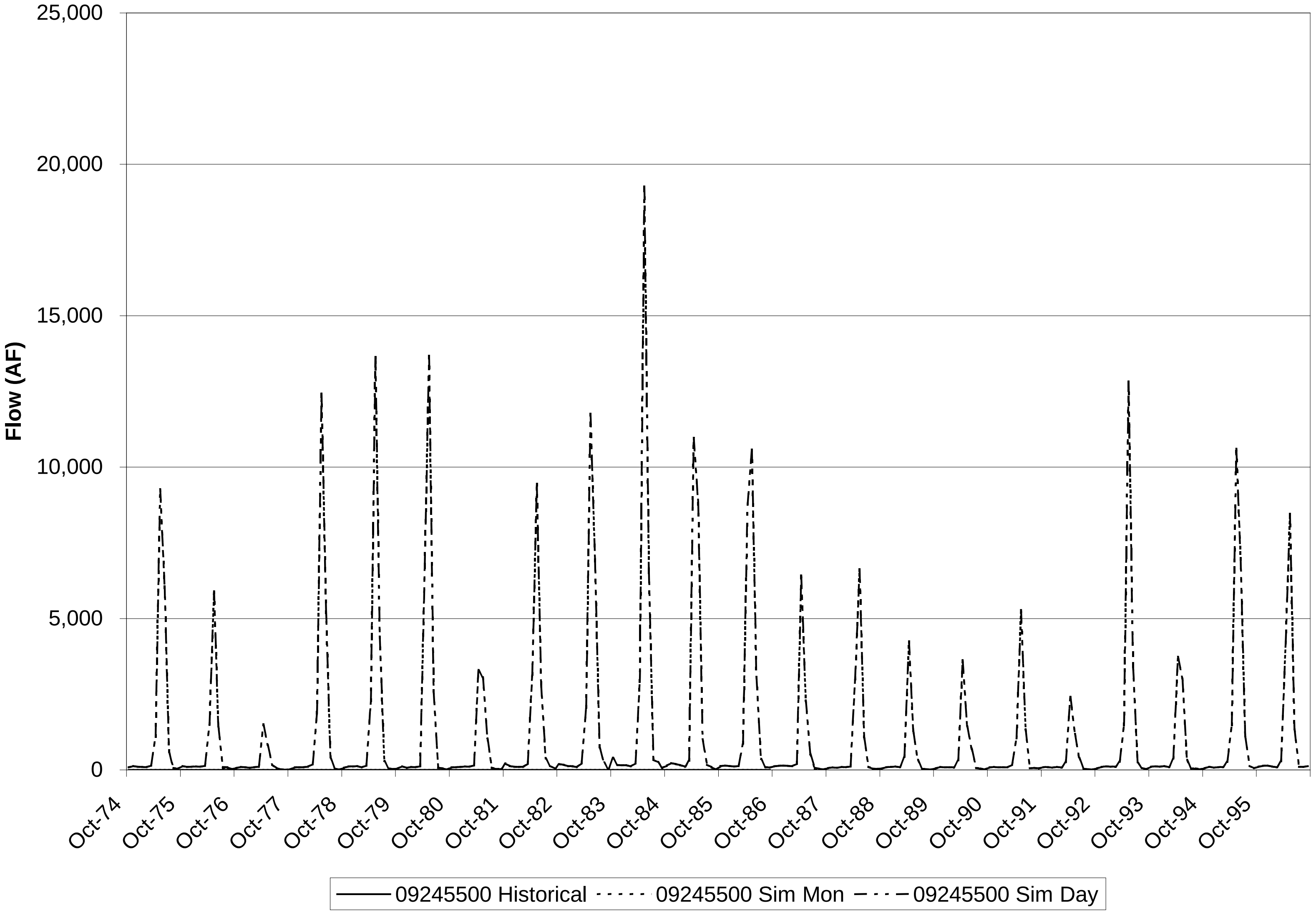

Figure 11 - Historical versus Simulated Monthly Flows, USGS 09245500 - N. Fork Elkhead Creek near Elkhead

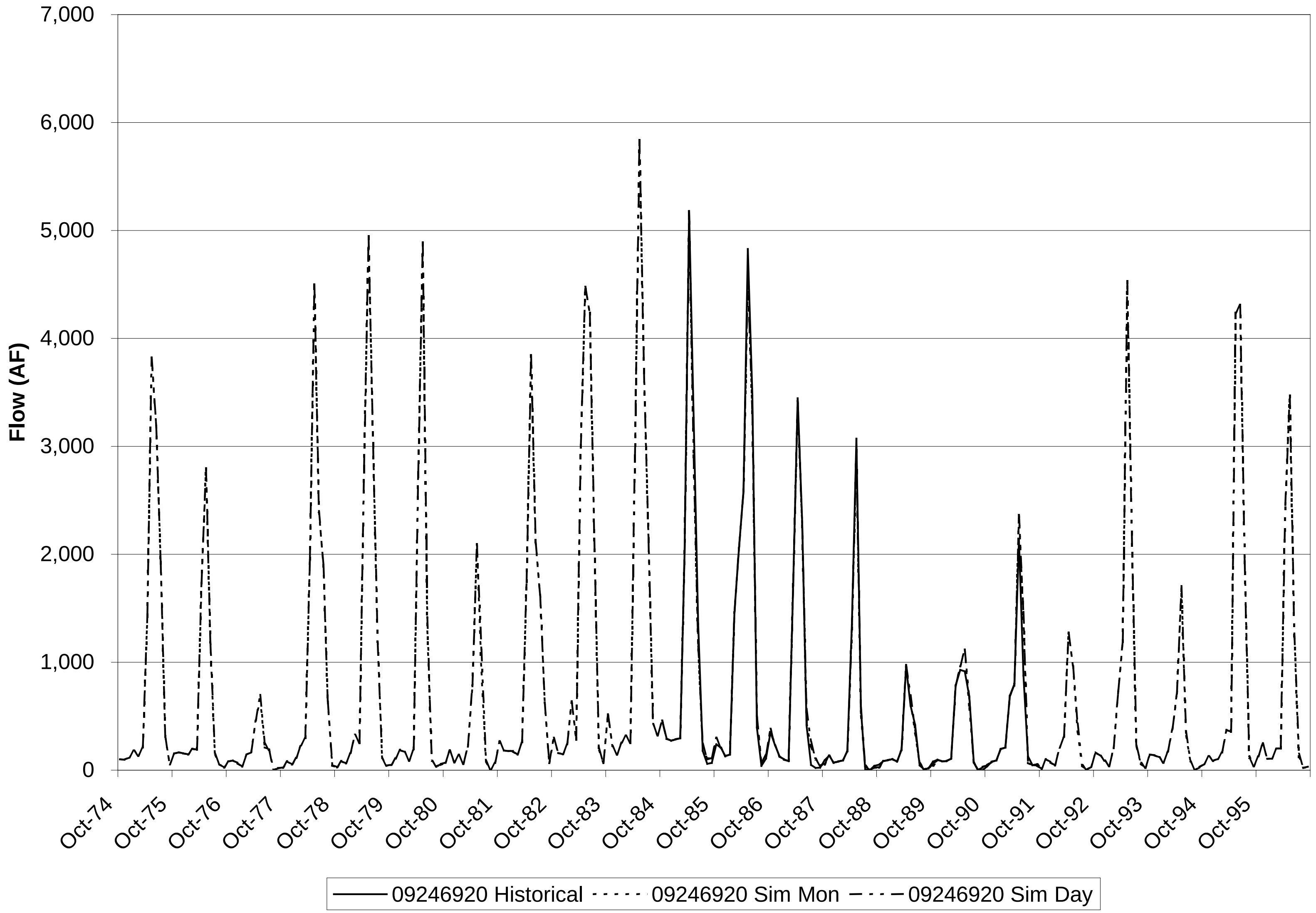

Figure 12 - Historical versus Simulated Monthly Flows, USGS 09246920 - Fortification Creek near Fortification

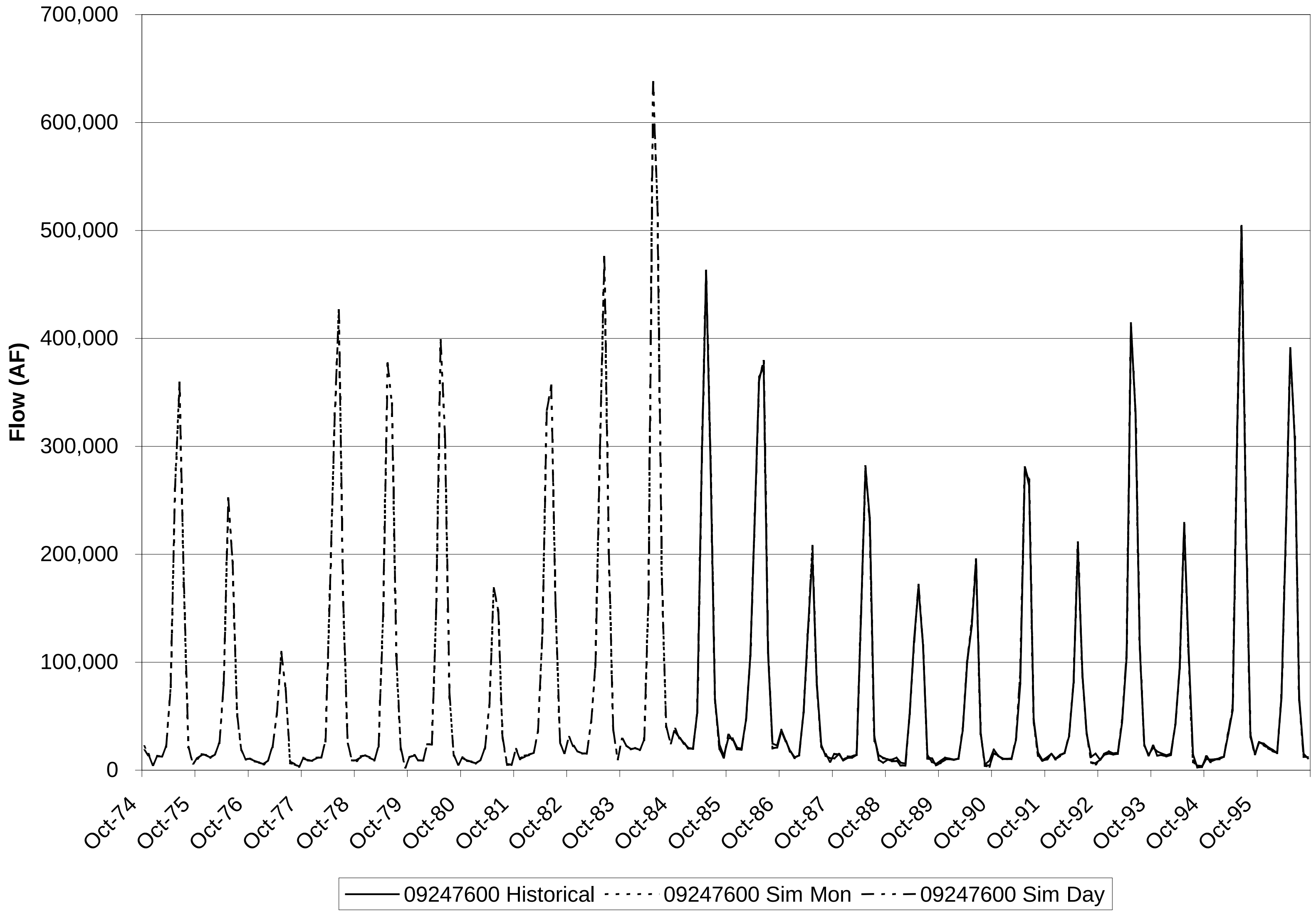

Figure 13 - Historical versus Simulated Monthly Flows, USGS 09247600 - Yampa River below Craig

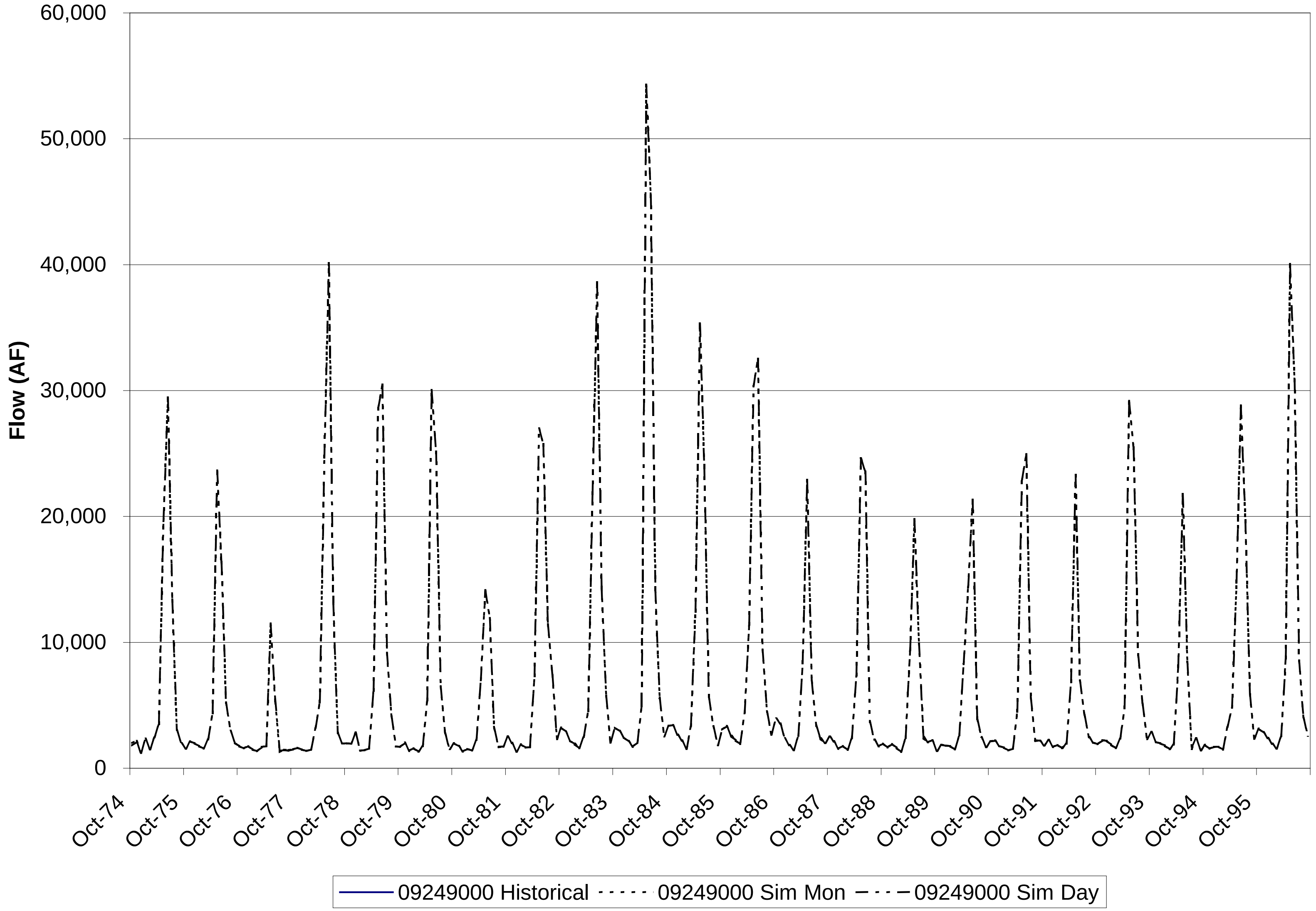

Figure 14 - Historical versus Simulated Monthly Flows, USGS 09249000 - E. Fork of Williams Fork near Pagoda

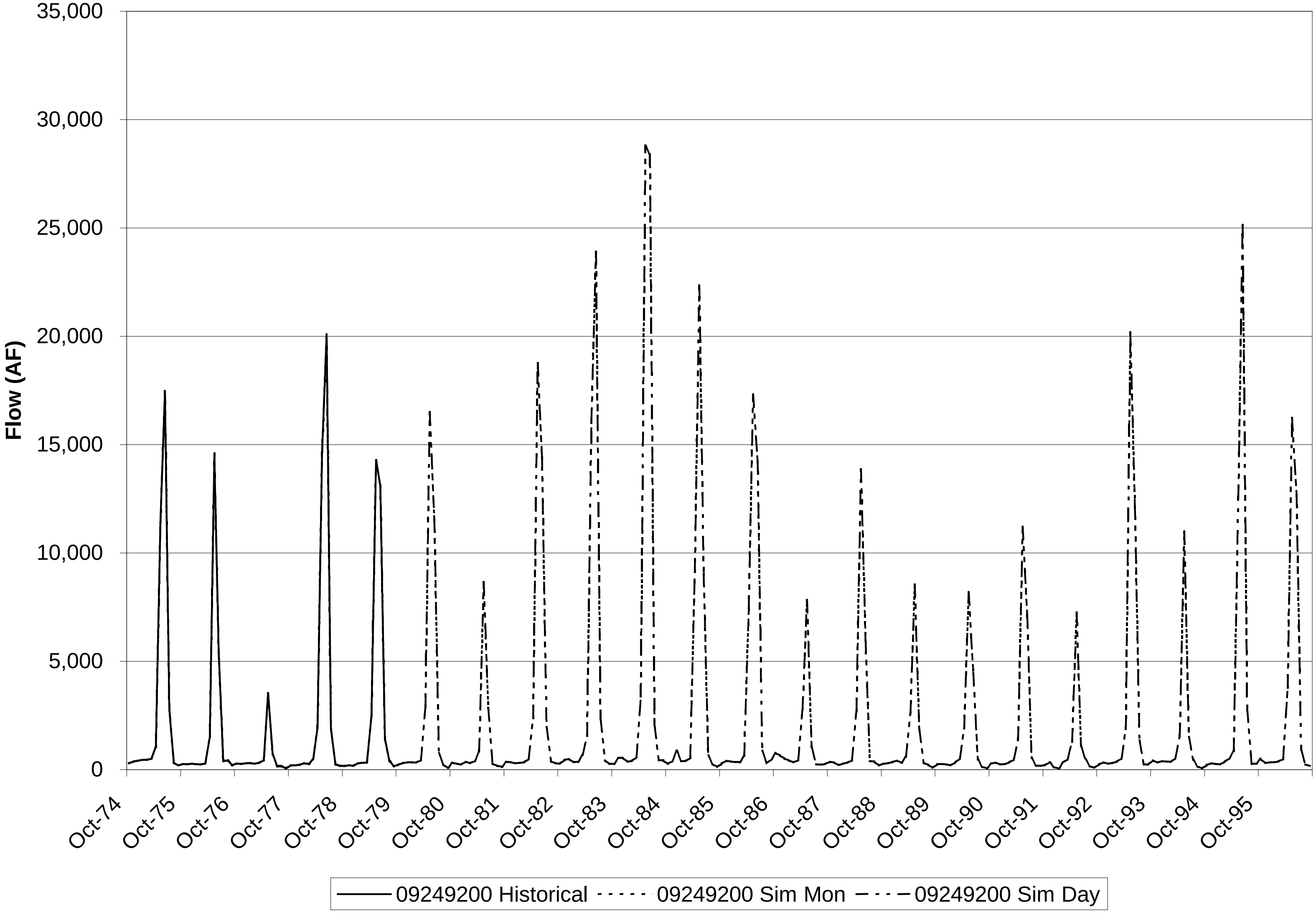

Figure 15 - Historical versus Simulated Monthly Flows, USGS 09249200 - S. Fork of Williams Fork near Pagoda

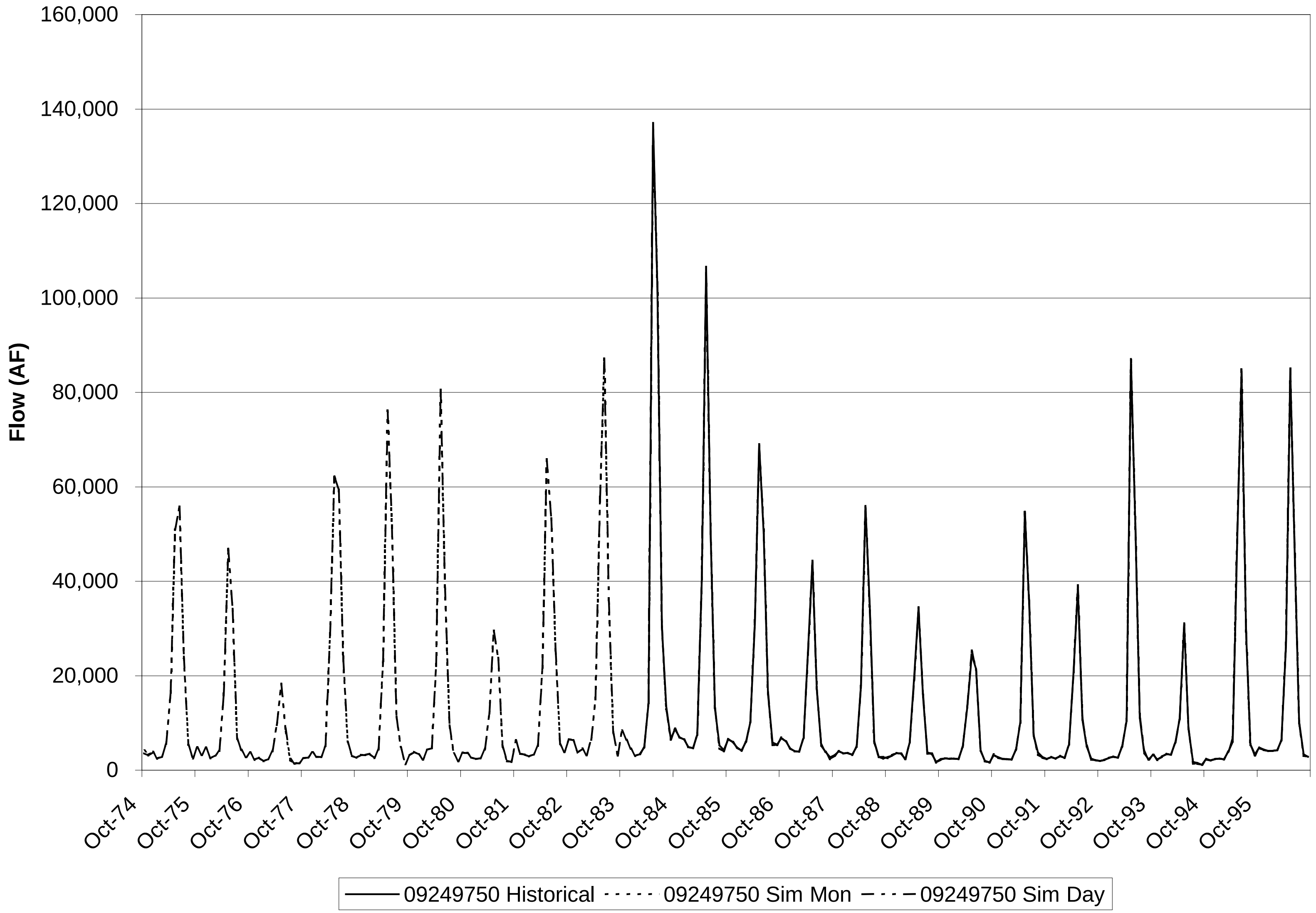

Figure 16 - Historical versus Simulated Monthly Flows, USGS 09249750 - Williams Fork at mouth, near Hamilton

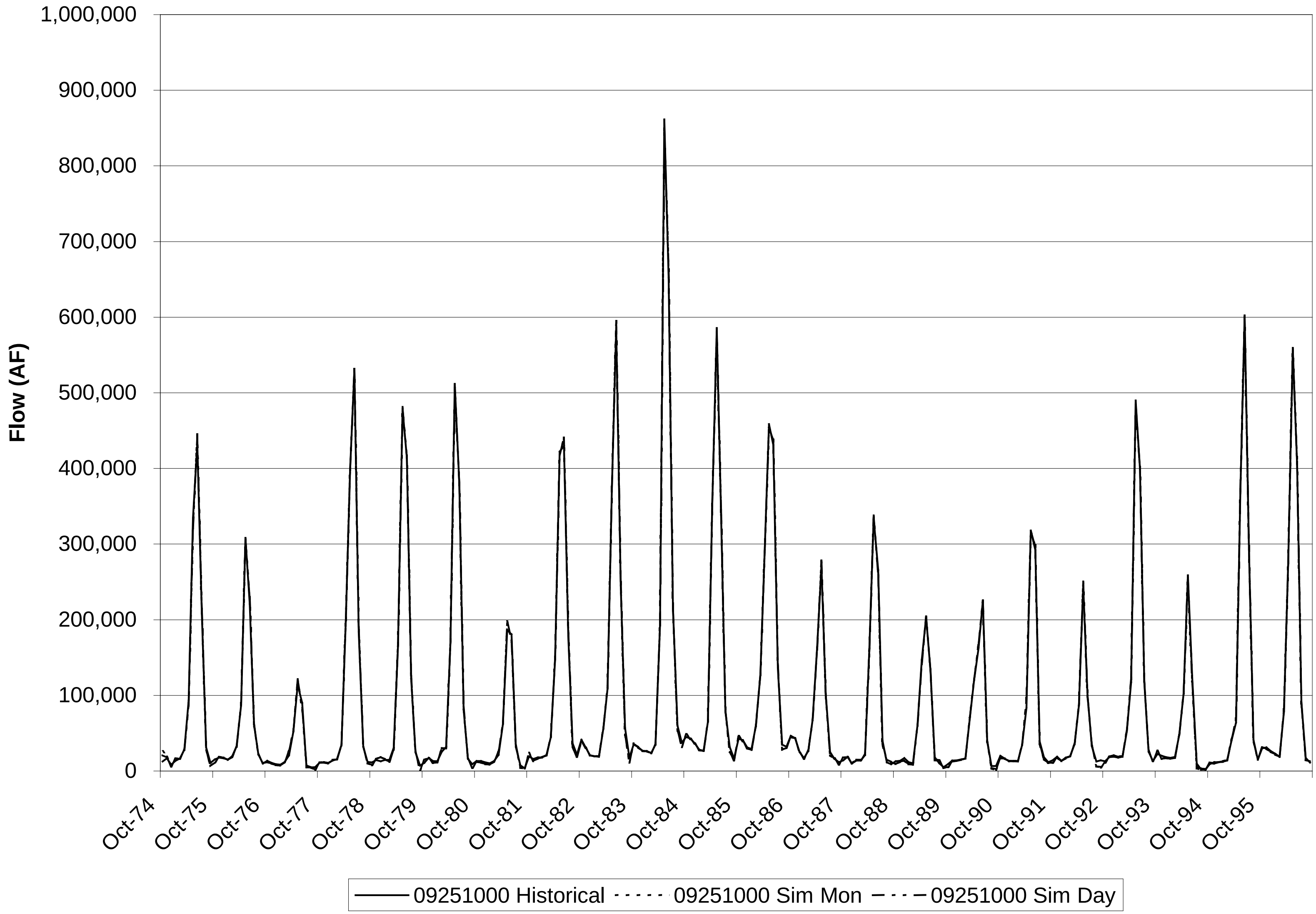

Figure 17 - Historical versus Simulated Monthly Flows, USGS 09251000 - Yampa River near Maybell

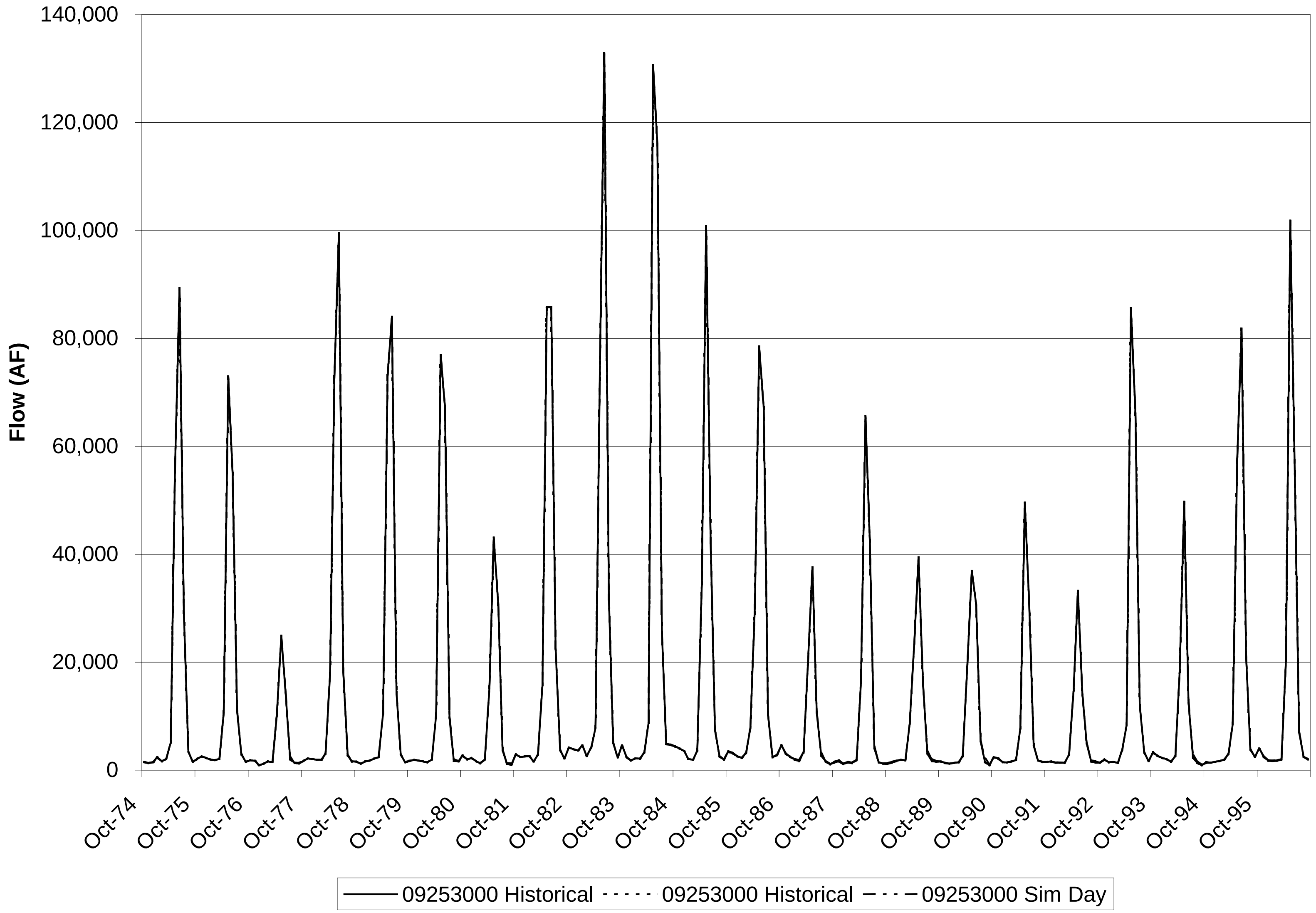

Figure 18 - Historical versus Simulated Monthly Flows, USGS 09253000 - Little Snake River near Slater

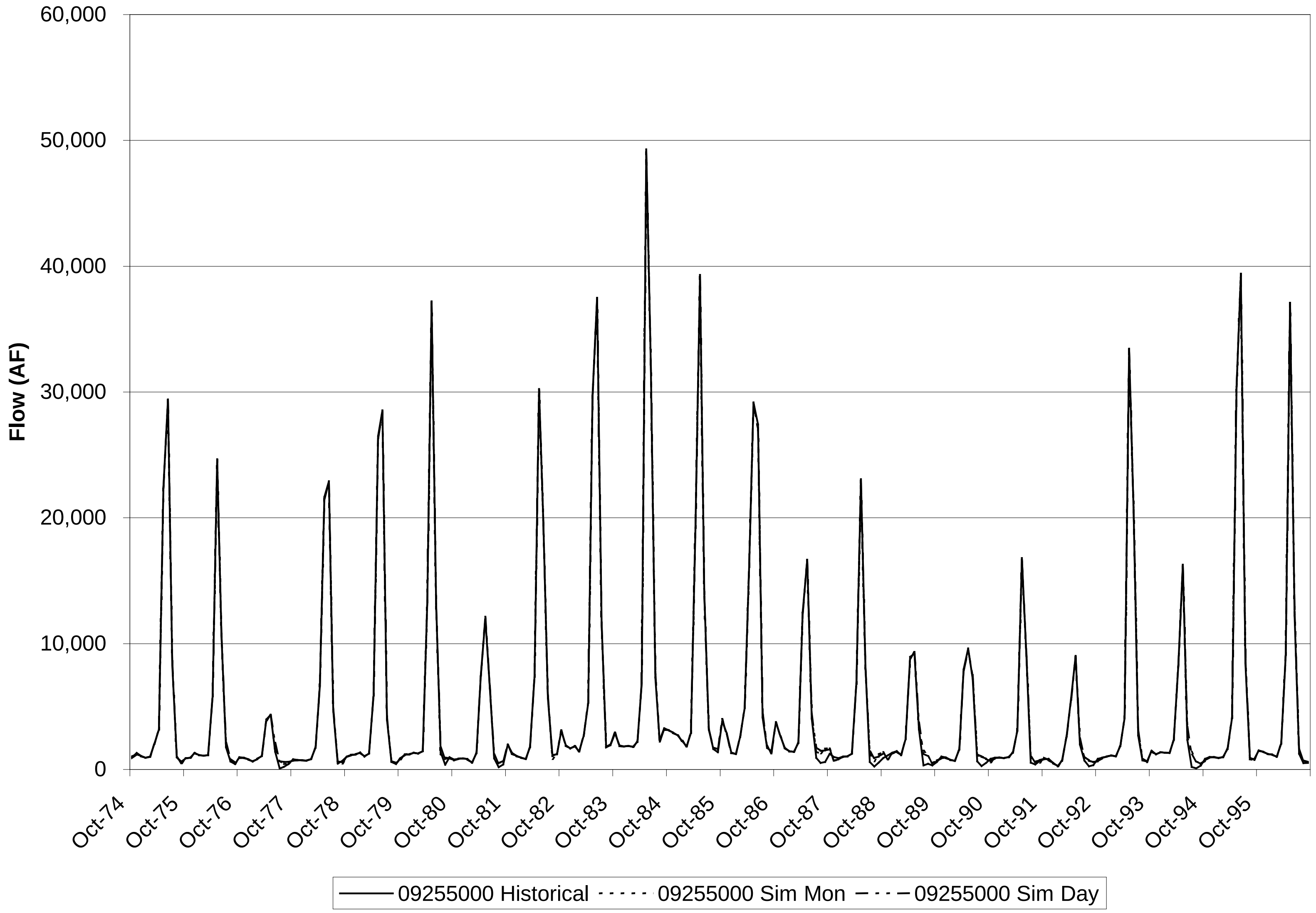

Figure 19 - Historical versus Simulated Monthly Flows, USGS 0925500 - Slater Fork near Slater

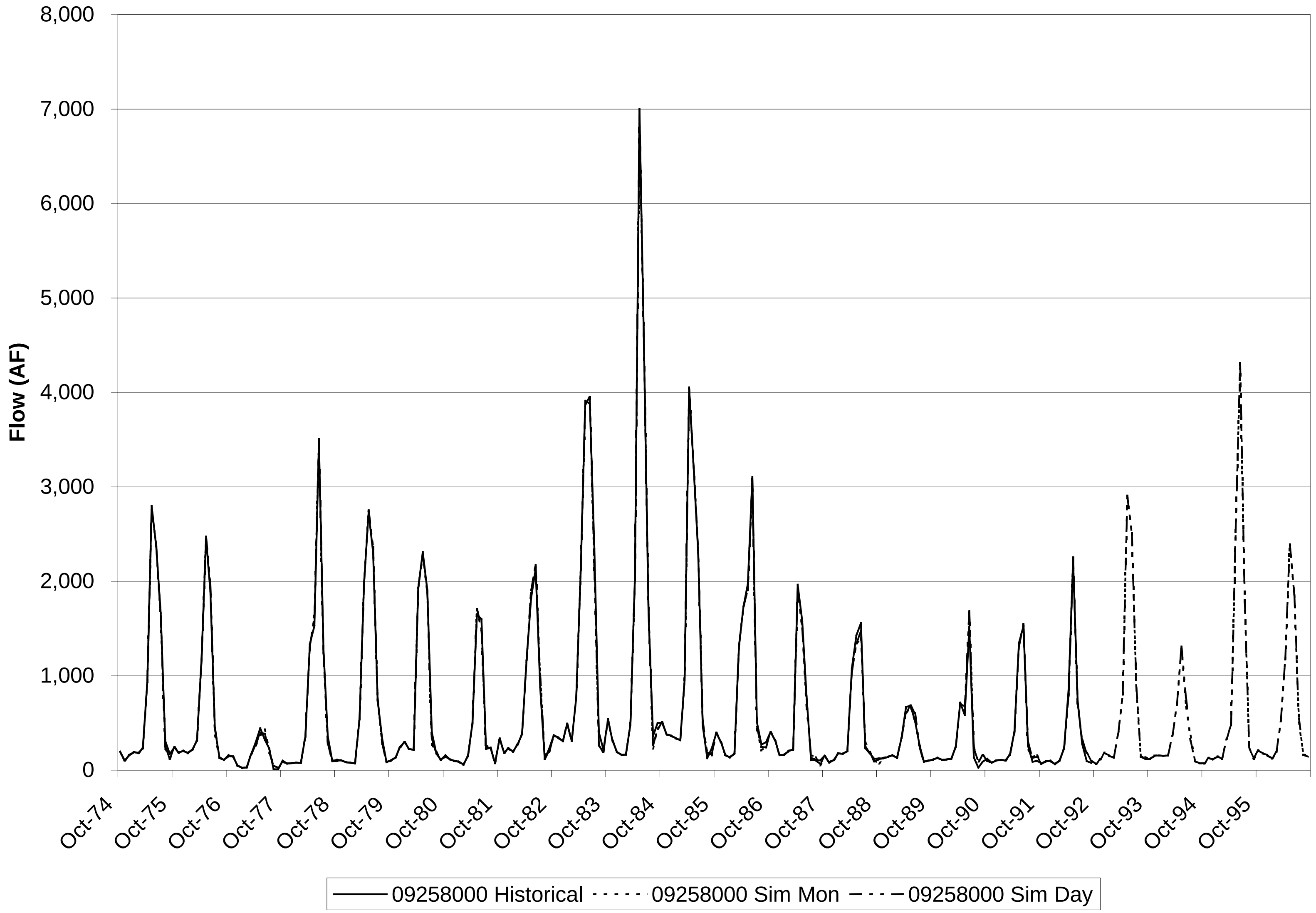

Figure 20 - Historical versus Simulated Monthly Flows, USGS 09258000 - Willow Creek near Dixon

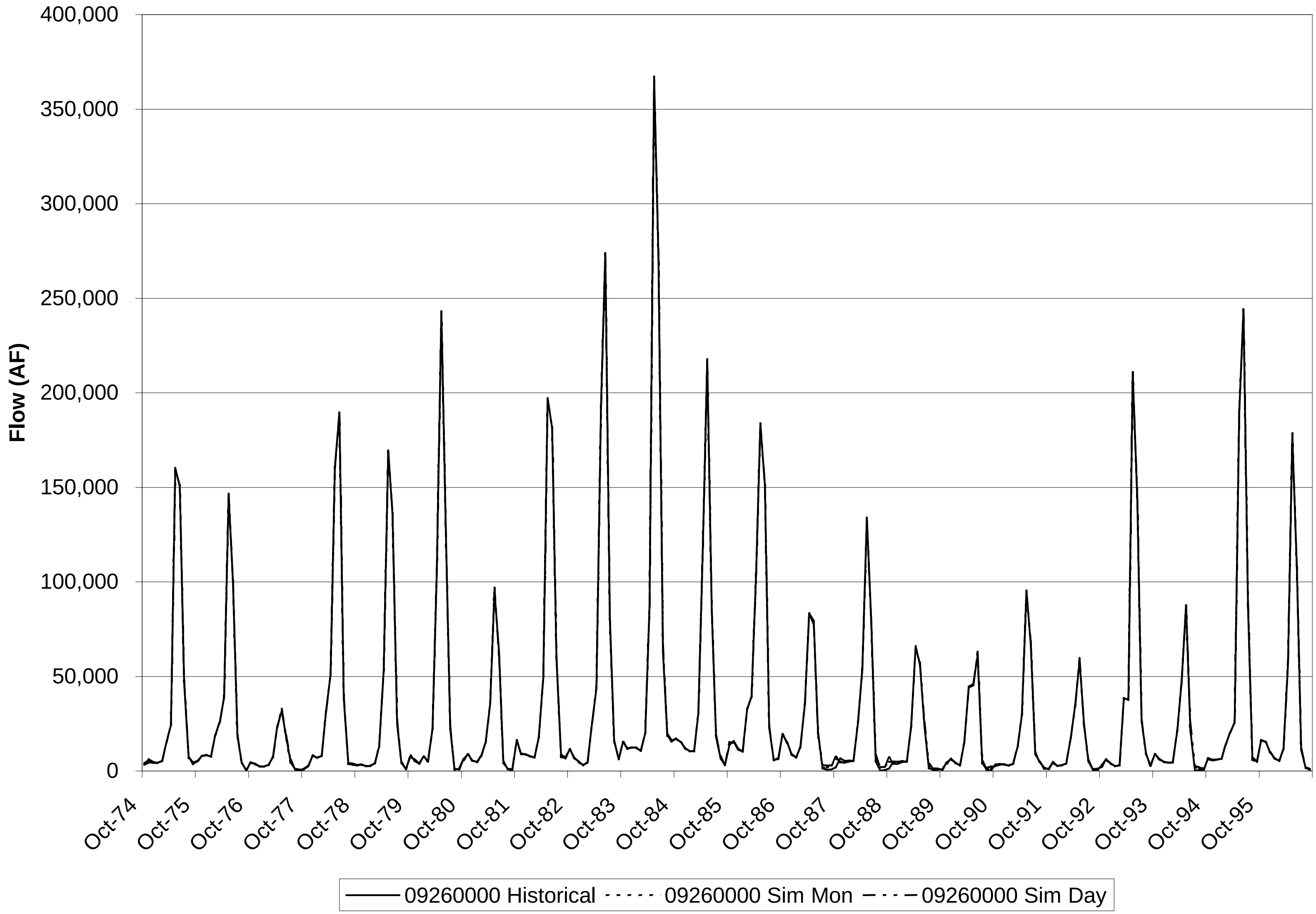

Figure 21 - Historical versus Simulated Monthly Flows, USGS 0926000 - Little Snake River near Lily

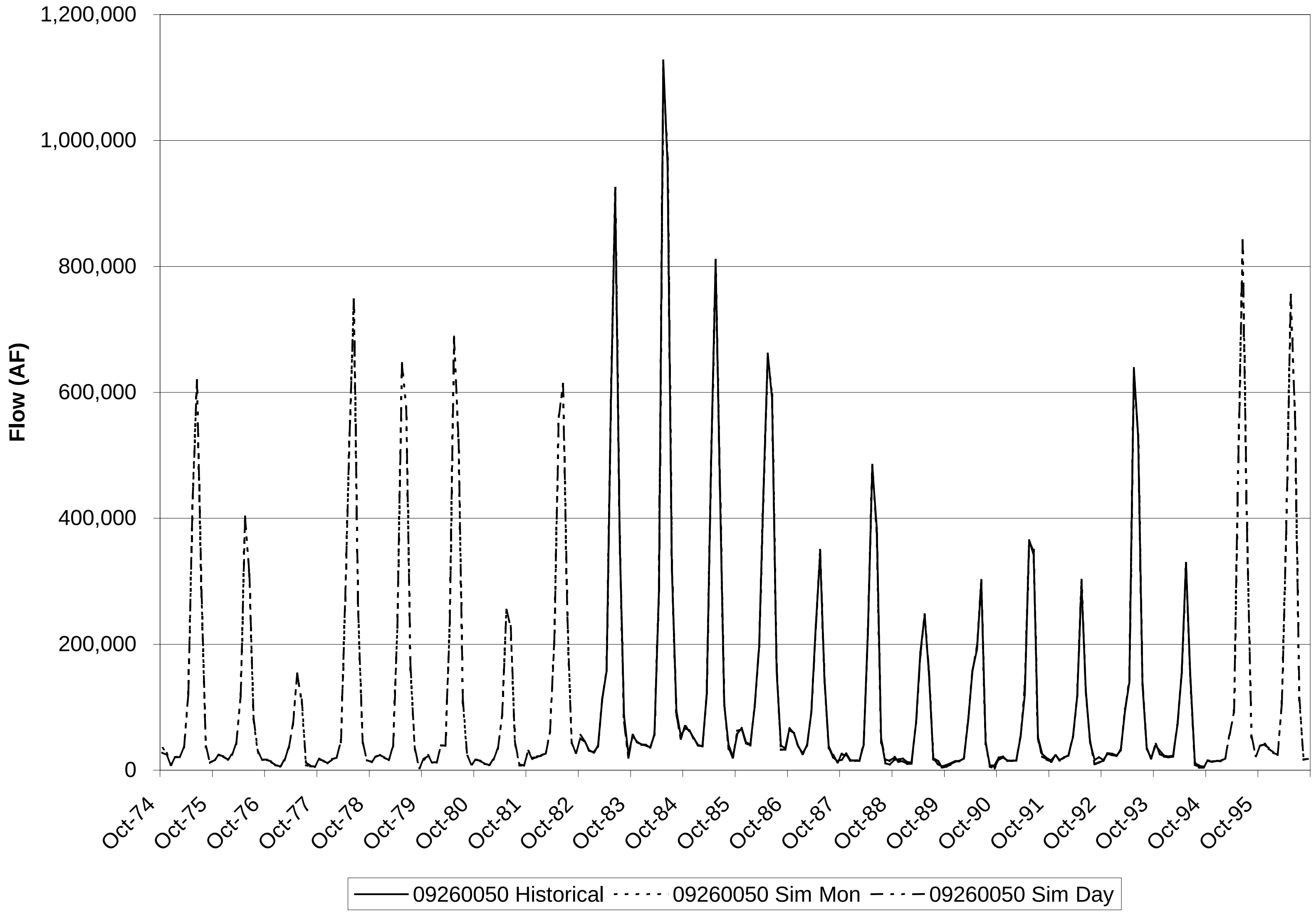

Figure 22 - Historical versus Simulated Monthly Flows, USGS 09260050 - Yampa River at Deerlodge

Historical versus Simulated Daily Flows for Water Year 1977

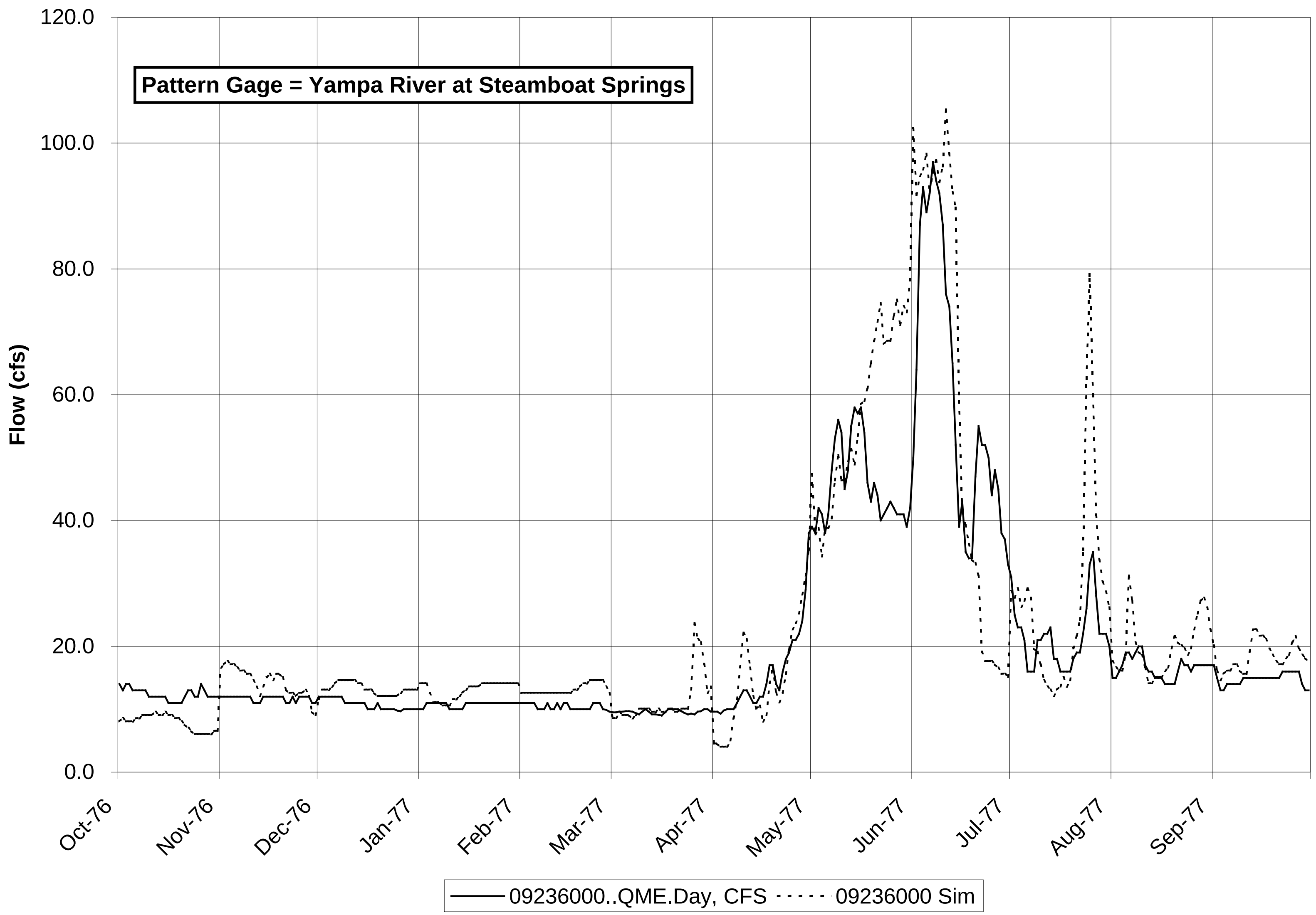

Figure 23 - Historical versus Simulated Daily Flows for Water Year 1977, USGS 09236000 - Bear River near Toponas

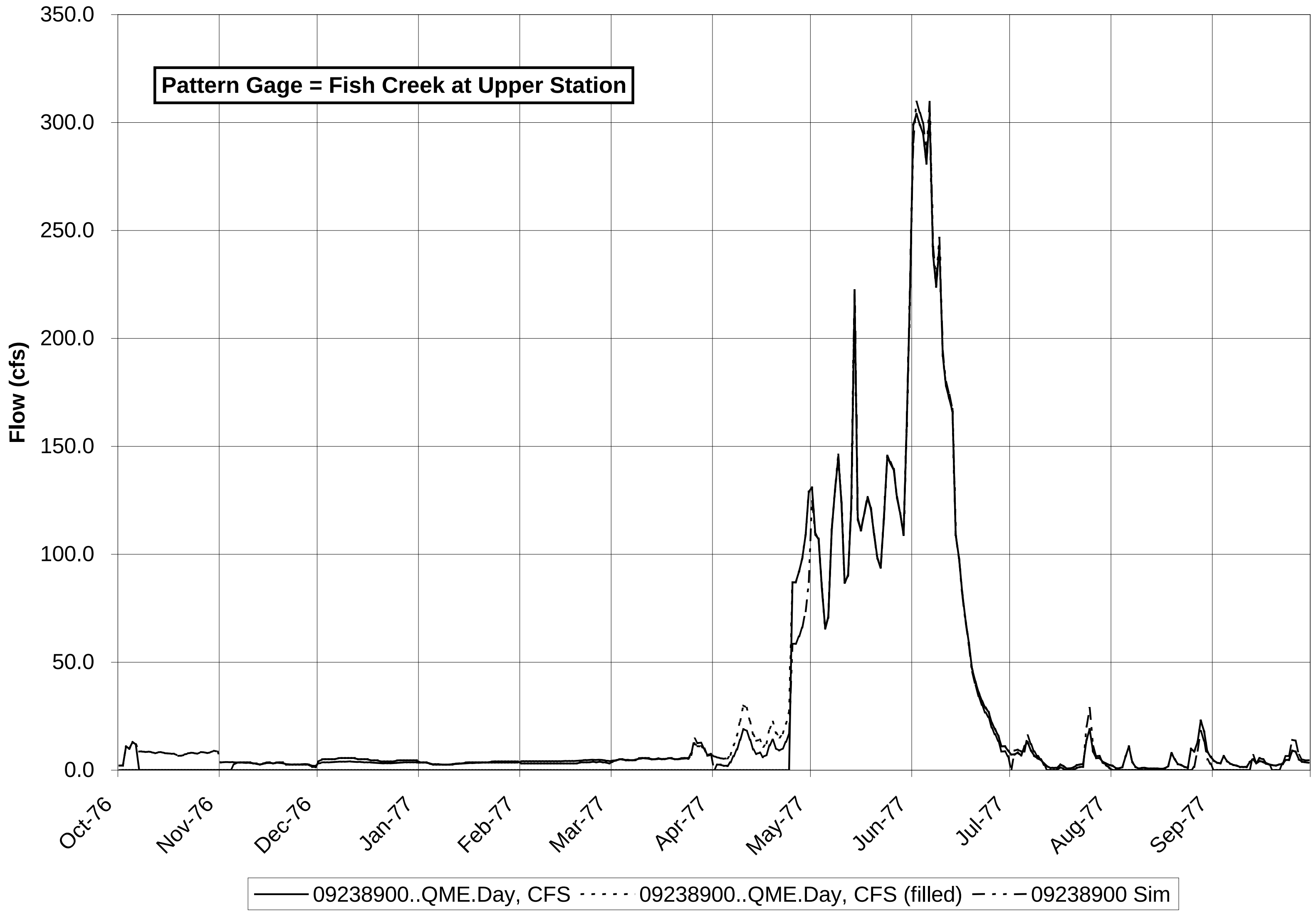

Figure 24 - Historical versus Simulated Daily Flows for Water Year 1977, USGS 09238900 - Fish Creek at Upper Station near Steamboat Springs

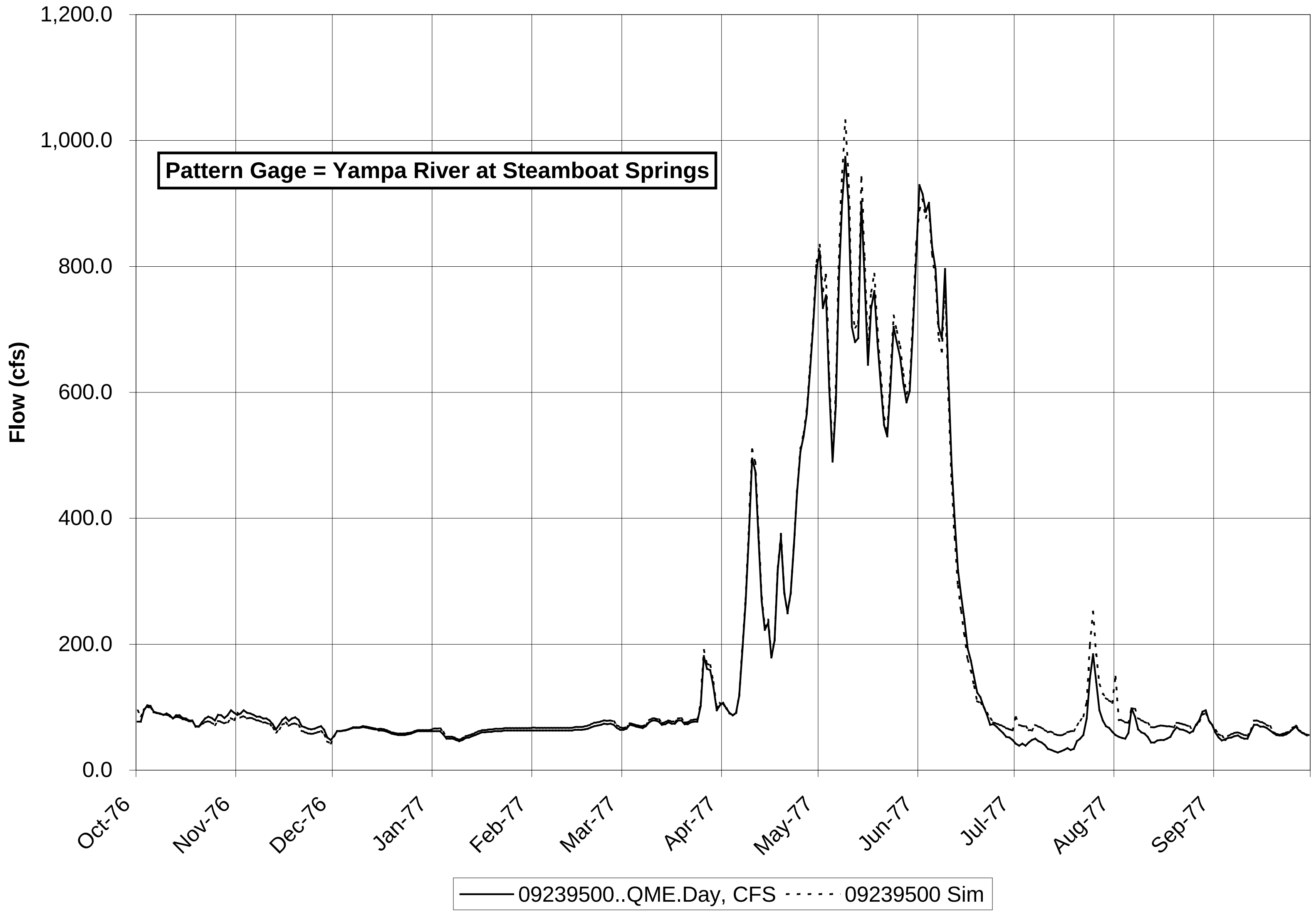

Figure 25 - Historical versus Simulated Daily Flows for Water Year 1977, USGS 09239500 - Yampa River at Steamboat Springs

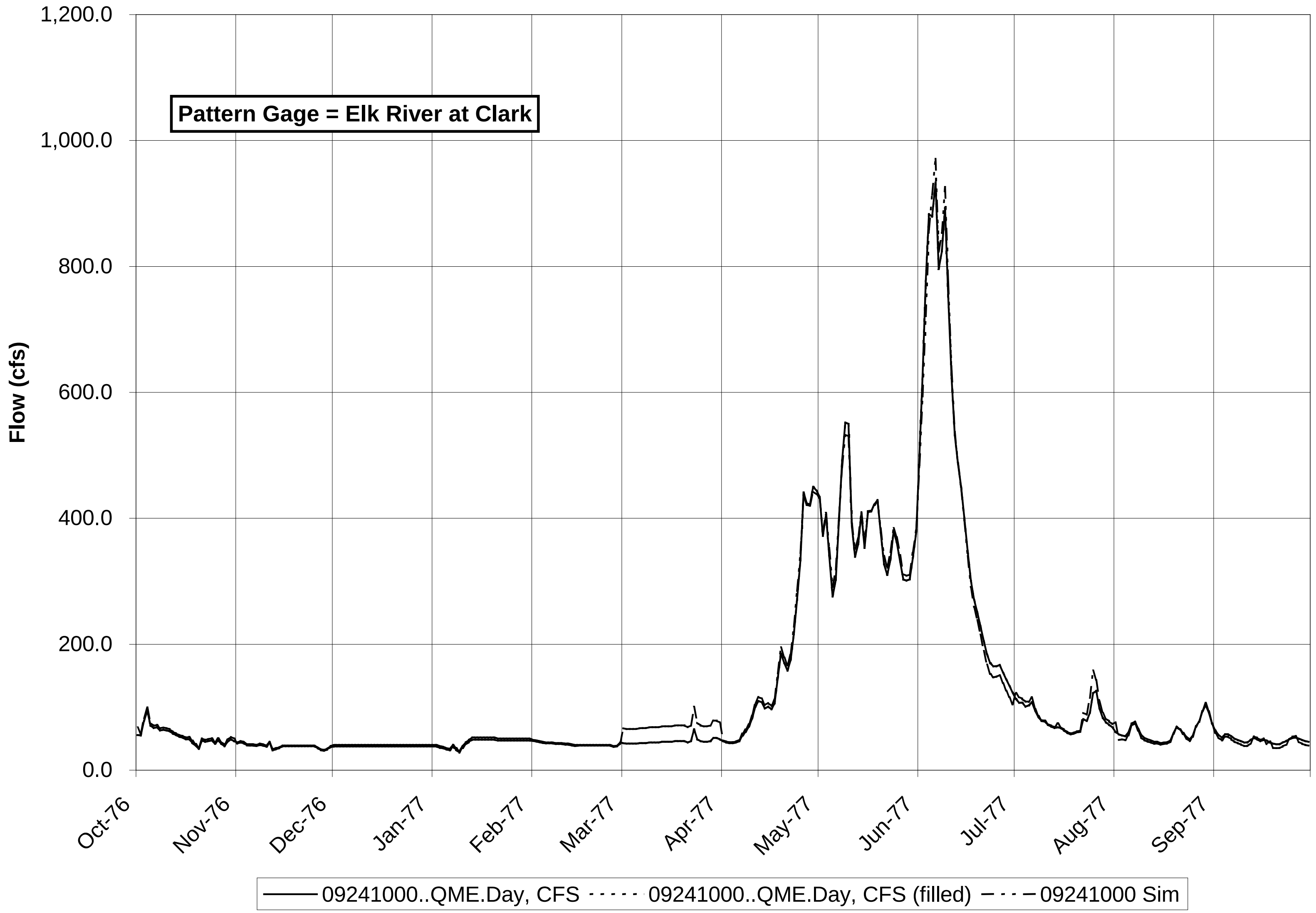

Figure 26 - Historical versus Simulated Daily Flows for Water Year 1977, USGS 09241000 - Elk River at Clark

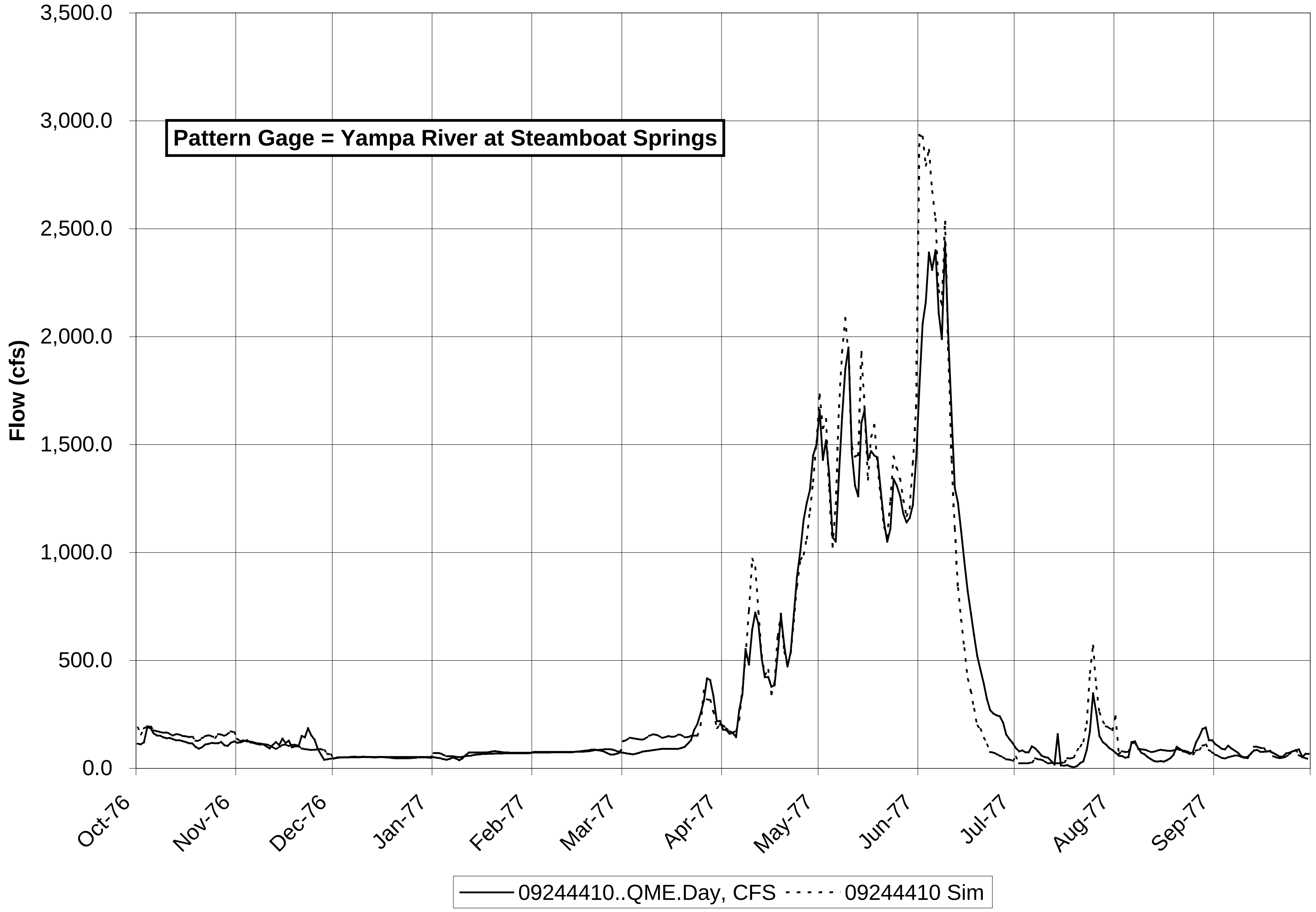

Figure 27 - Historical versus Simulated Daily Flows for Water year 1977, USGS 09244410 - Yampa River below diversion near Hayden

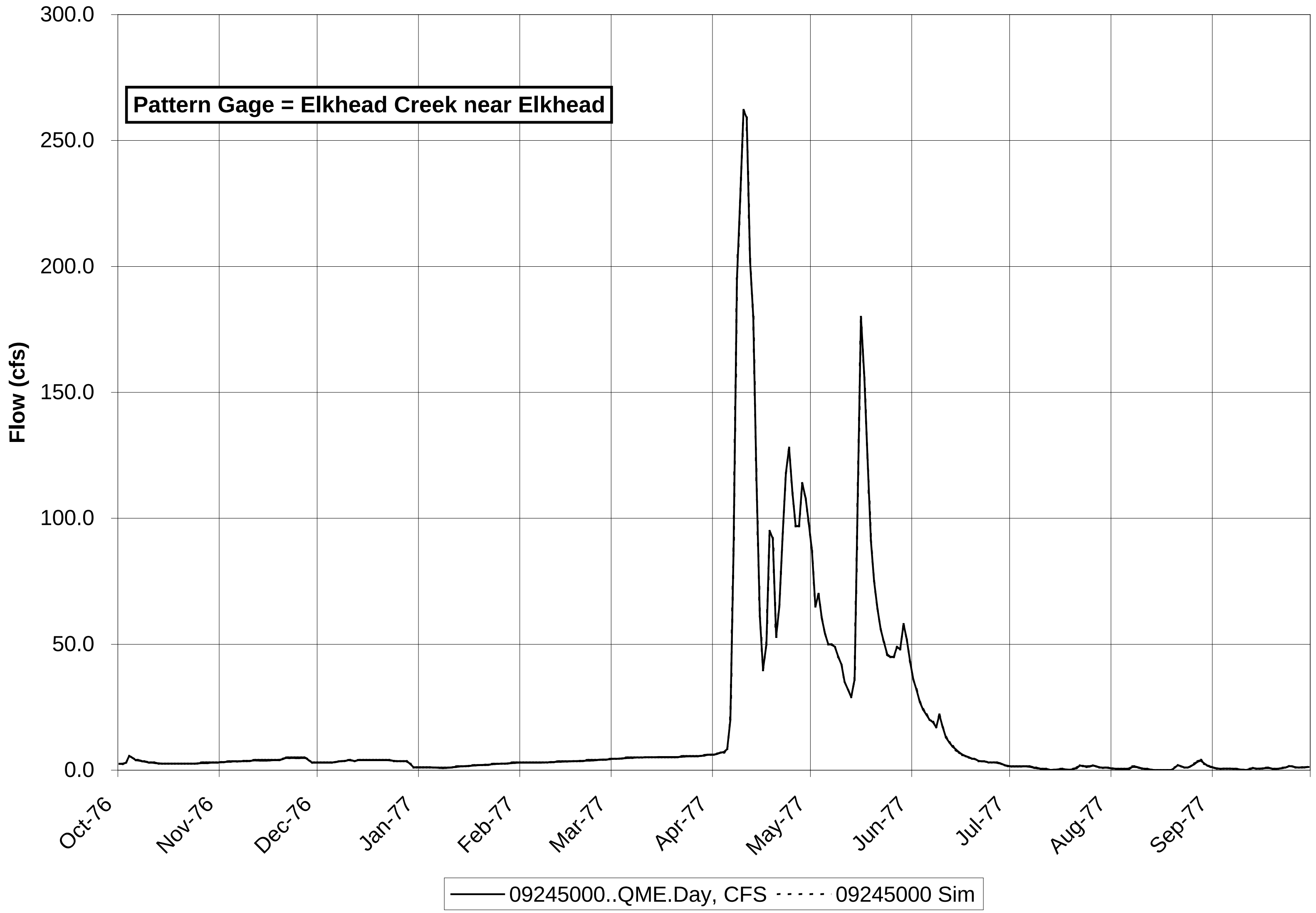

Figure 28 - Historical versus Simulated Daily Flows for Water Year 1977, USGS 09245000 - Elkhead Creek near Elkhead

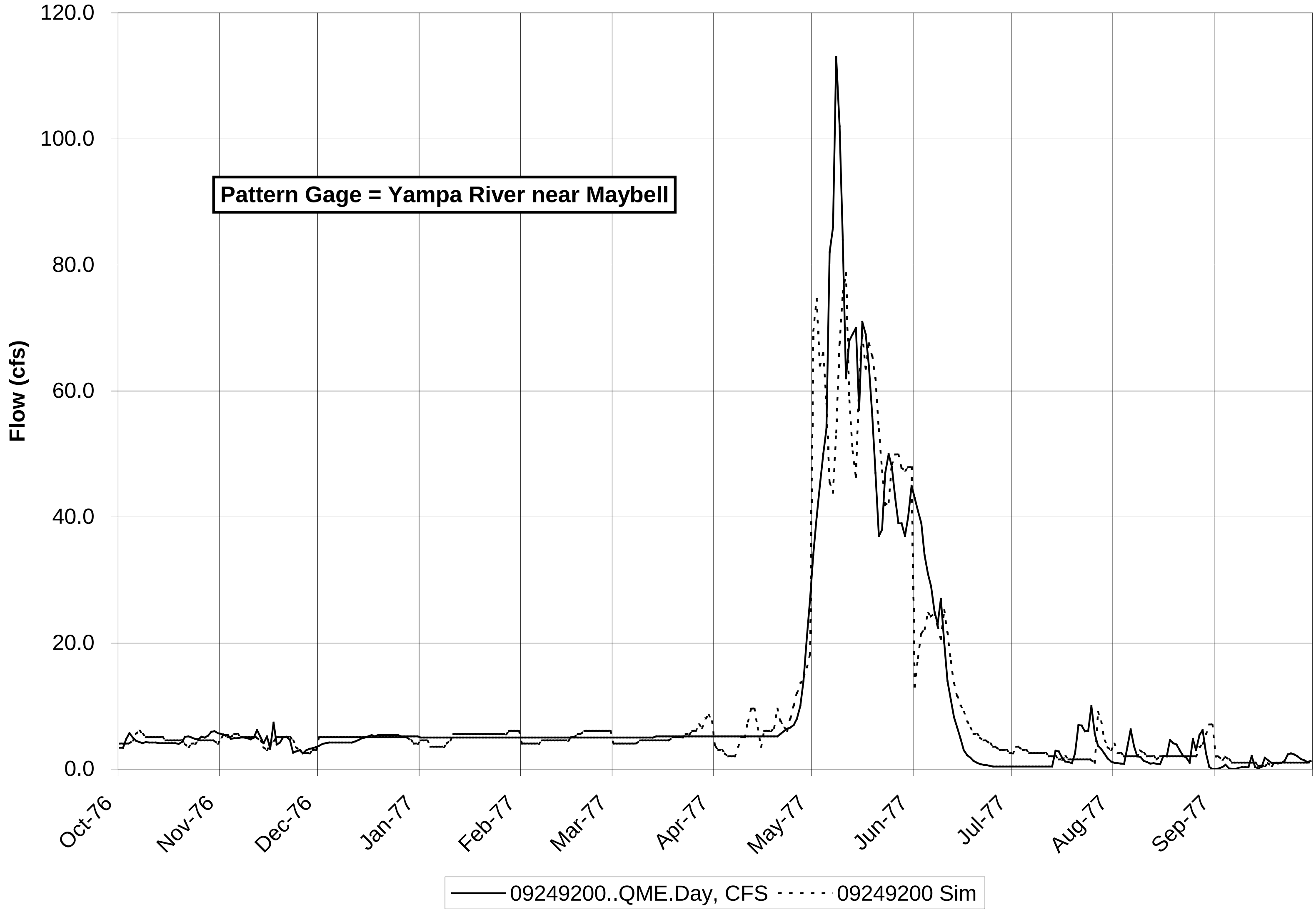

Figure 29 - Historical versus Simulated Daily Flows for Water Year 1977, USGS 09249200 - S. Fork of Williams Fork near Pagoda

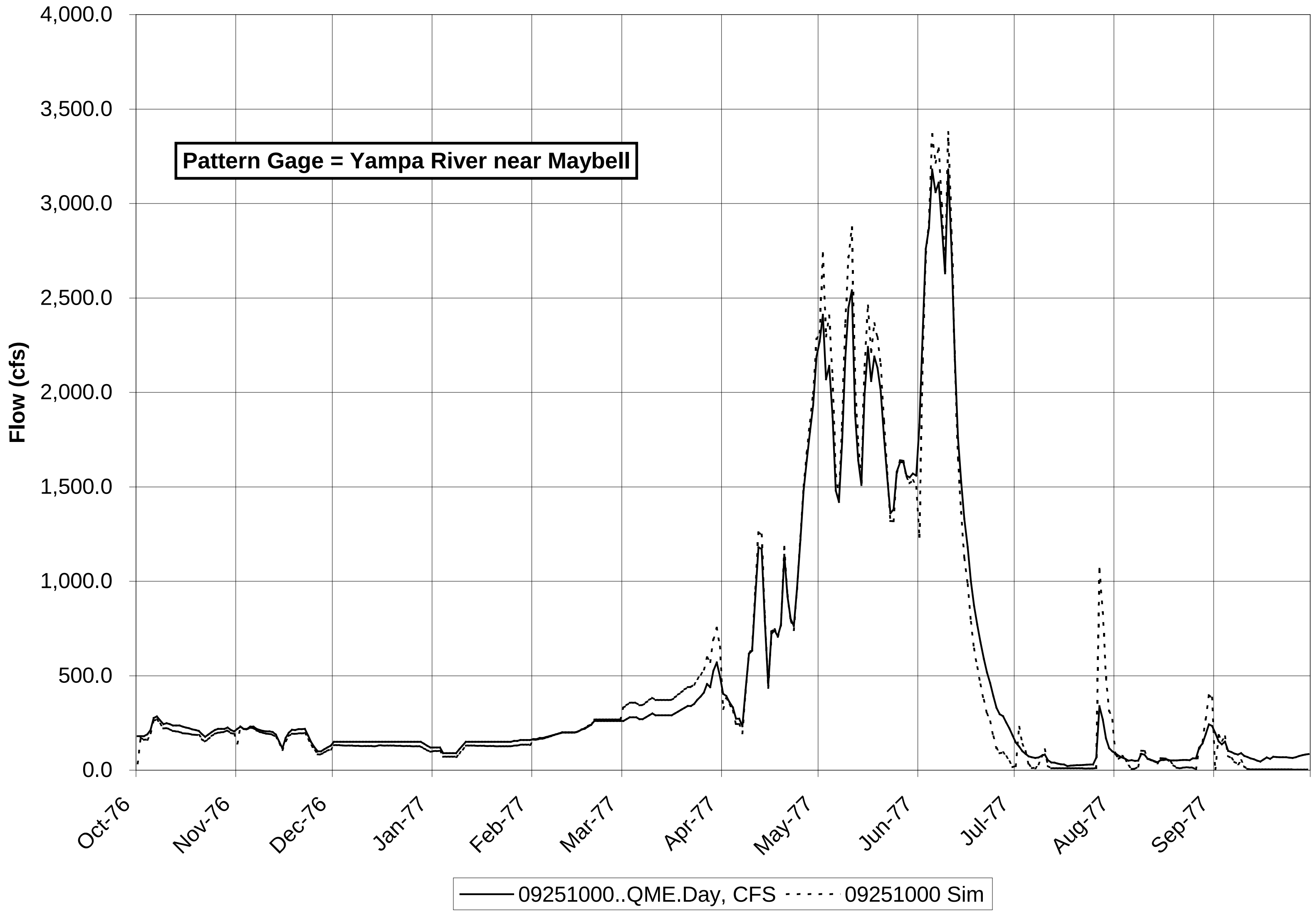

Figure 30 - Historical versus Simulated Daily Flows for Water Year 1977, USGS 09251000 - Yampa River near Maybell

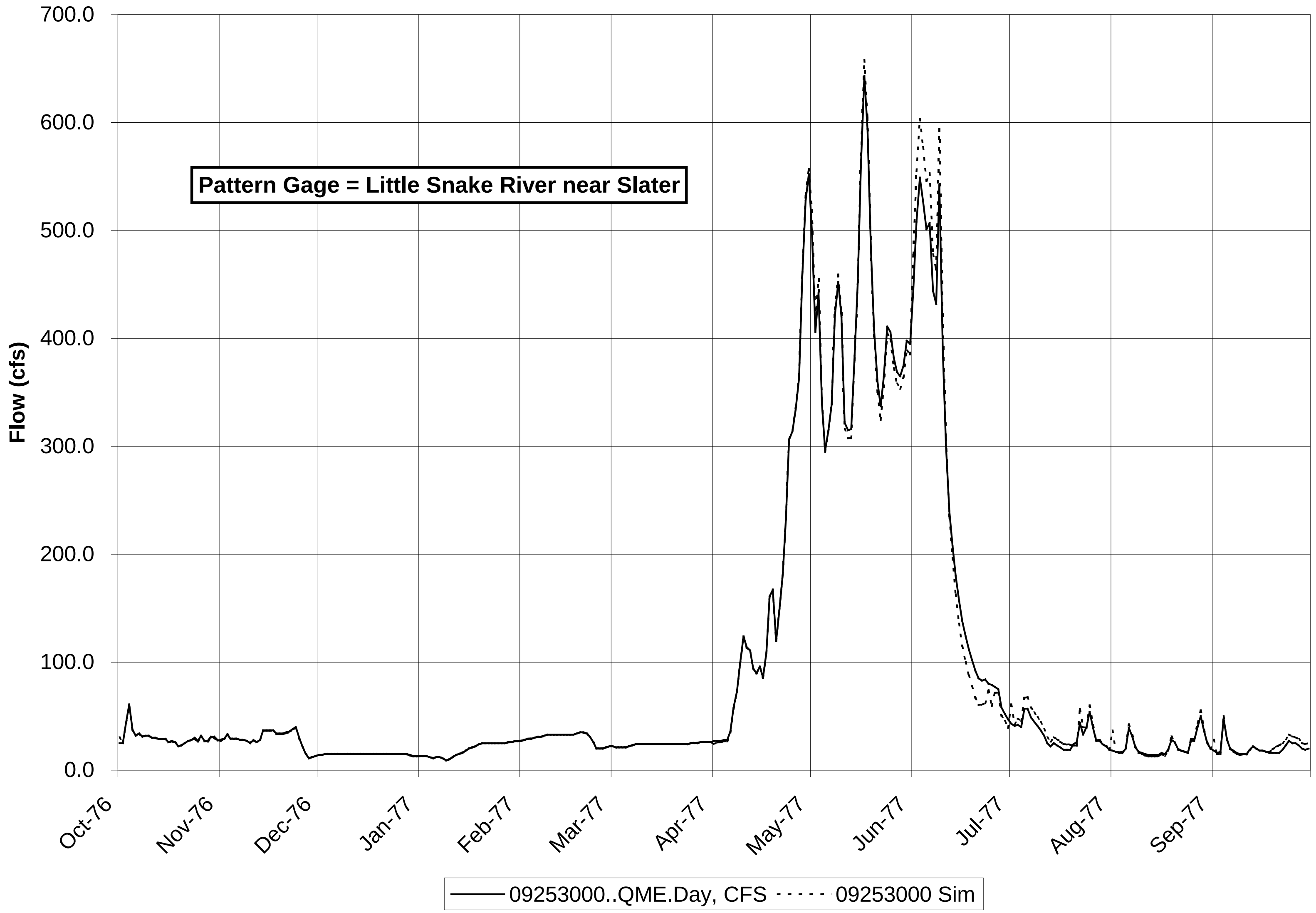

Figure 31 - Historical versus Simulated Daily Flows for Water Year 1977, USGS 09253000 - Little Snake River near Slater

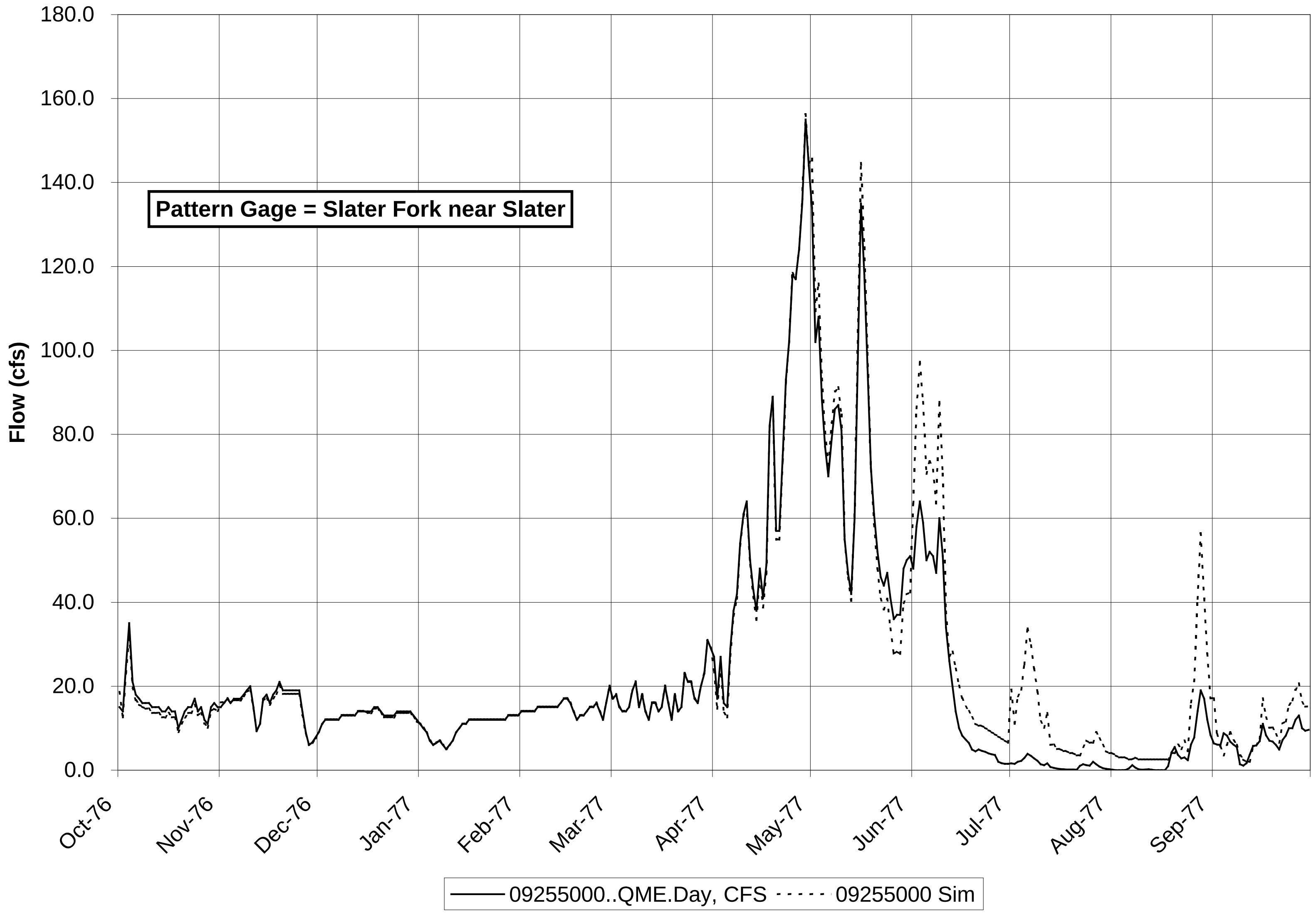

Figure 32 - Historical versus Simulated Daily Flows for Water year 1977, USGS 09255000 - Slater Fork near Slater

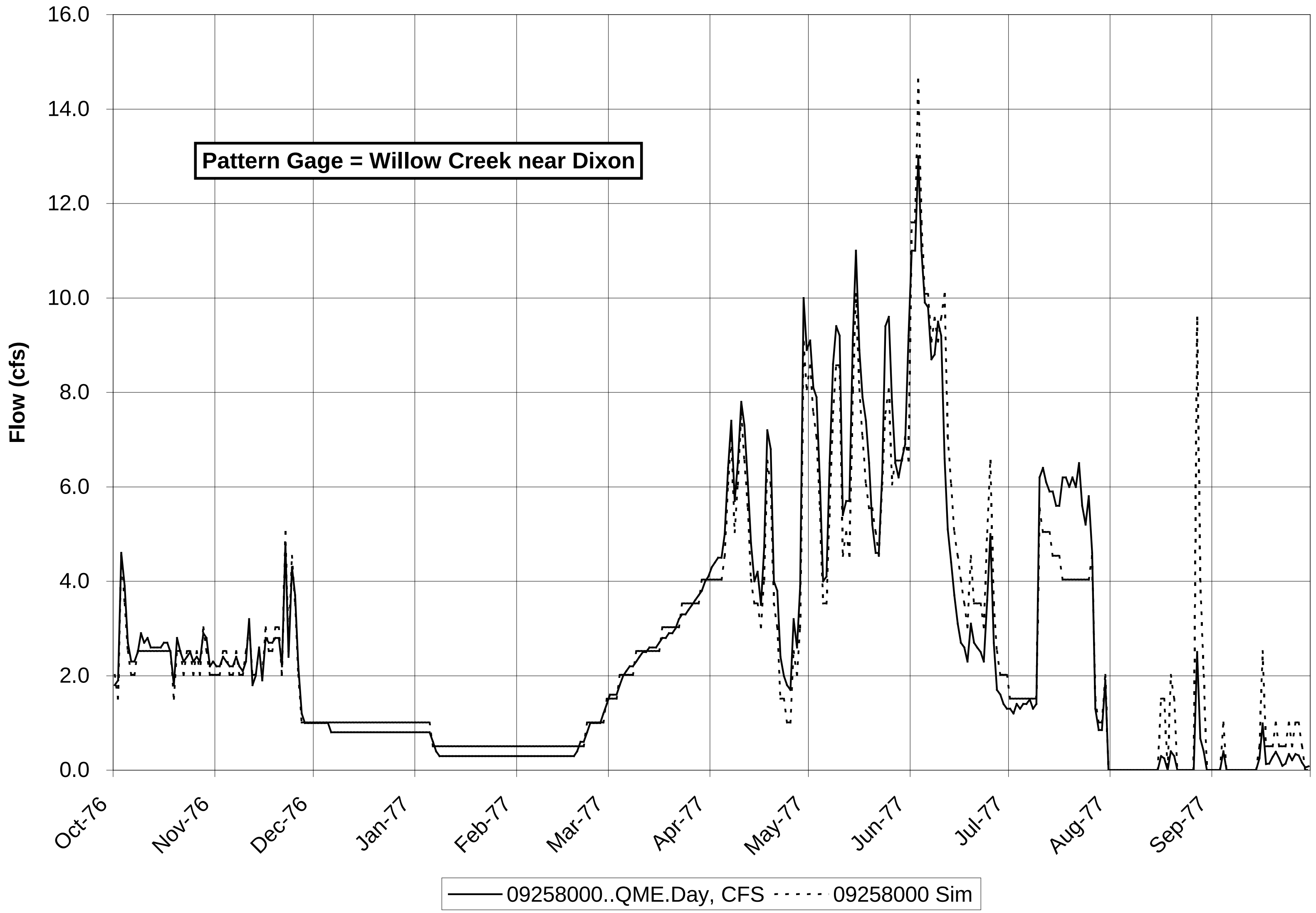

Figure 33 - Historical versus Simulated Daily Flows for Water Year 1977, USGS 09258000 - Willow Creek near Dixon

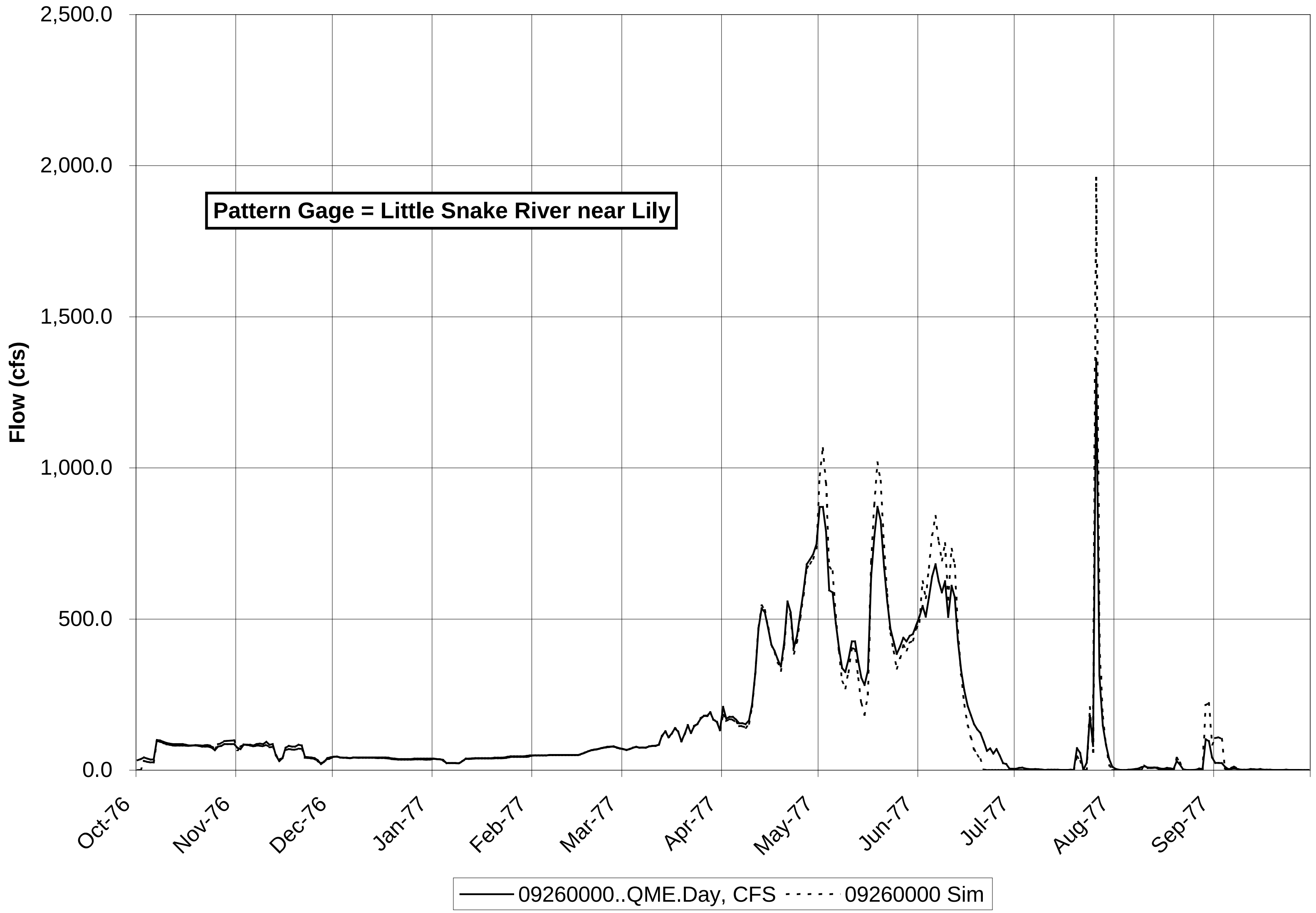

Figure 34 - Historical versus Simulated Daily Flows for Water Year 1977, USGS 0926000 - Little Snake River near Lily

Historical versus Simulated Daily Flows for Water Year 1983

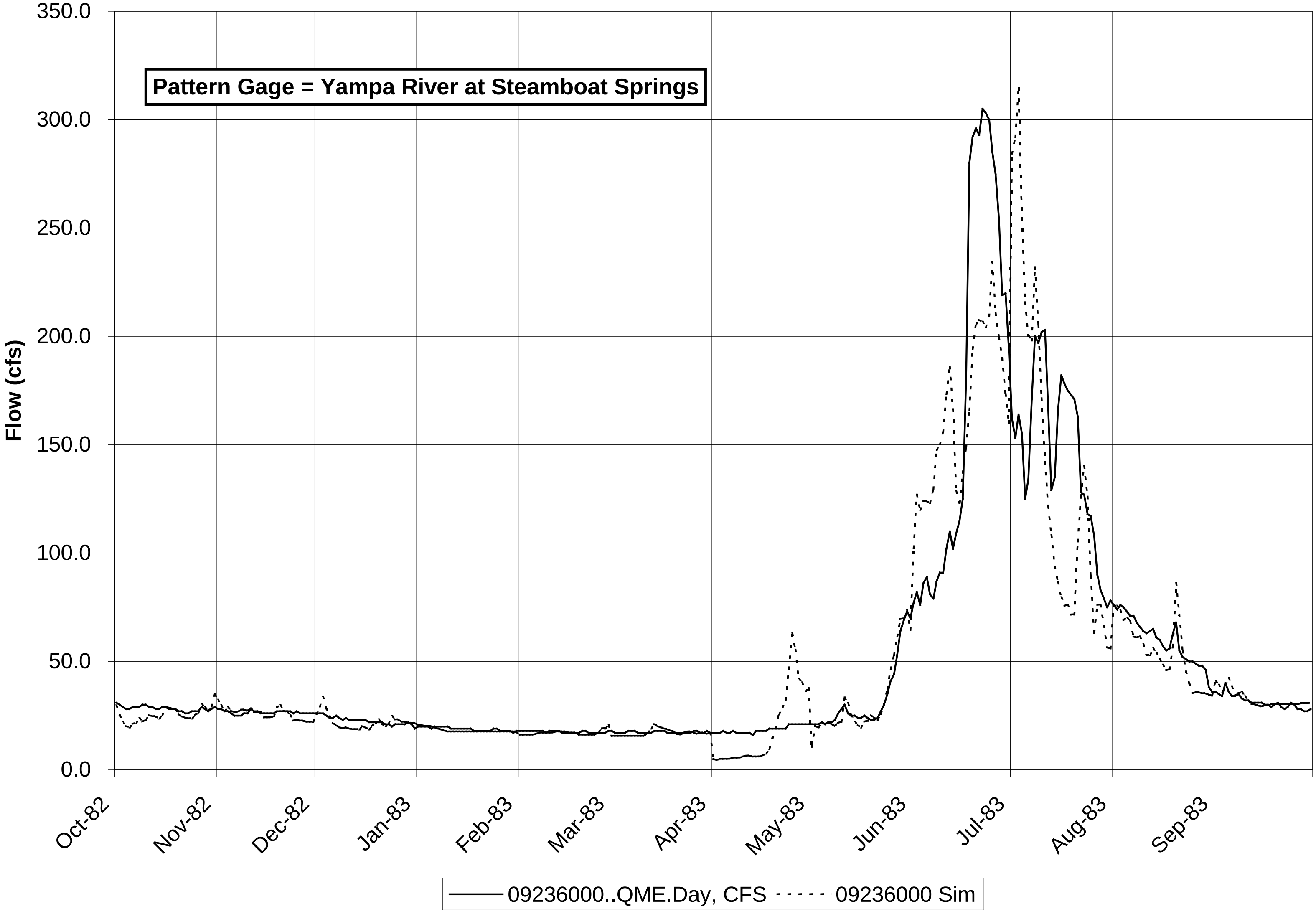

Figure 35 - Historical versus Simulated Daily Flows for Water Year 1983, USGS 09236000 - Bear River near Toponas

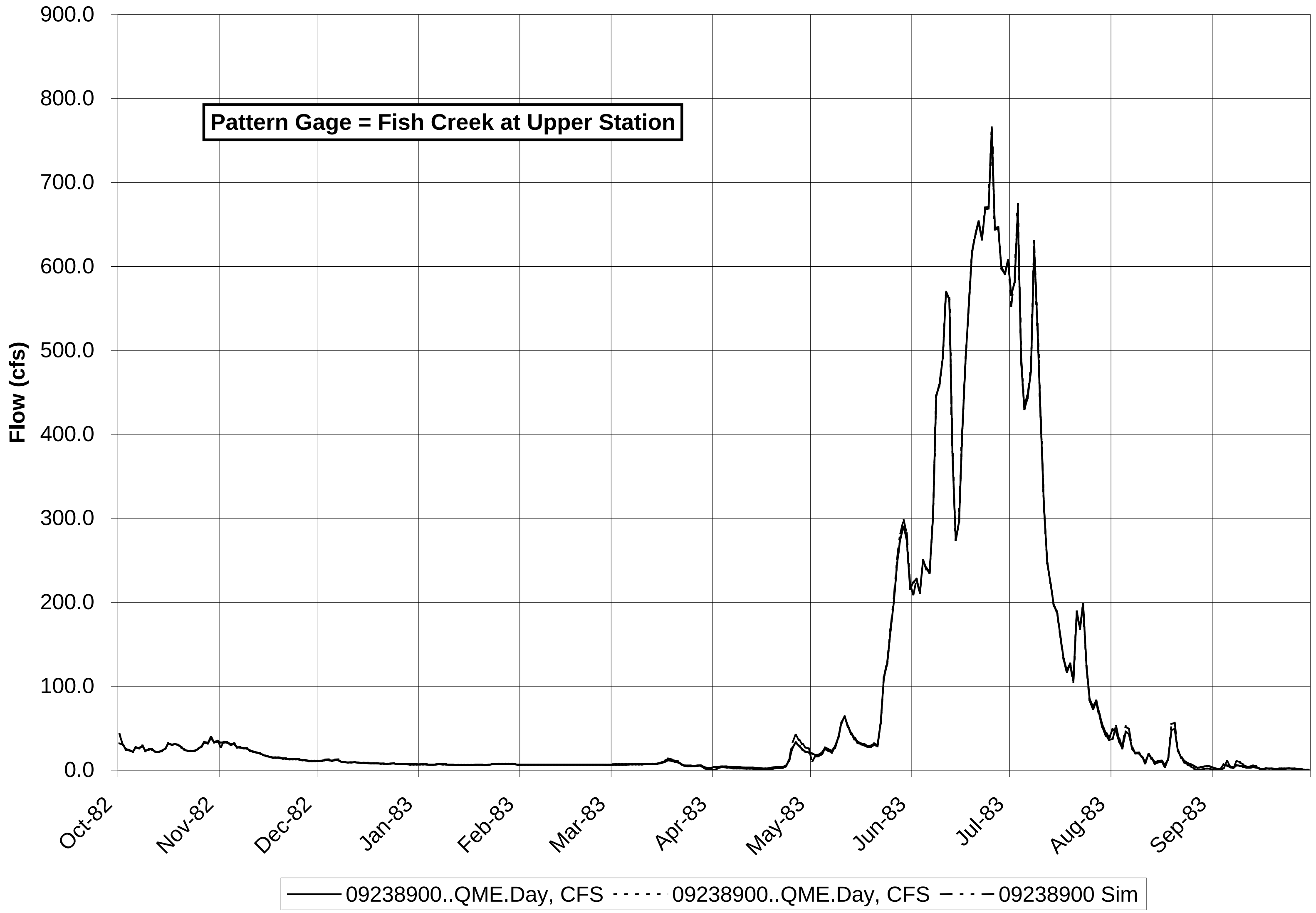

Figure 36 - Historical versus Simulated Daily Flows for Water Year 1983, USGS 09238900 - Bear River at Upper Station near Steamboat Springs

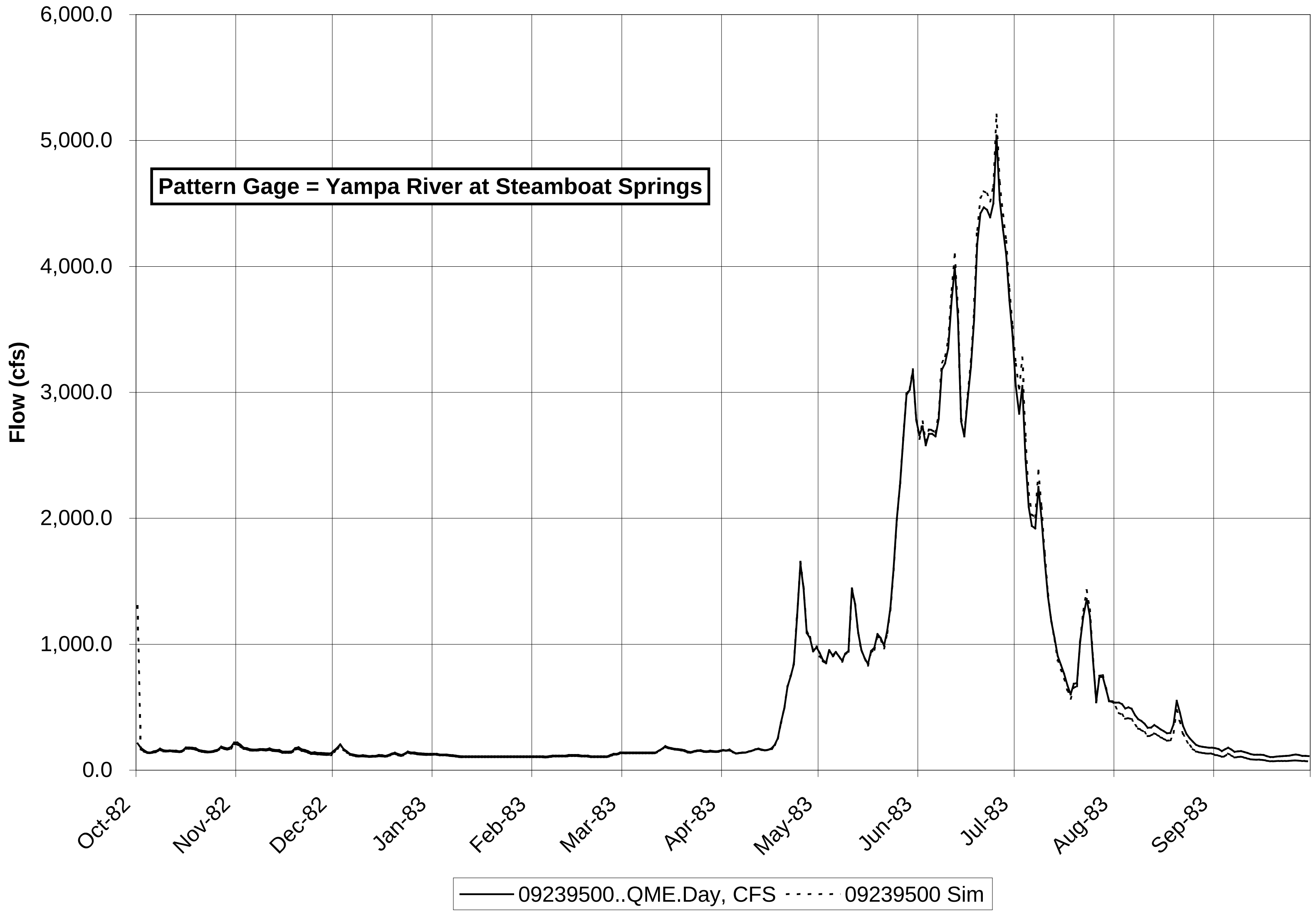

Figure 37 - Historical versus Simulated Daily Flows for Water Year 1983, USGS 09239500 - Yampa River at Steamboat Springs

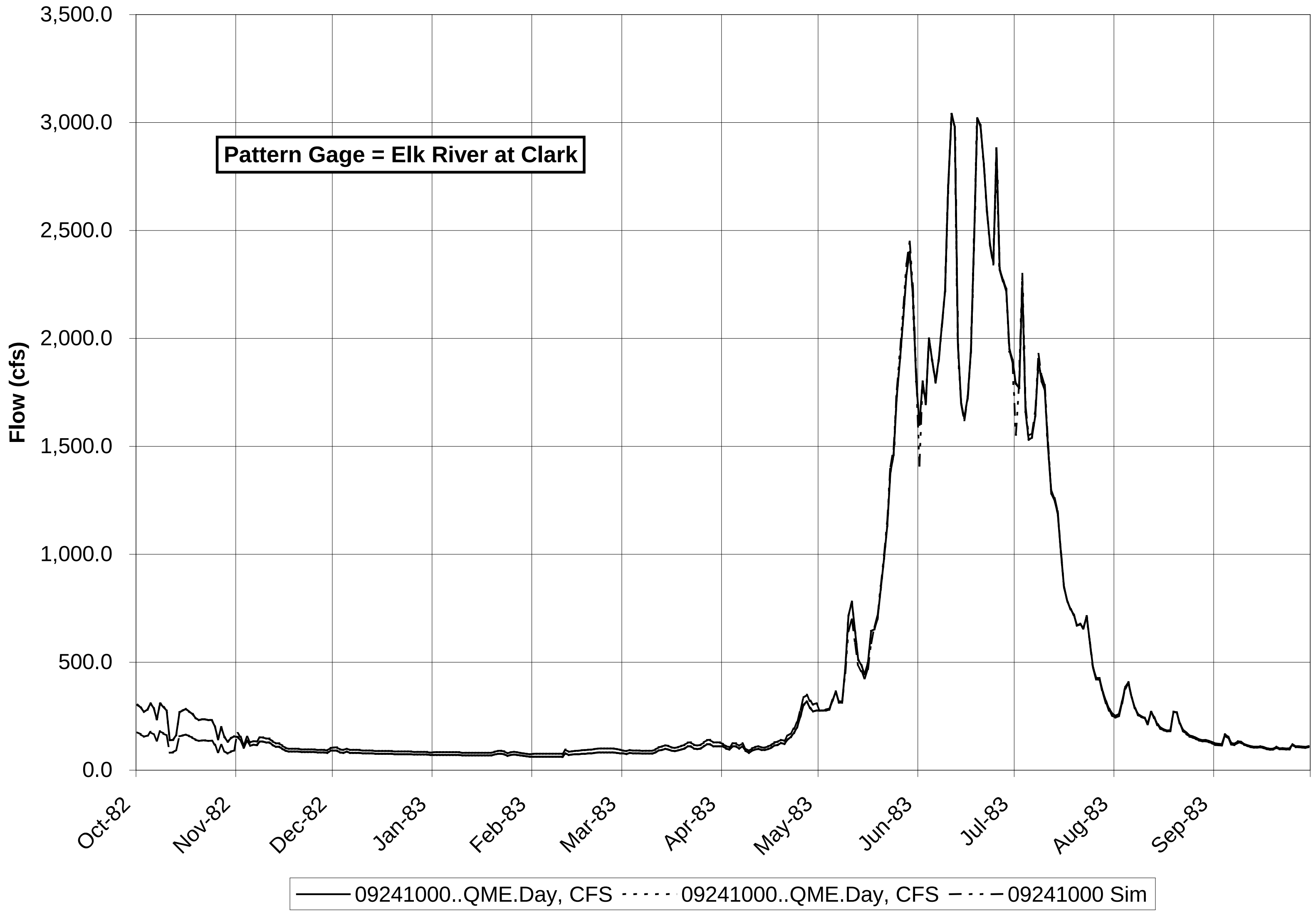

Figure 38 - Historical versus Simulated Daily Flows for Water Year 1983, USGS 09241000 - Elk River at Clark

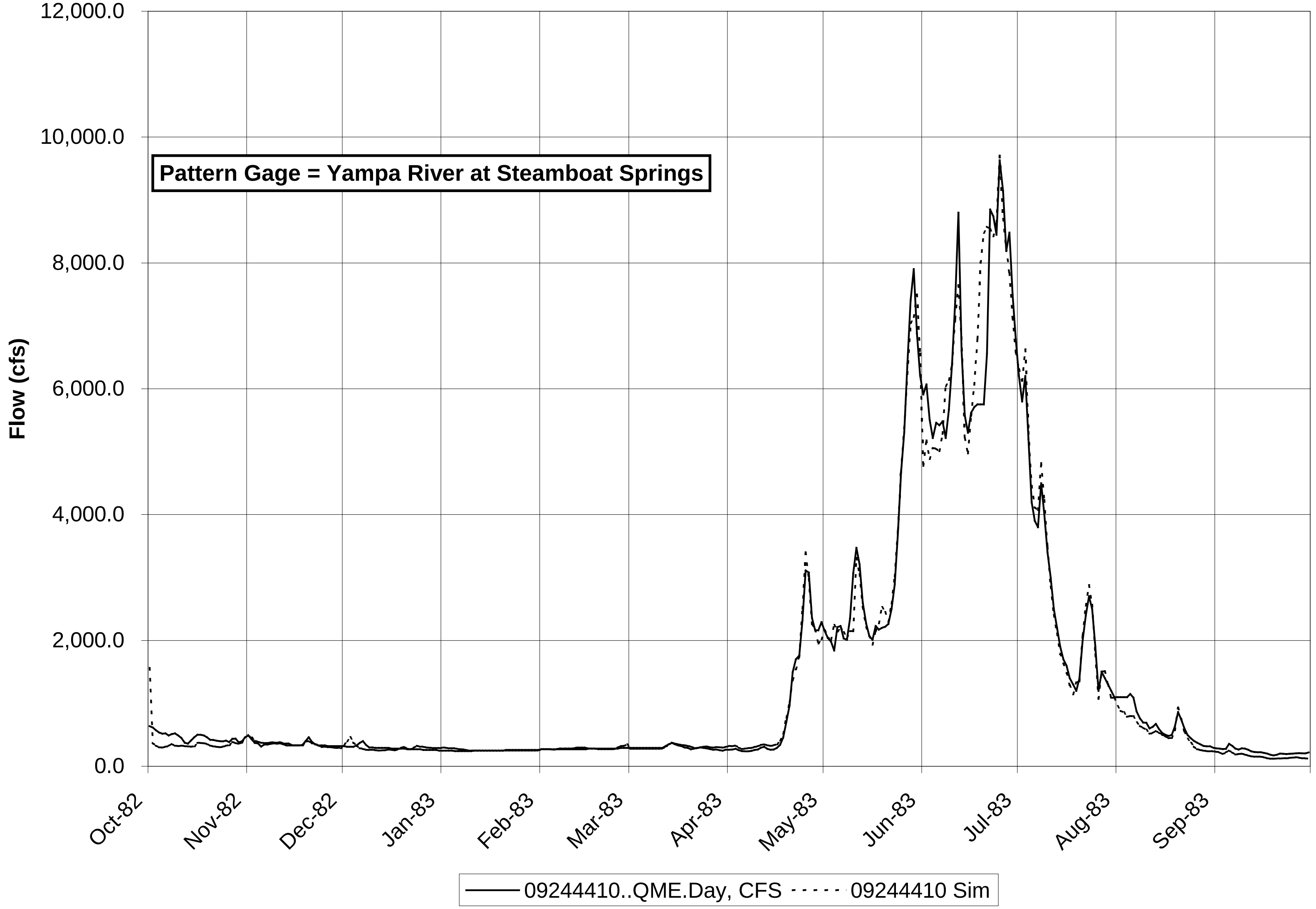

Figure 39 - Historical versus Simulated Daily Flows for Water Year 1983, USGS 09244410 - Yampa River below diversion near Hayden

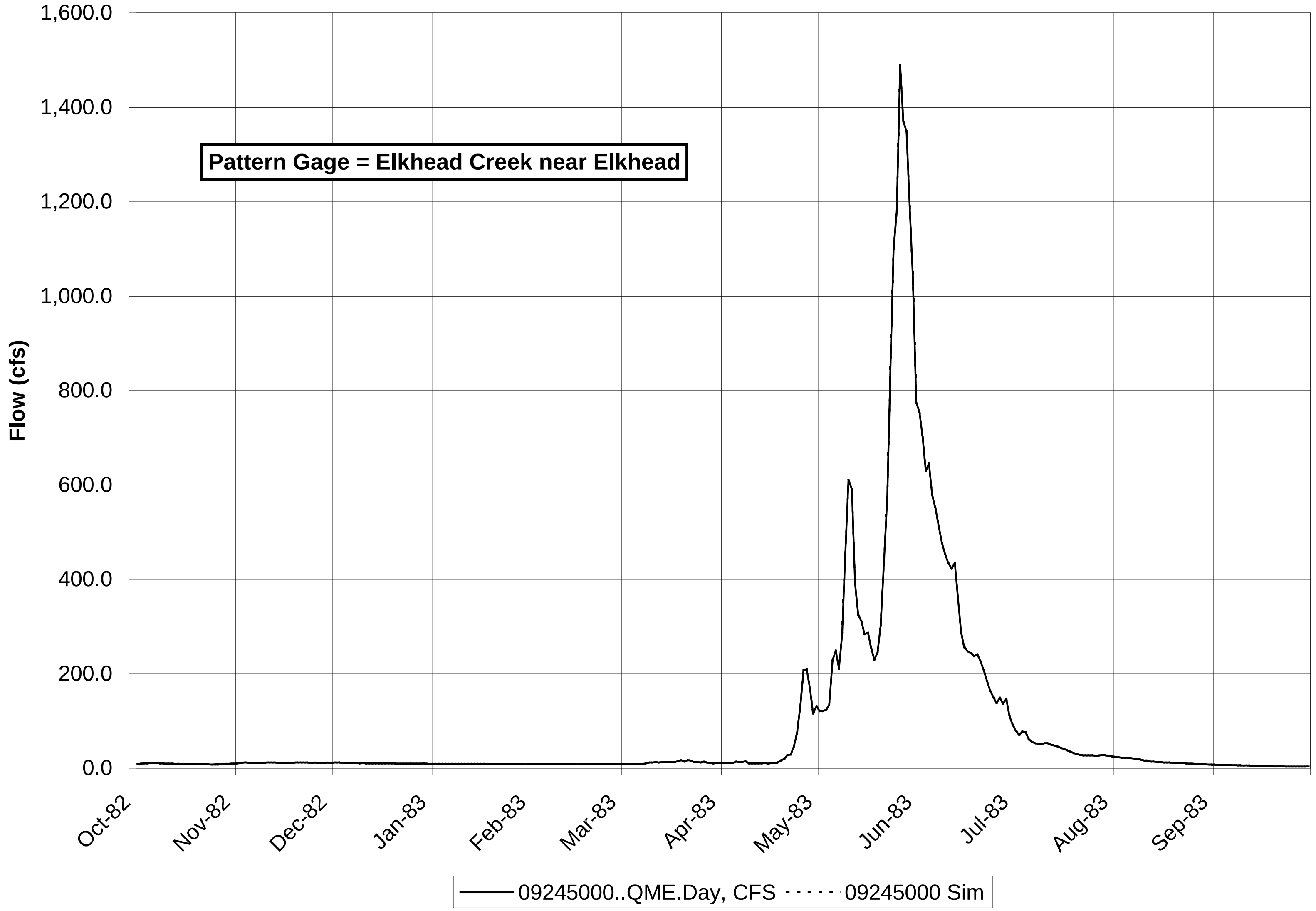

Figure 40 - Historical versus Simulated Daily Flows for Water Year 1983, USGS 09245000 - Elkhead Creek near Elkhead

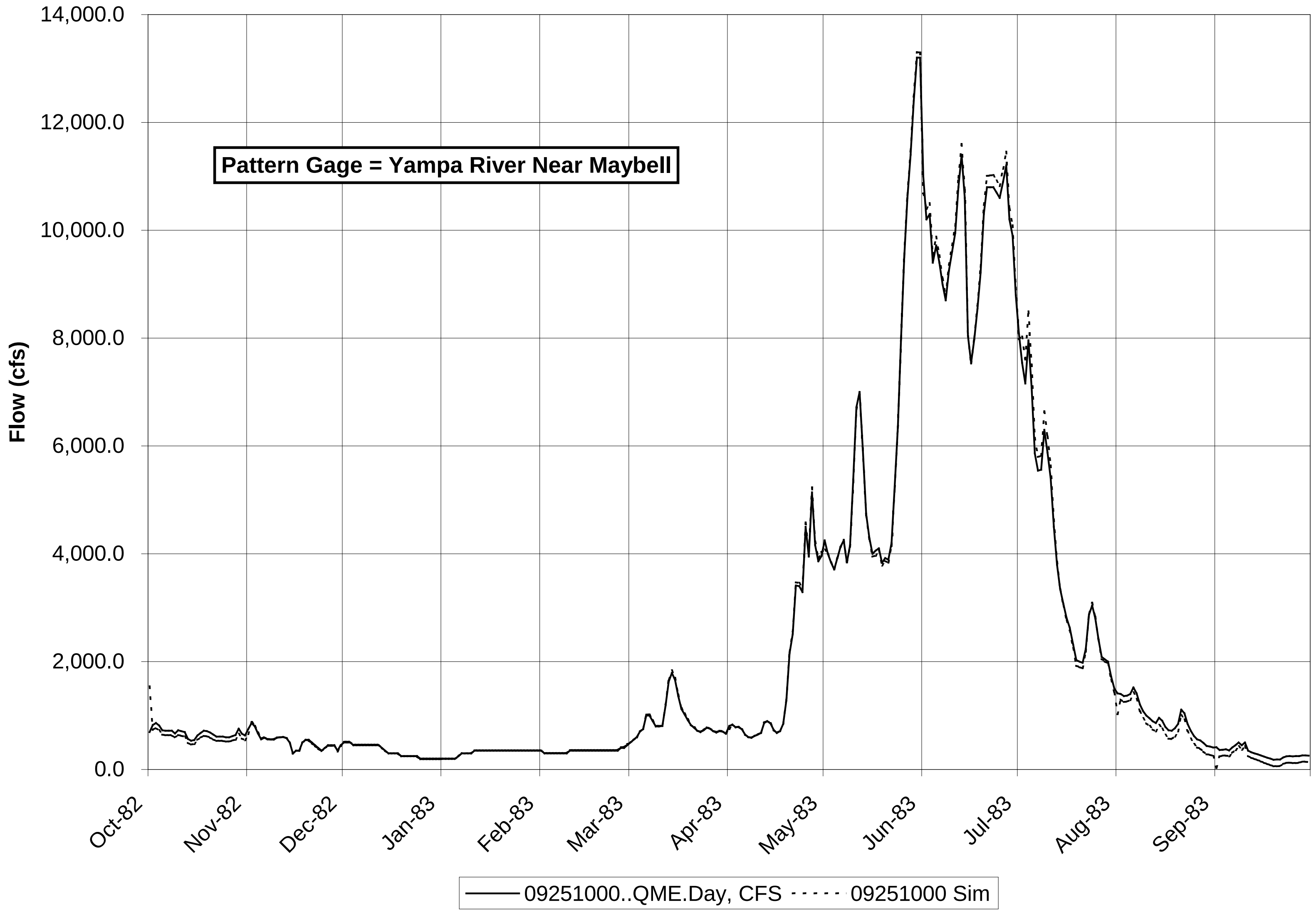

Figure 41 - Historical versus Simulated Daily Flows for Water year 1983, USGS 09251000 - Yampa River near Maybell

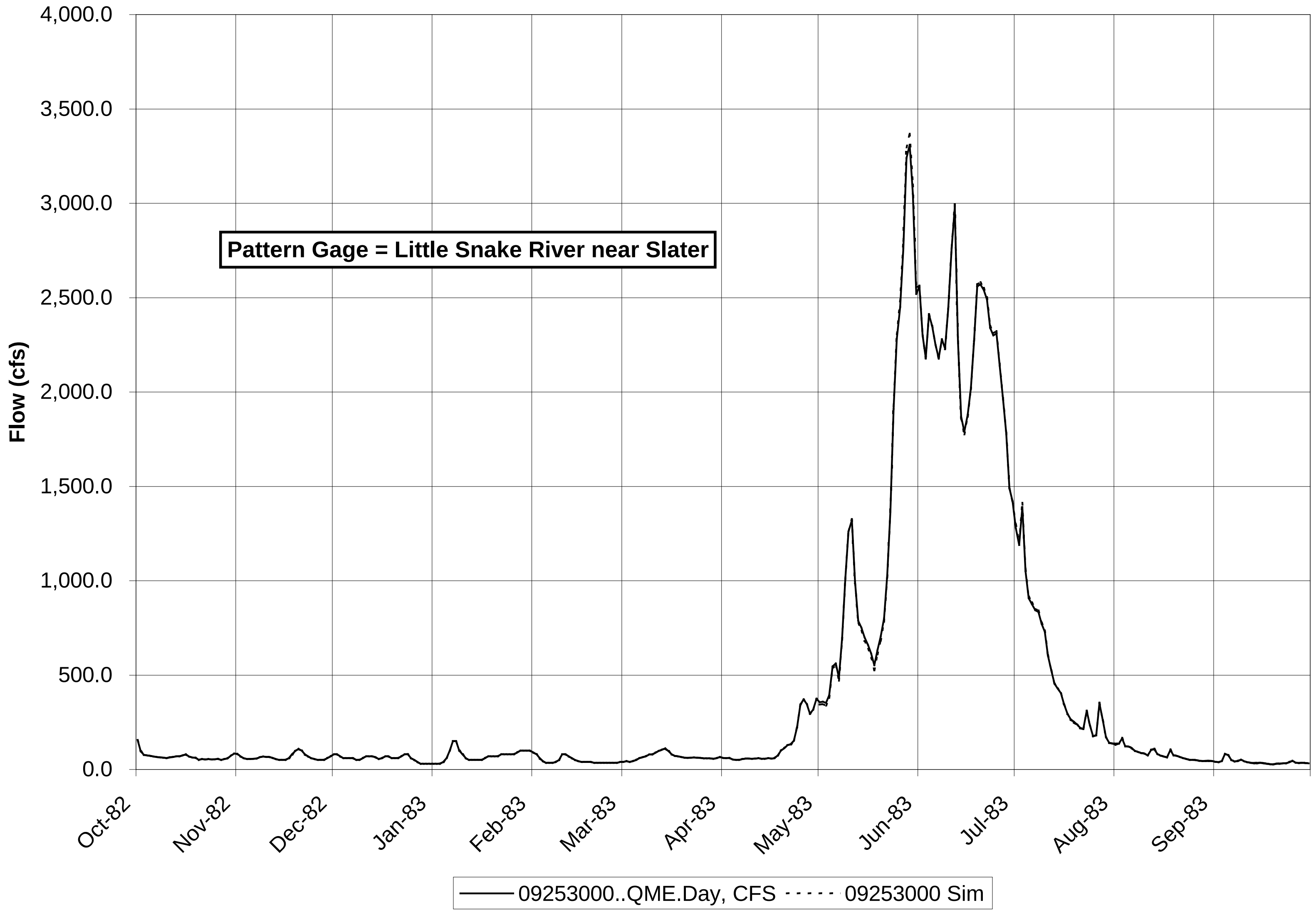

Figure 42 - Historical versus Simulated Daily Flows for Water Year 1983, USGS 09253000 - Little Snake River near Slater

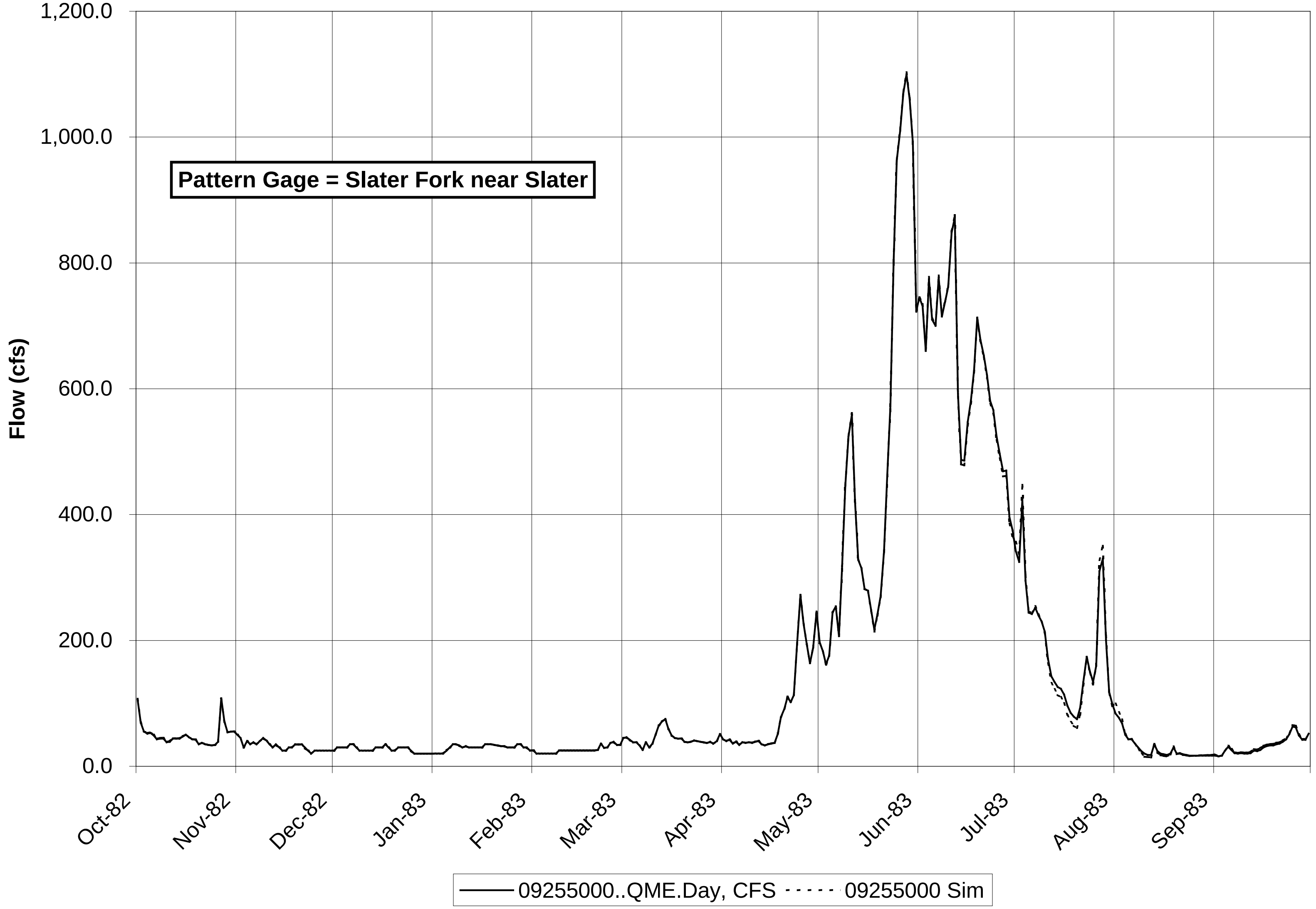

Figure 43 - Historical versus Simulated Daily Flows for Water Year 1983, USGS 0925000 - Slater Fork near Slater

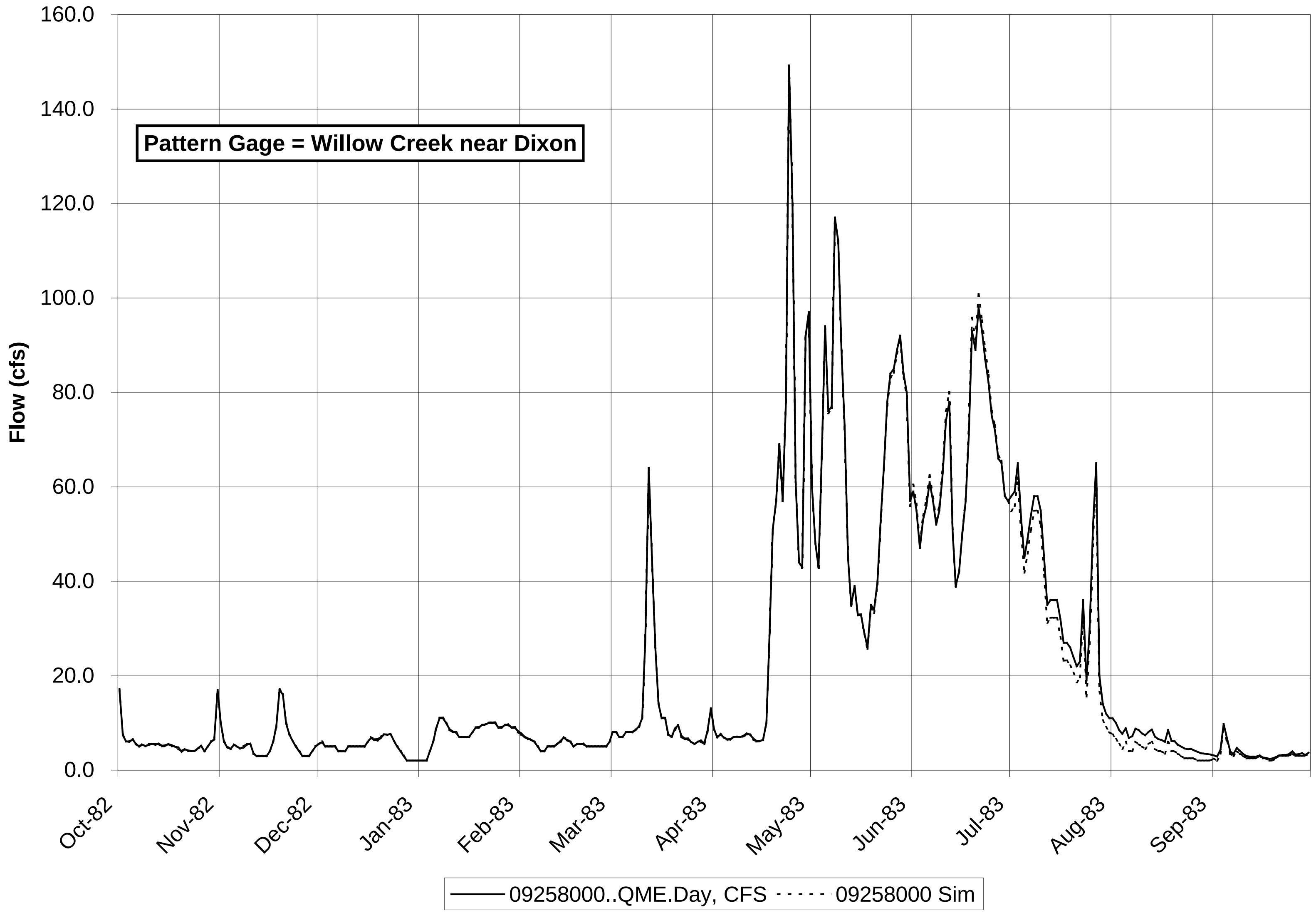

Figure 44 - Historical versus Simulated Daily Flows for Water year 1983, USGS 09258000 - Willow Creek near Dixon

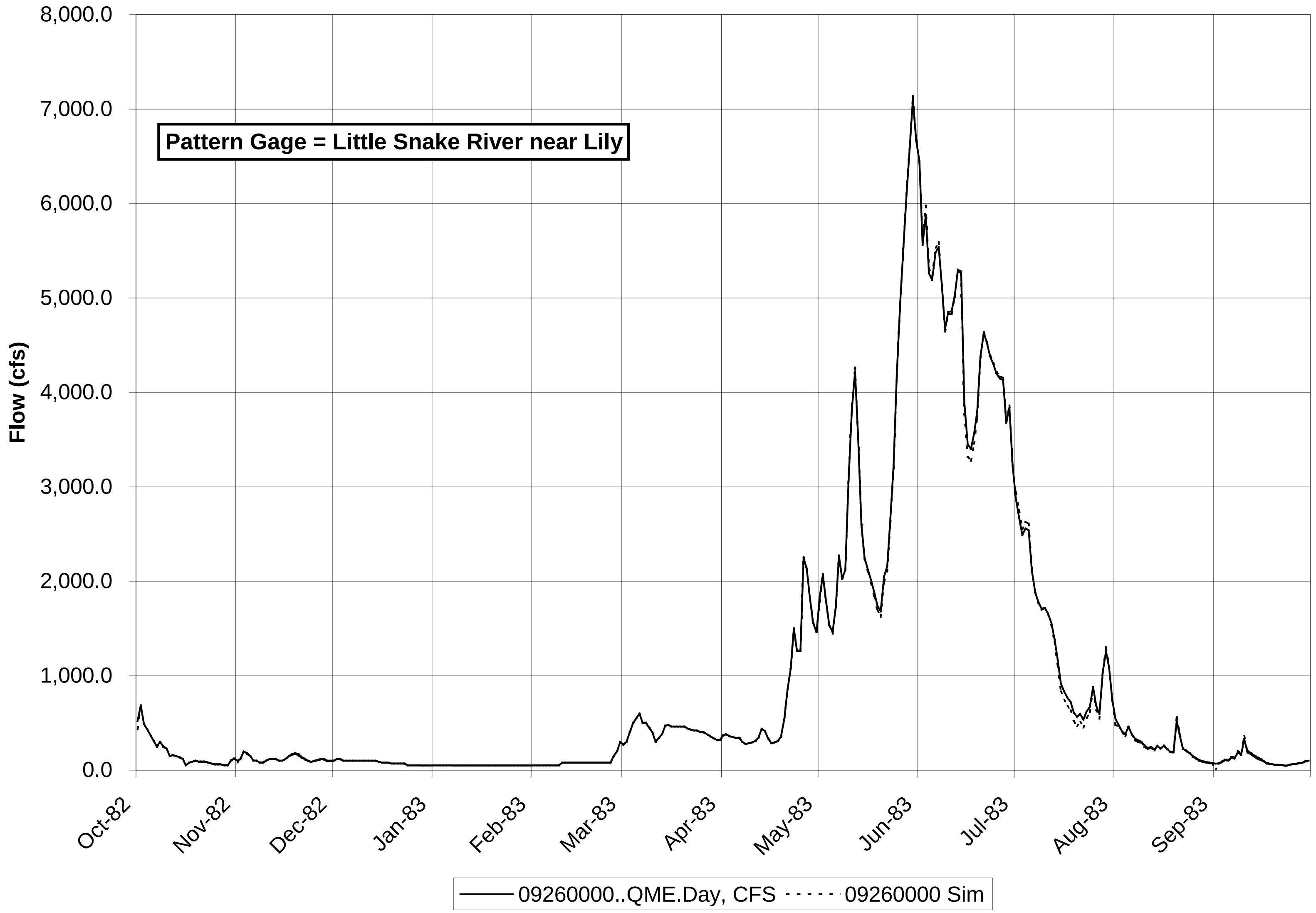

Figure 45 - Historical versus Simulated Daily Flows for Water Year 1983, USGS 09260000 - Little Snake River near Lily

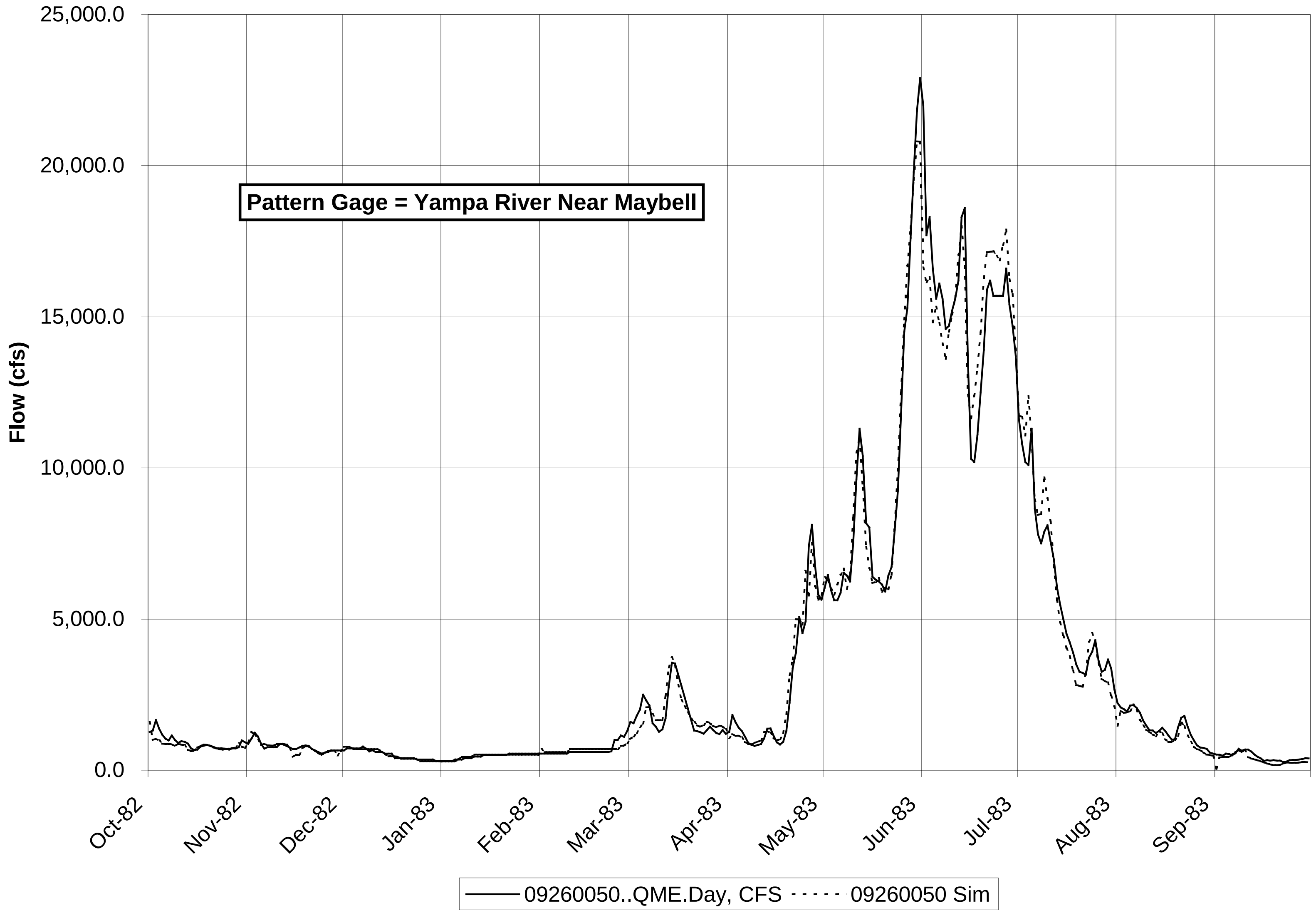

Figure 46 - Historical versus Simulated Daily Flows for Water Year 1983, USGS 09260050 - Yampa River at Deerlodge

Historical versus Simulated Daily Flows for Water Year 1988

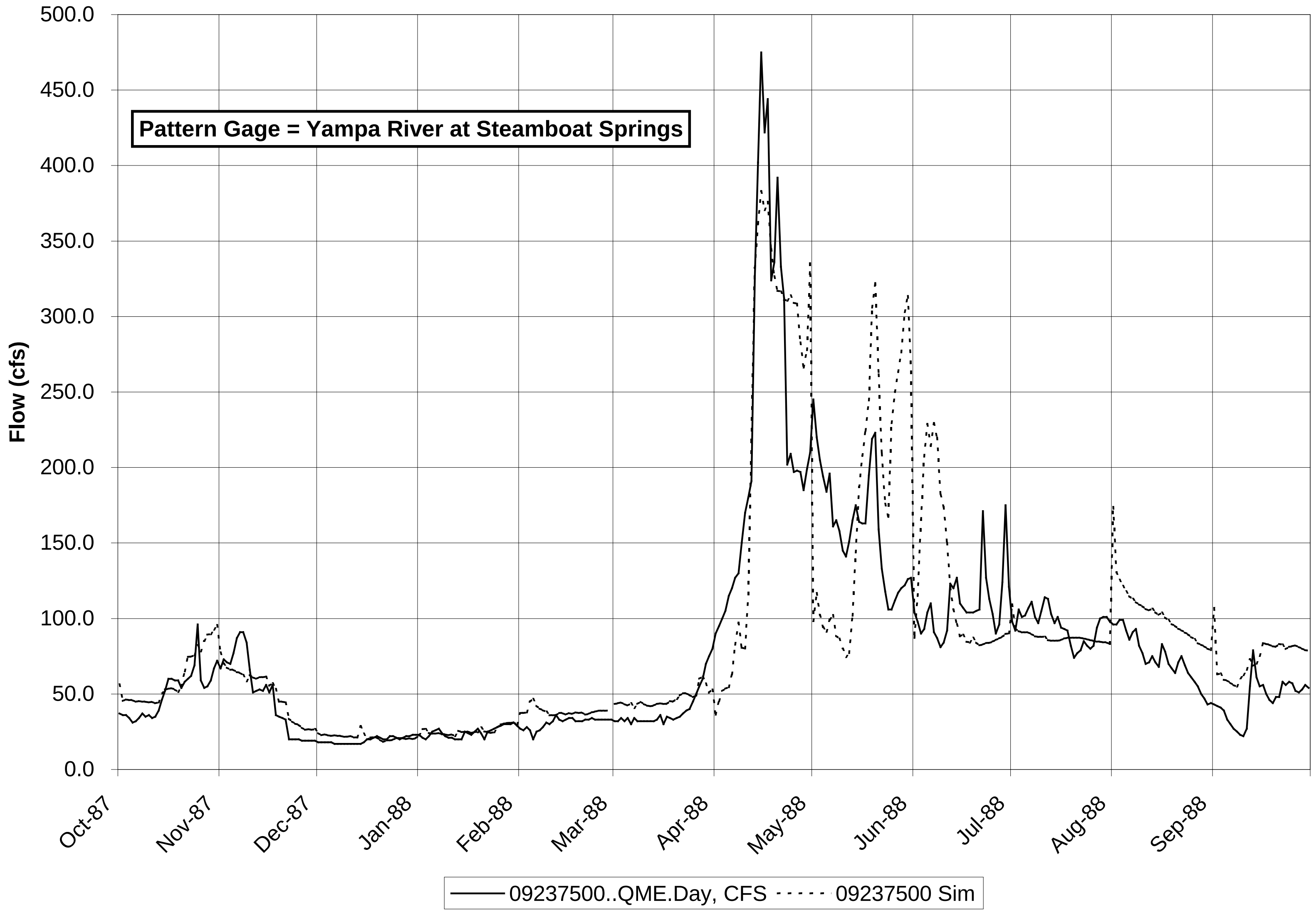

Figure 47 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 09237500 - Yampa River below Stagecoach Reservoir

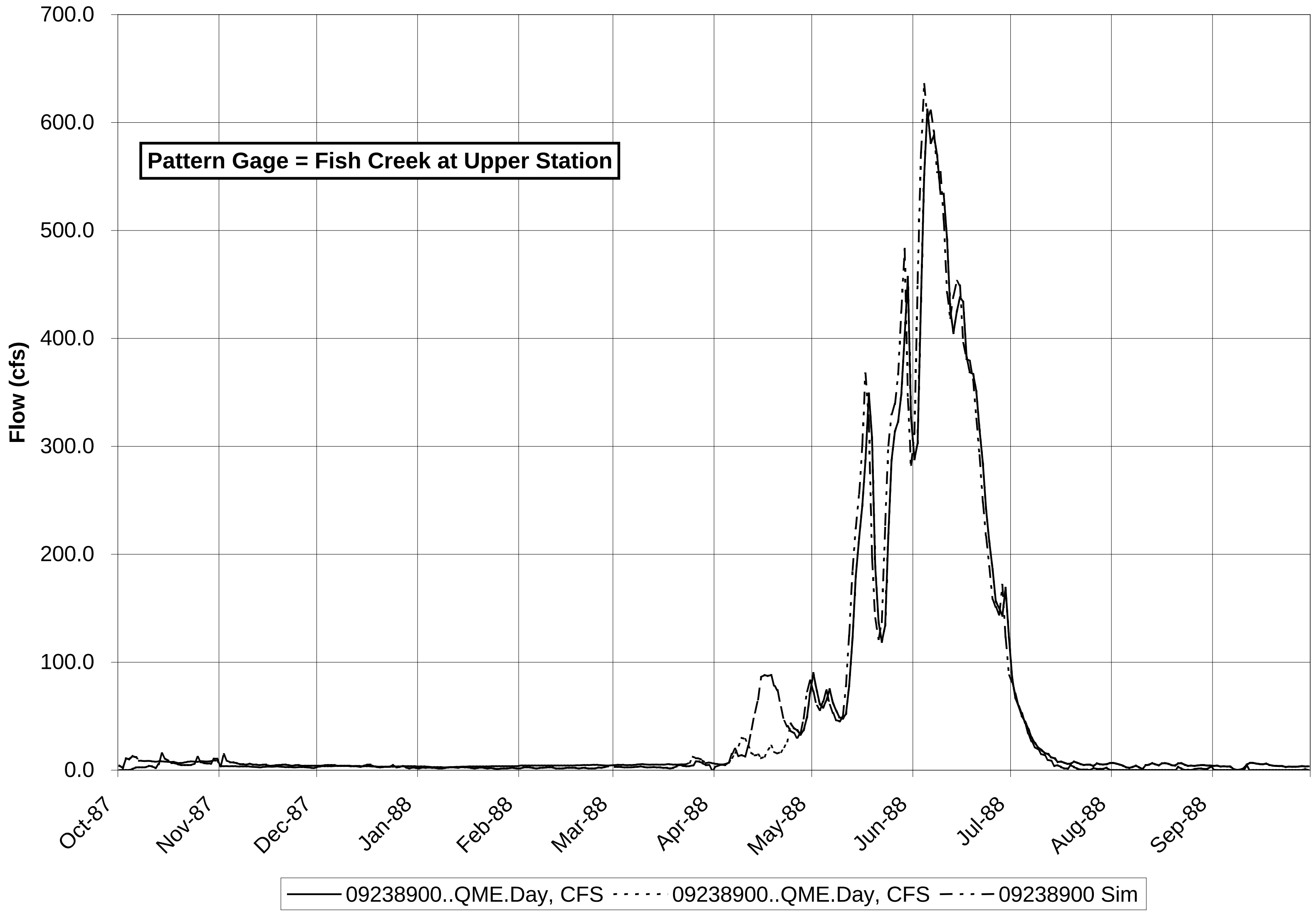

Figure 48 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 09238900 - Fish Creek at Upper Station near Steamboat Springs

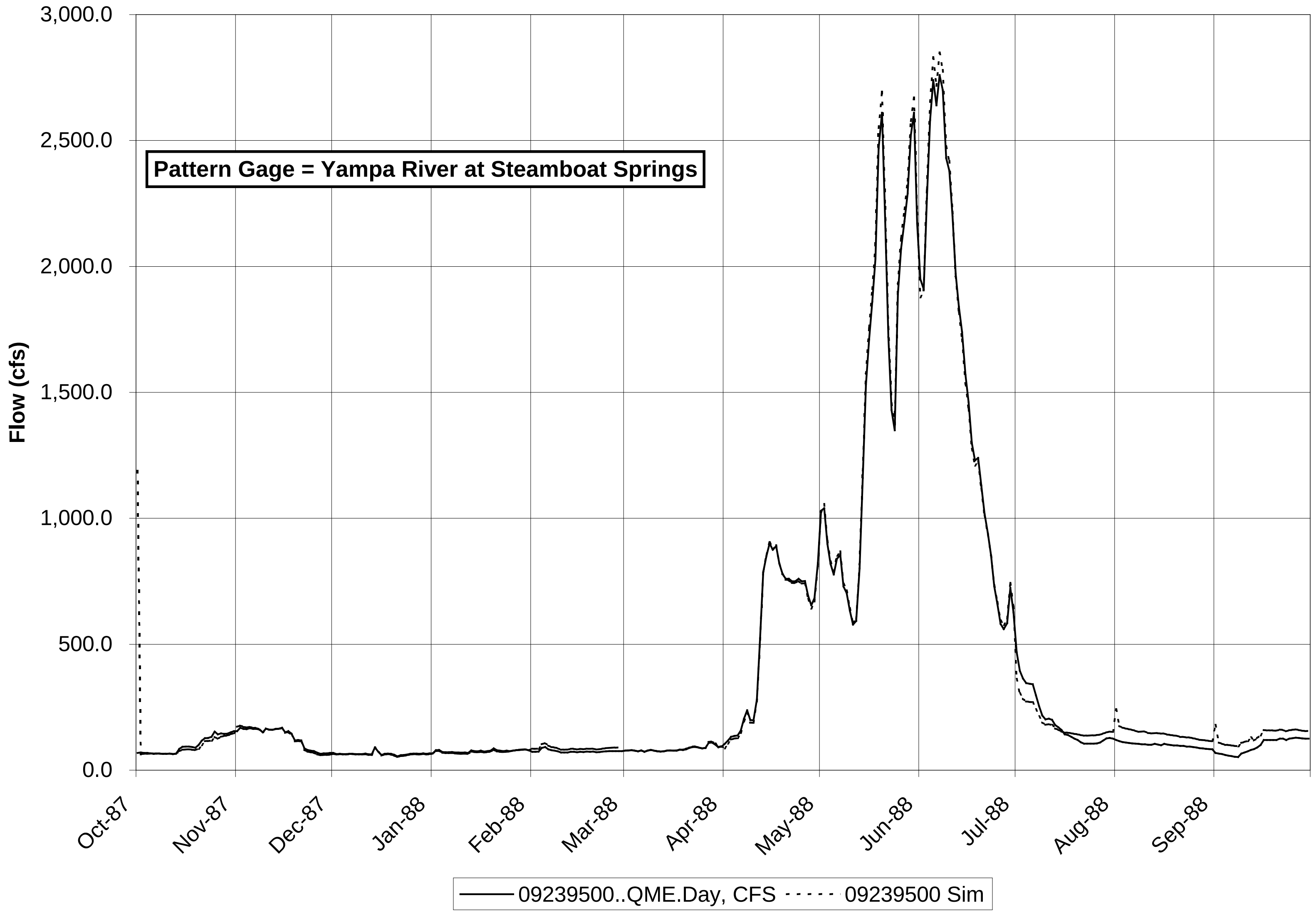

Figure 49 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 09239500 - Yampa River at Steamboat Springs

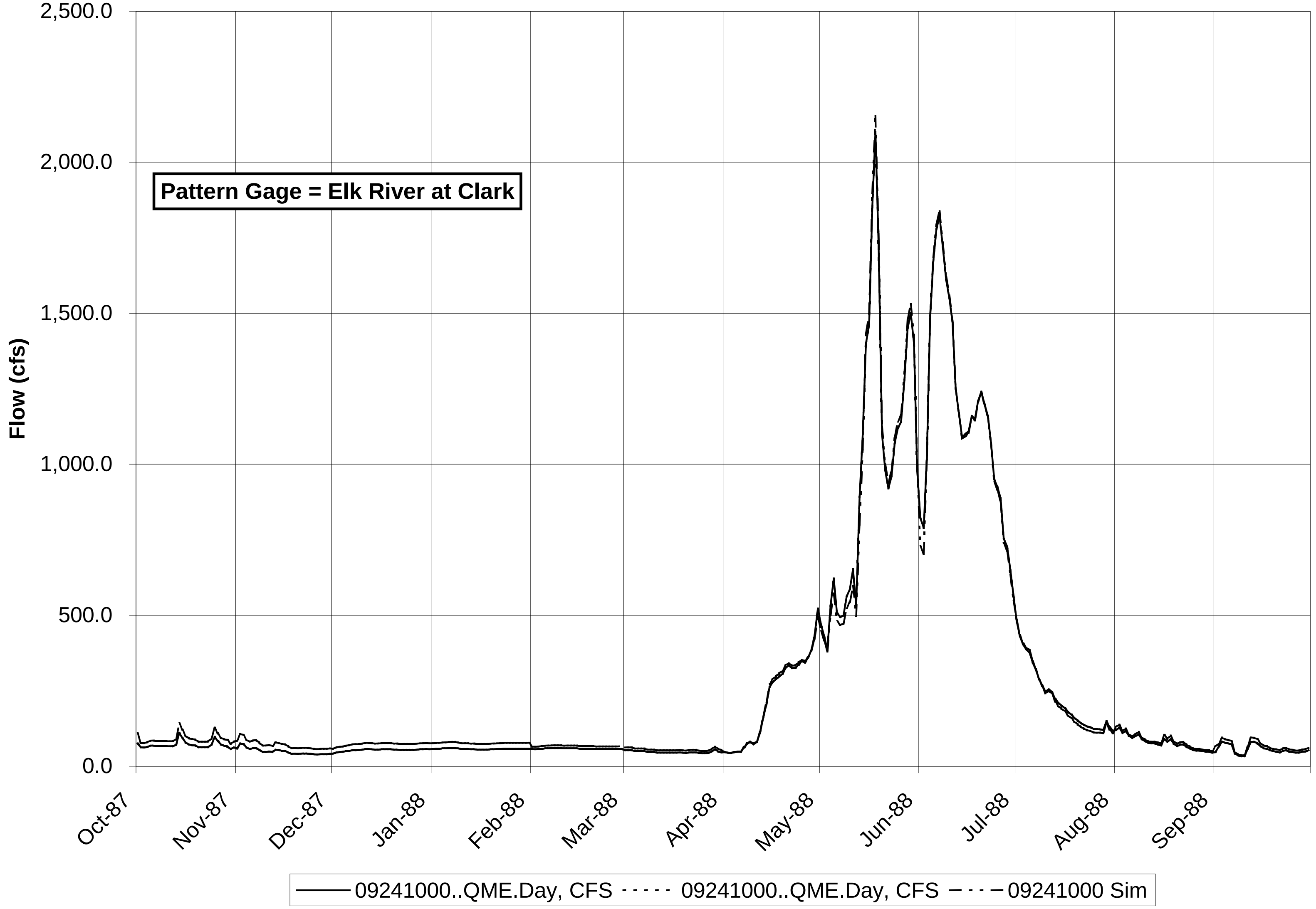

Figure 50 - Historical versus Simulated Daily flows for Water Year 1988, USGS 09241000 - Elk River at Clark

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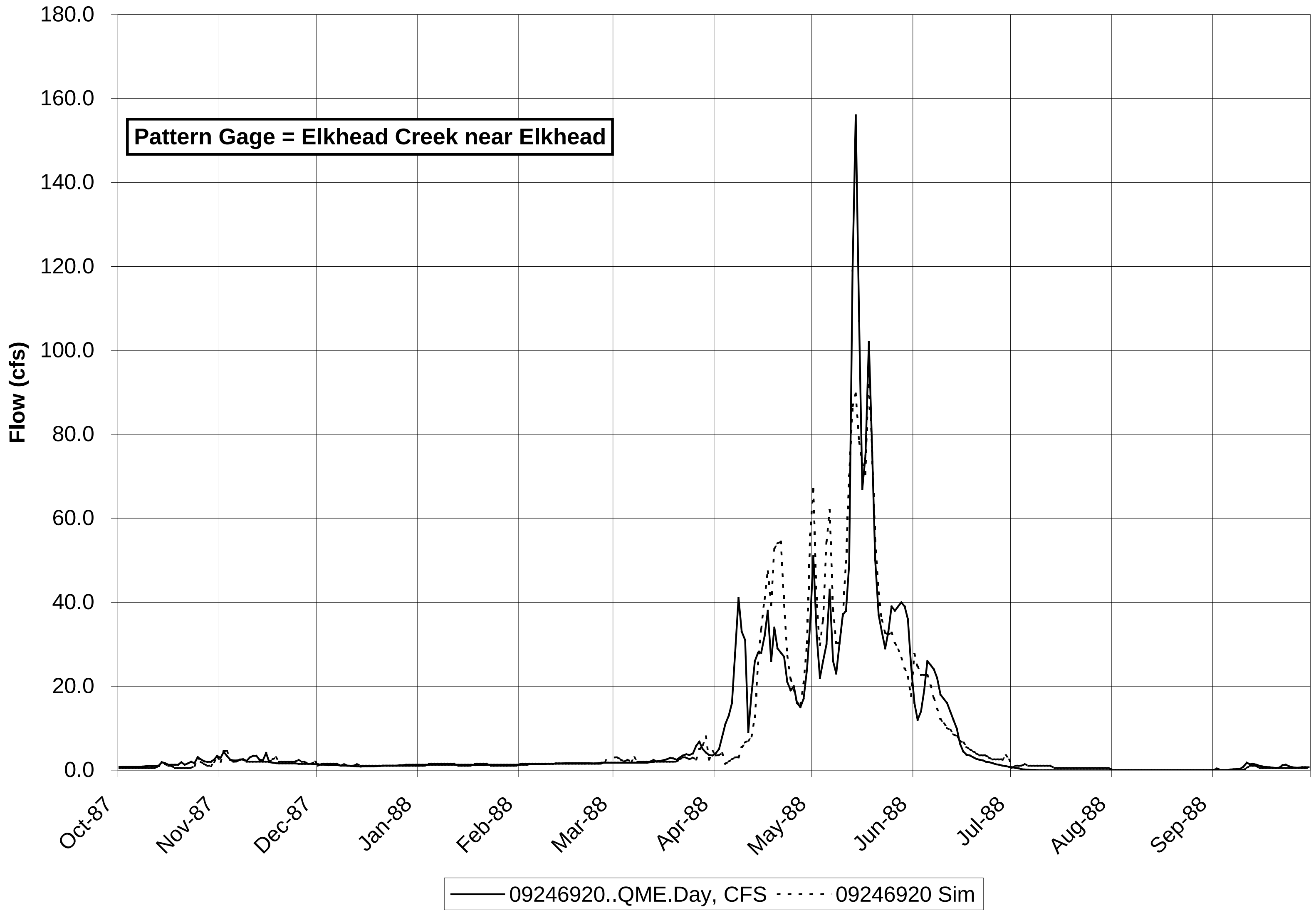

Figure 51 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 09246920 - Fortification Creek near Fortification

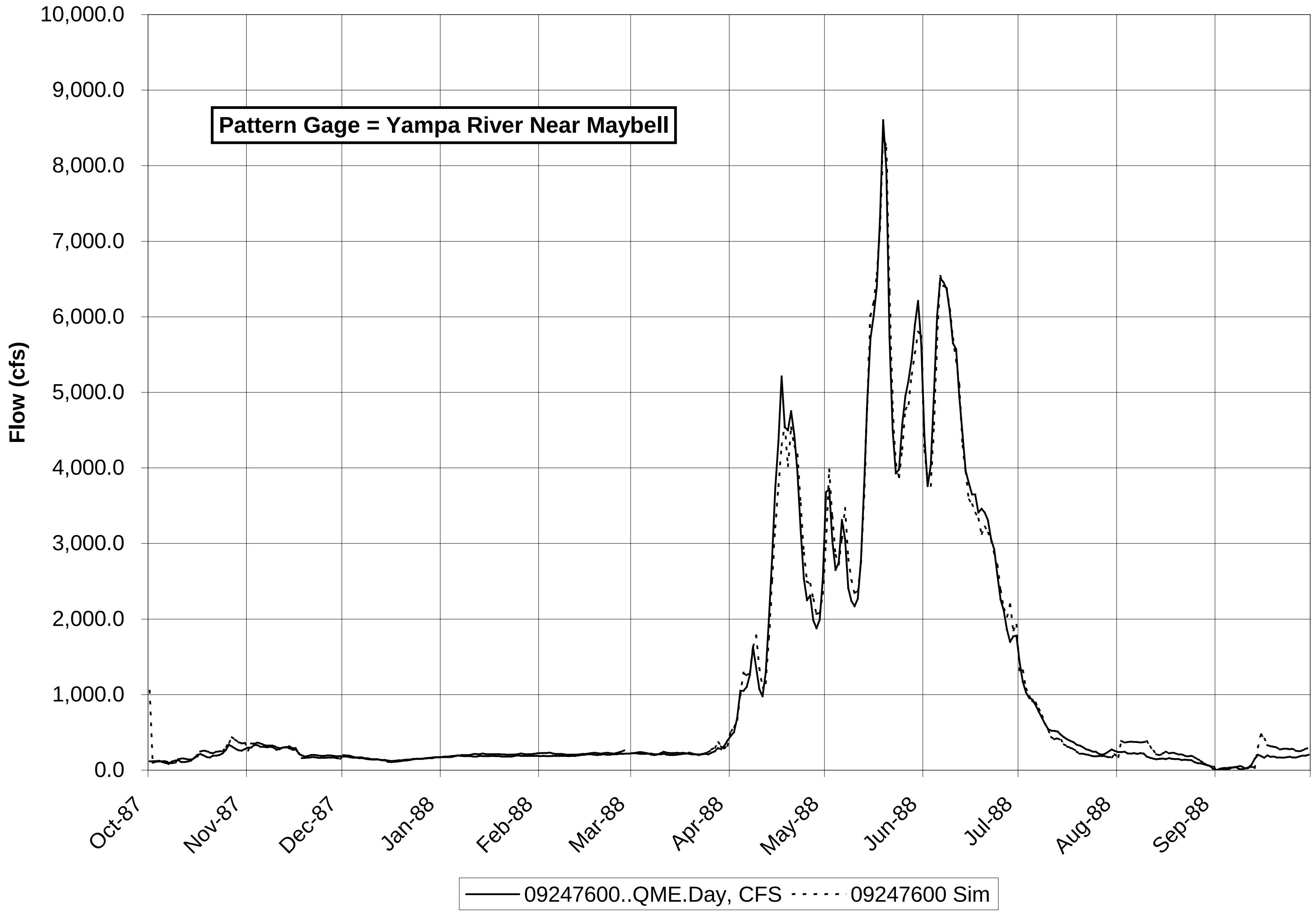

Figure 52 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 09247600 - Yampa River below Craig

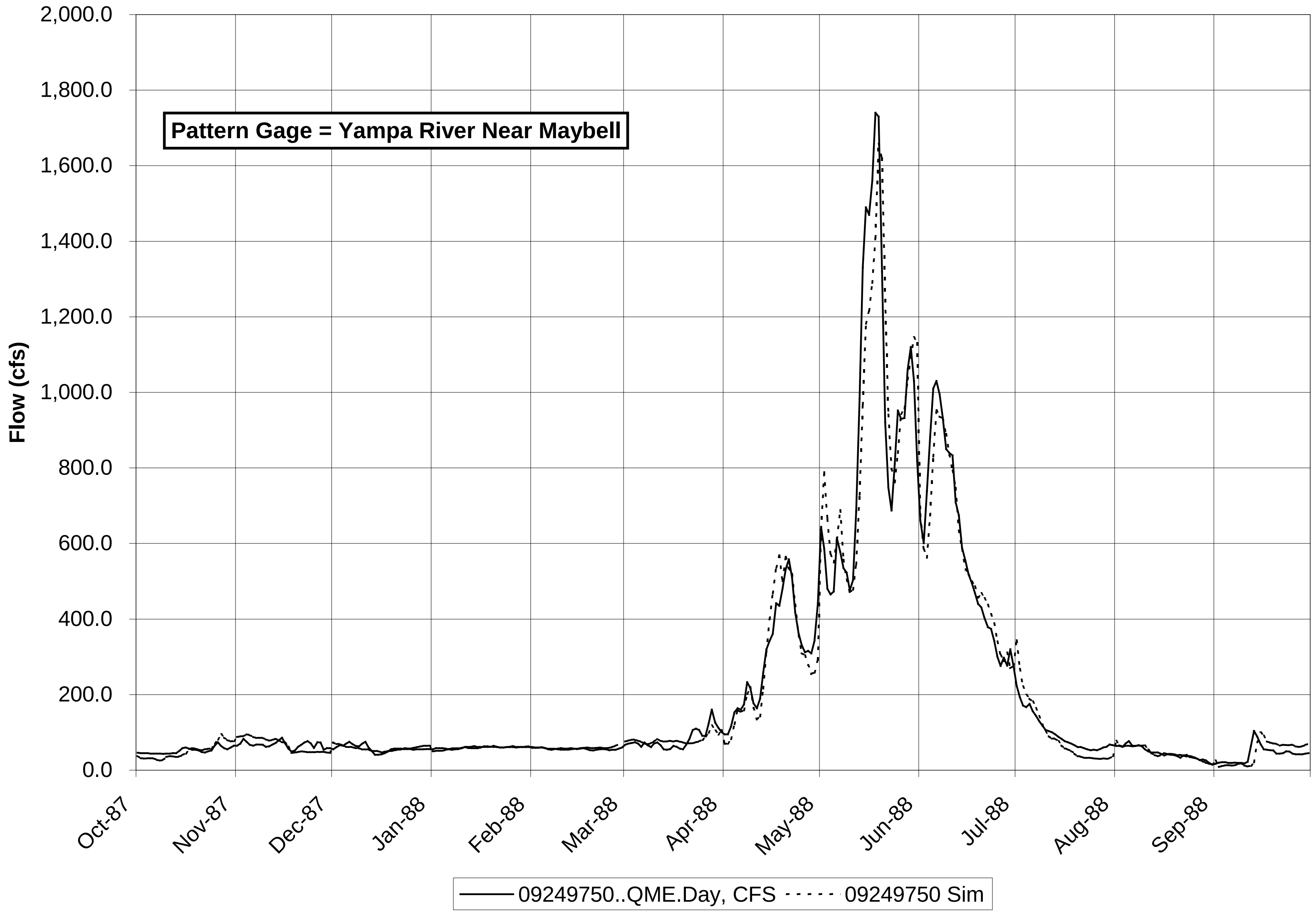

Figure 53 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 09249750 - Williams Fork at mouth, near Hamilton

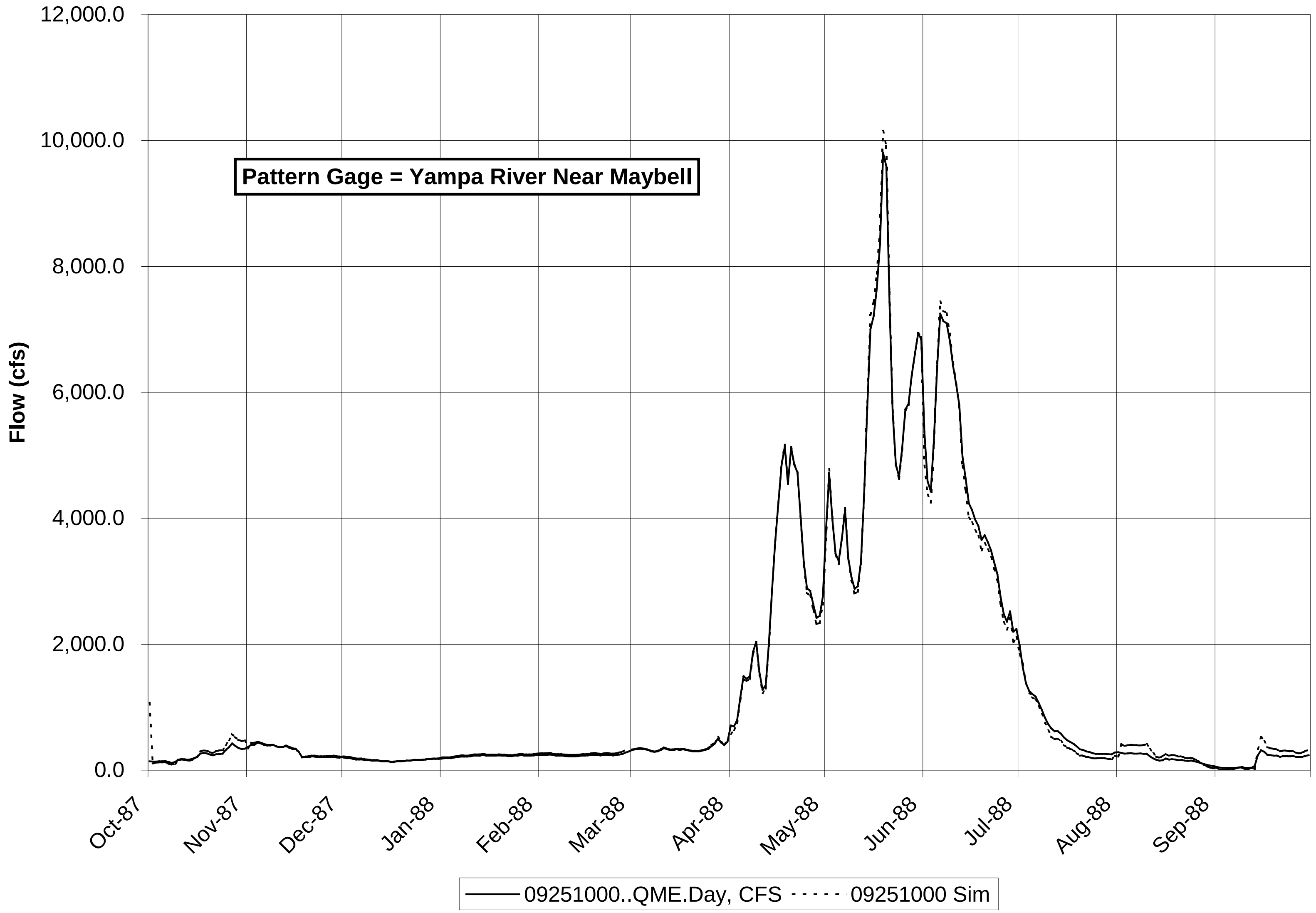

Figure 54 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 09251000 - Yampa River near Maybell

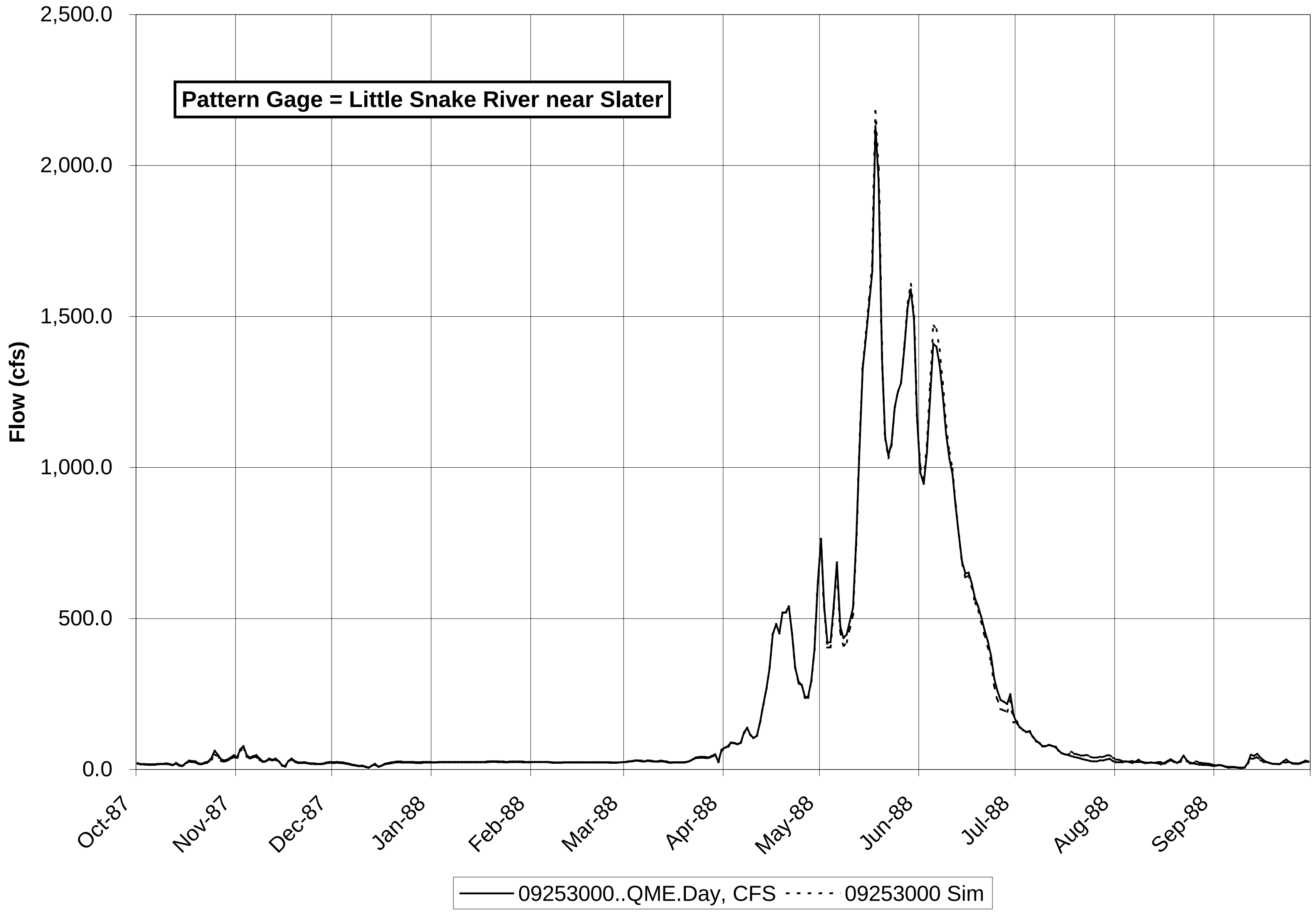

Figure 55 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 09253000 - Little Snake River near Slater

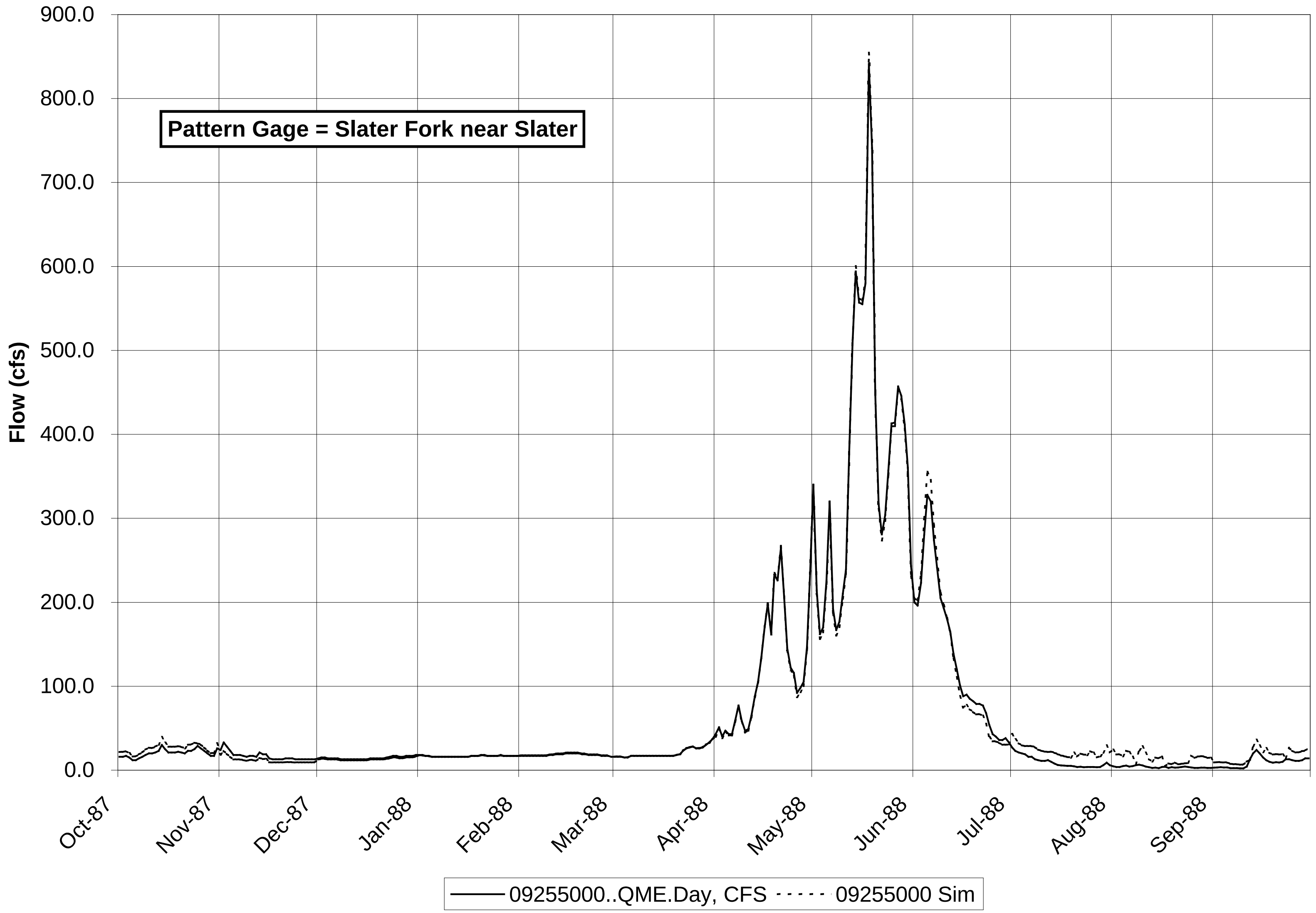

Figure 56 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 09255000 - Slater Fork near Slater

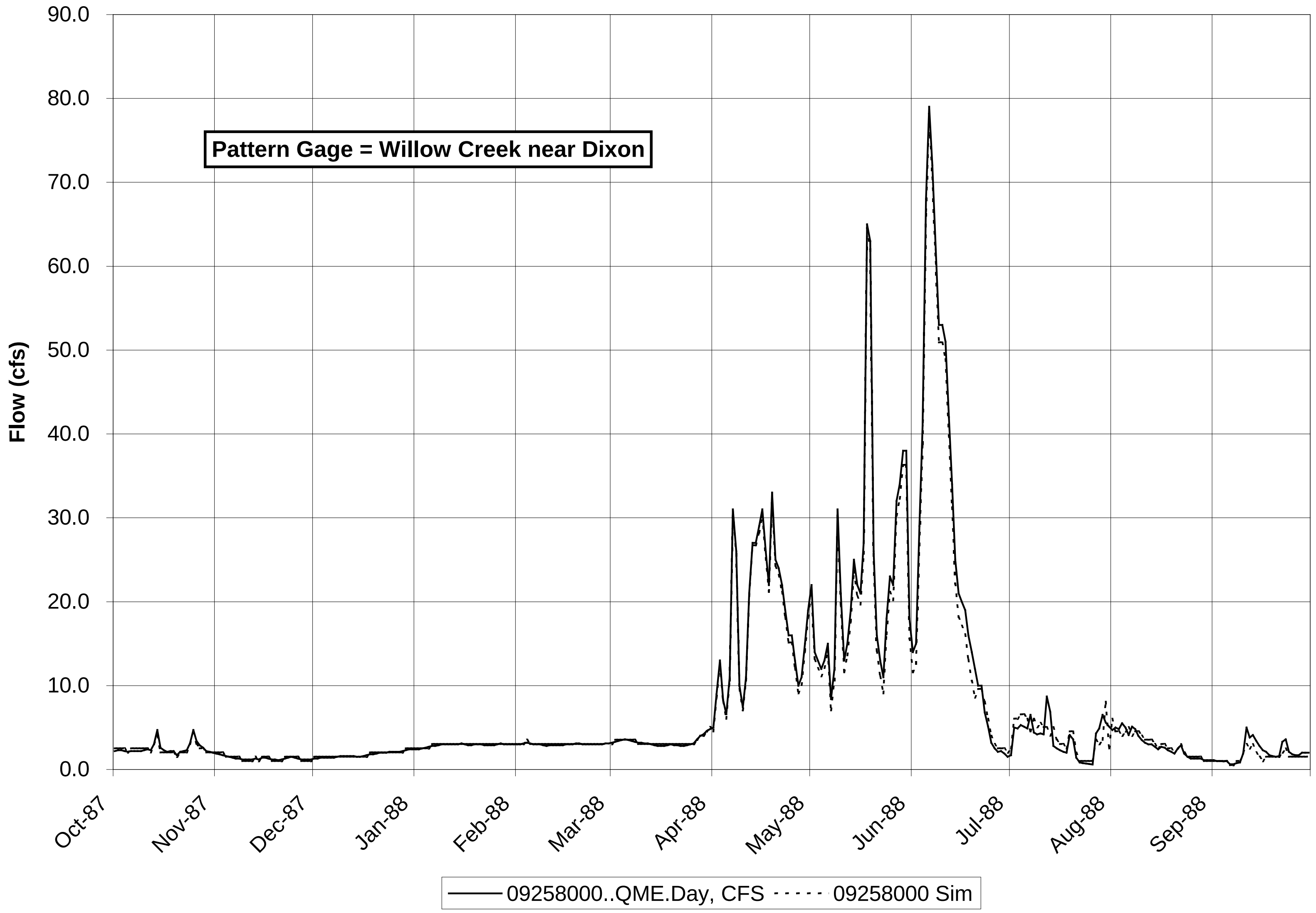

Figure 57 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 09258000 - Willow Creek near Dixon

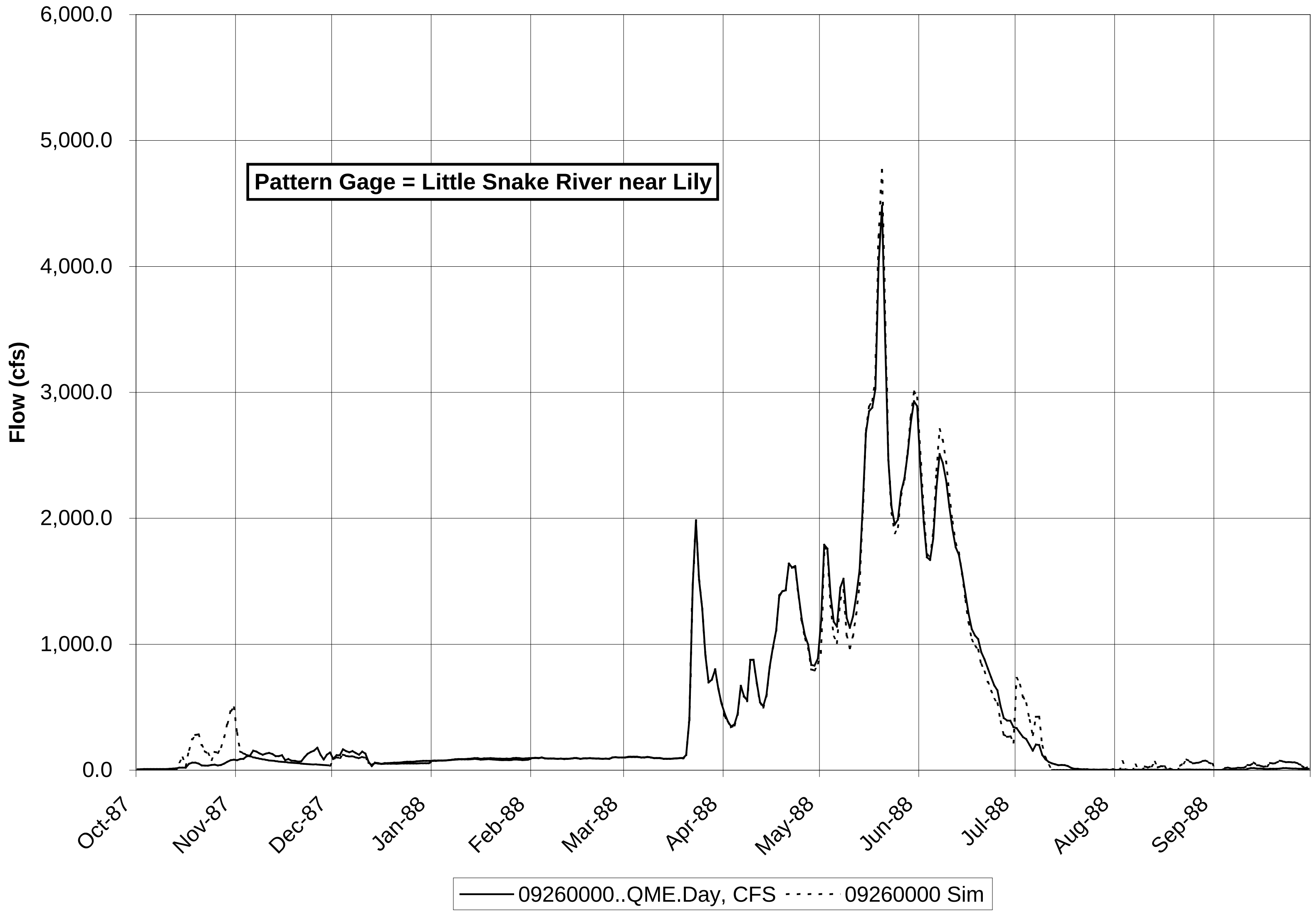

Figure 58 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 0926000 - Little Snake River near Lily

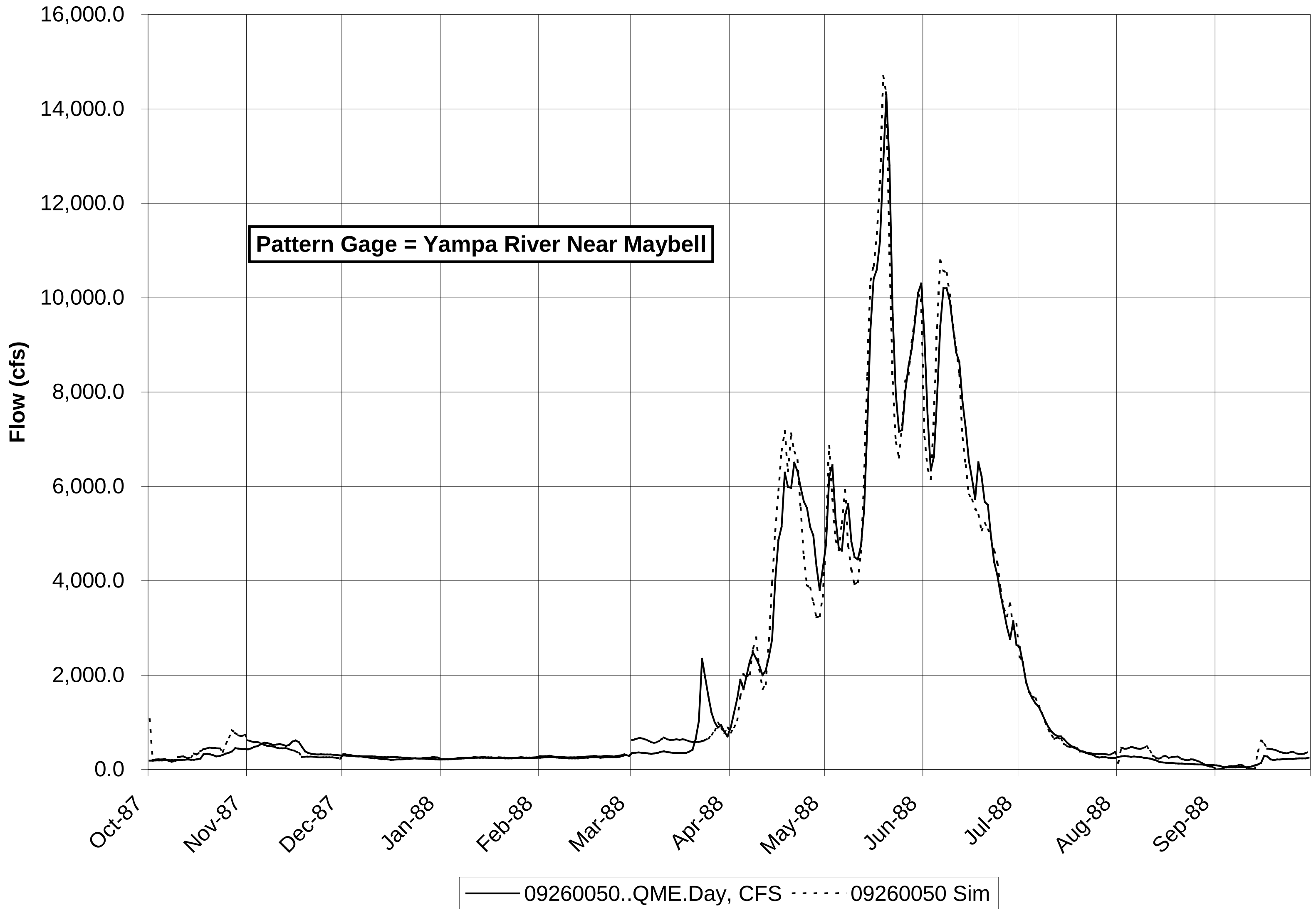

Figure 59 - Historical versus Simulated Daily Flows for Water Year 1988, USGS 09260050 - Yampa River at Deerlodge

Selected Historical versus Simulated Daily Diversions for Water Years 1977, 1983 and 1988

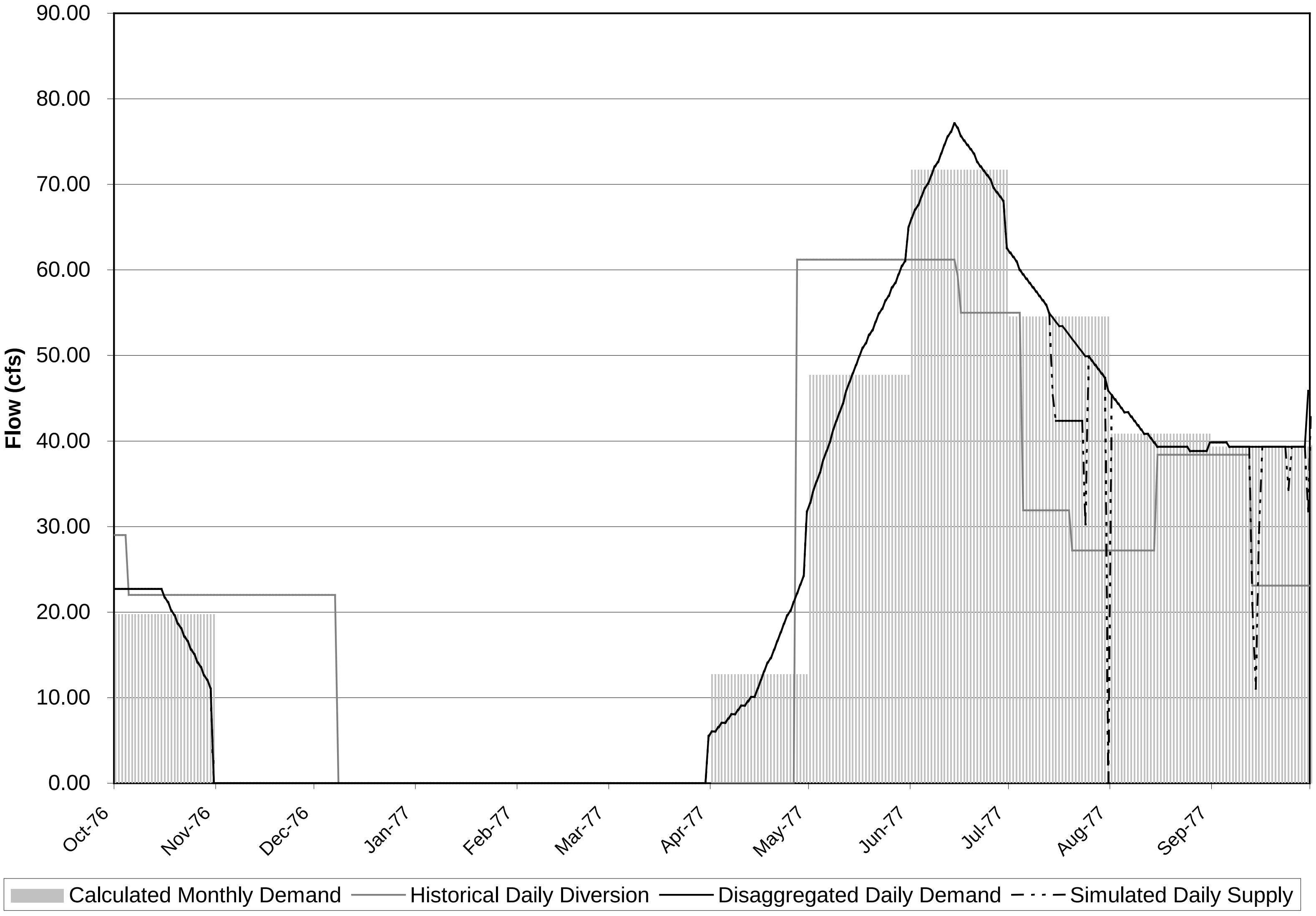

Figure 60 - Historical Diversion versus Simulated Daily Demand and Supply for Water Year 1977, Maybell Canal

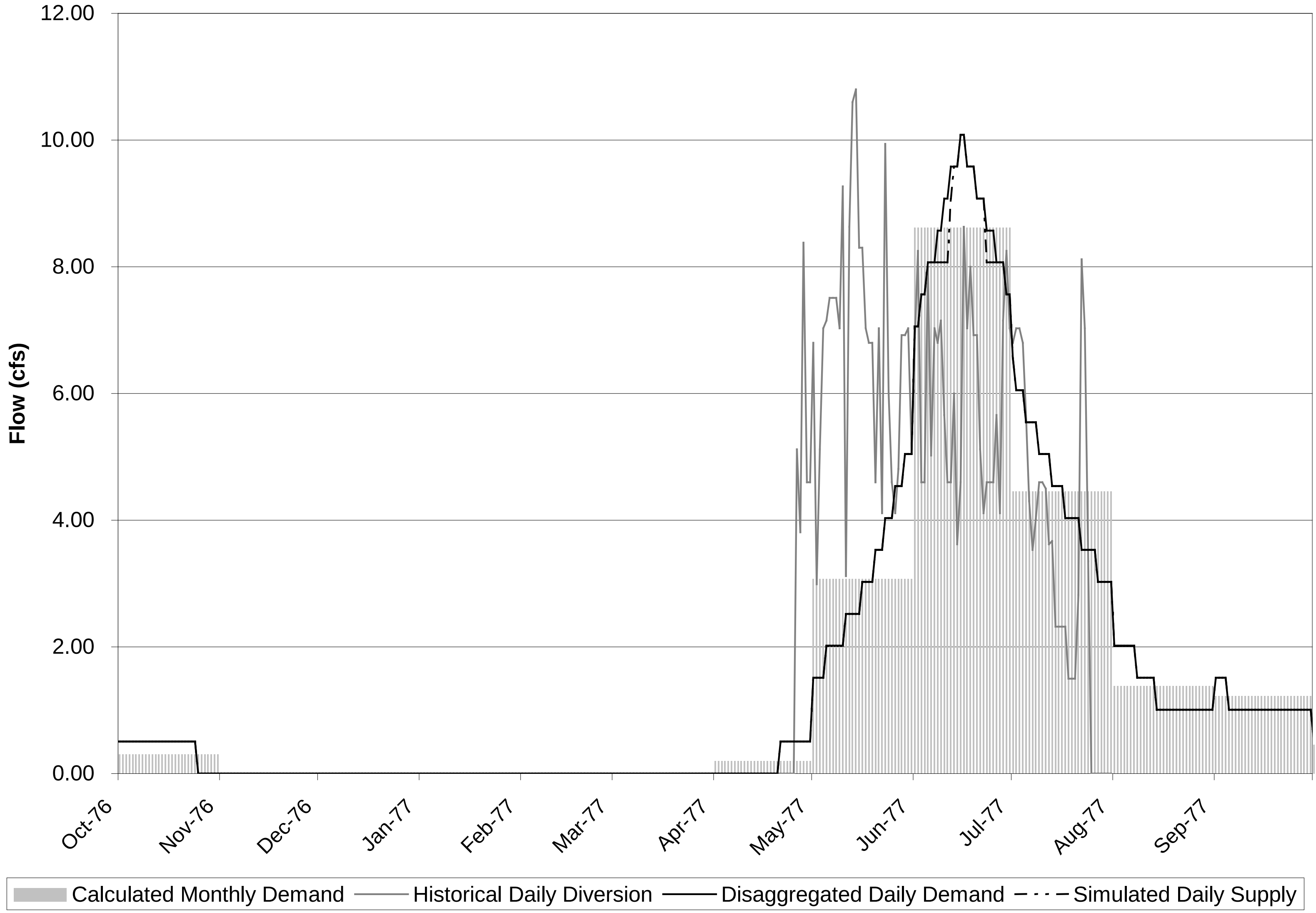

Figure 61 - Historical Diversion versus Simulated Daily Demand and Supply for Water Year 1977, Nickell Ditch

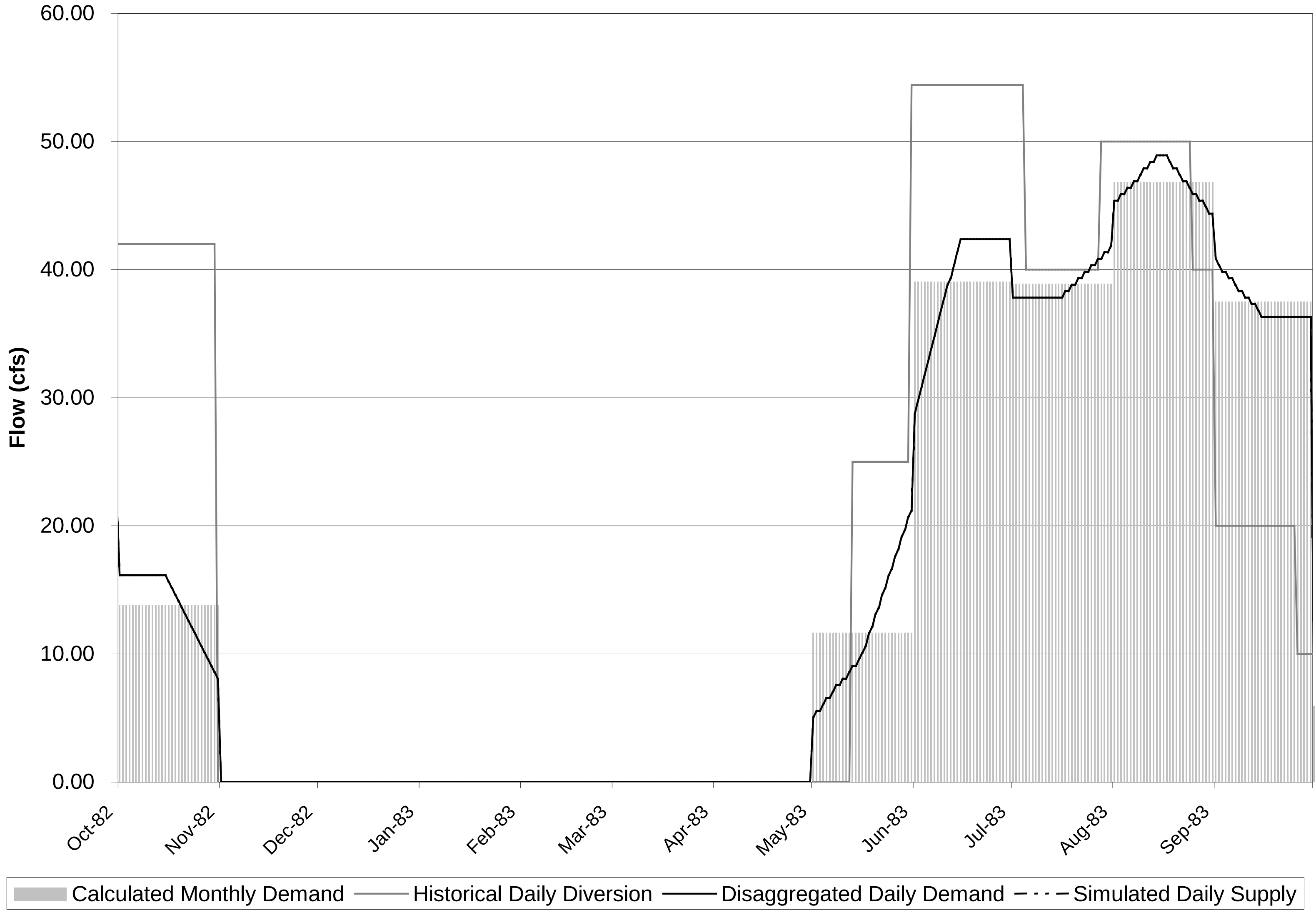

Figure 62 - Historical Diversion versus Simulated Daily Demand and Supply for Water Year 1983, Maybell Canal

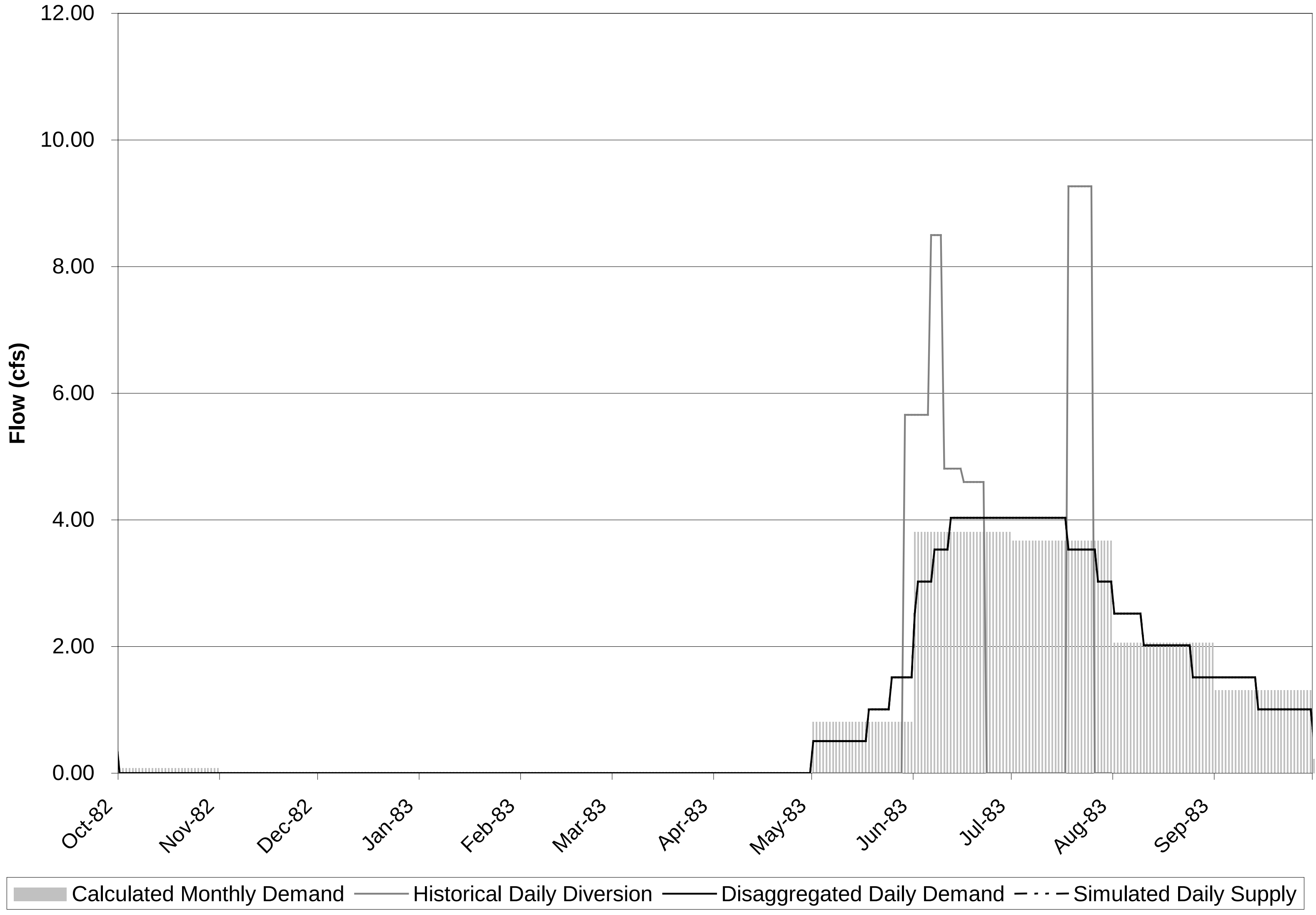

Figure 63 - Historical Diversion versus Simulated Daily Demand and Supply for Water Year 1983, Nickell Ditch

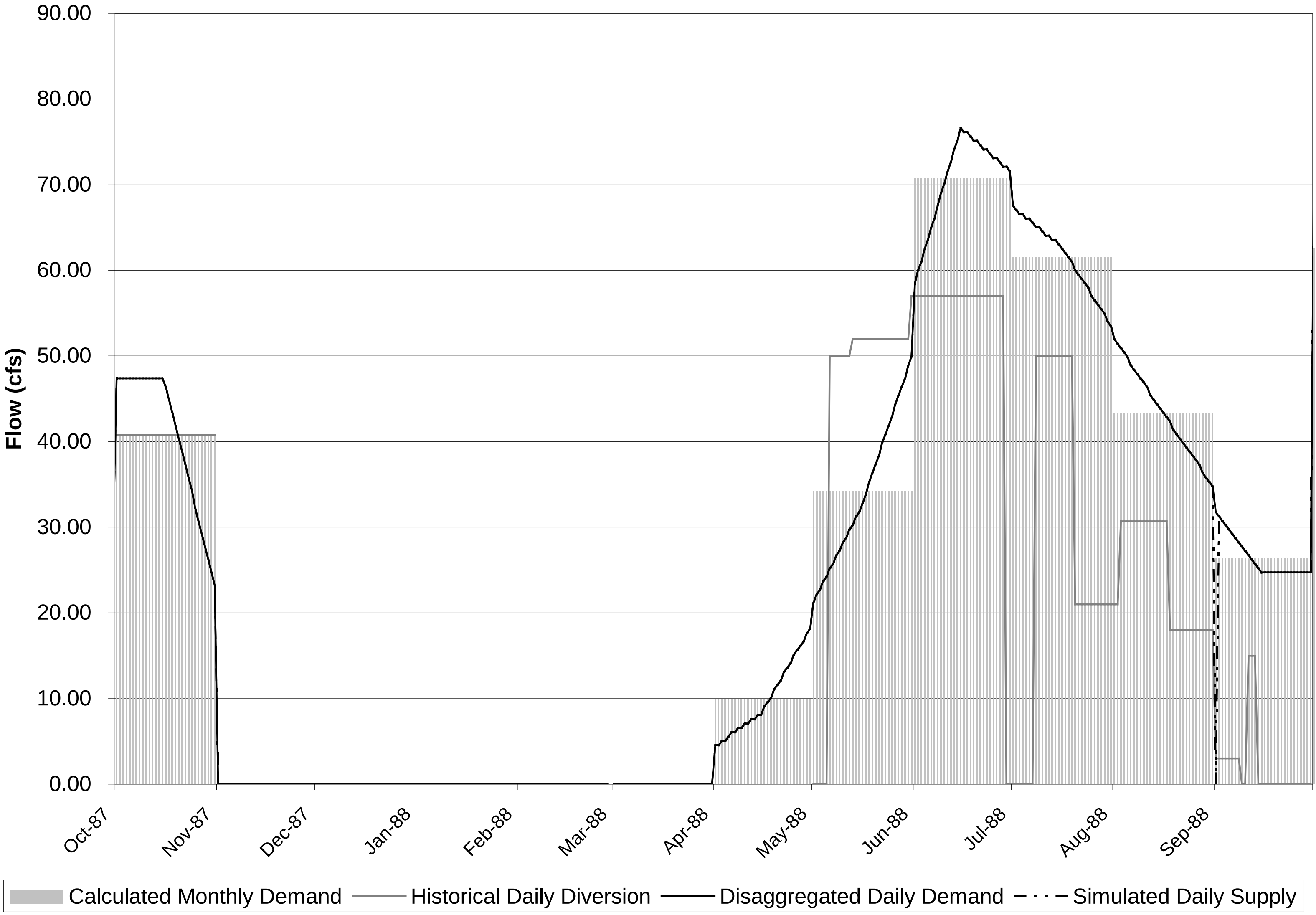

Figure 64 - Historical Diversion versus Simulated Daily Demand and Supply for Water Year 1988, Maybell Canal

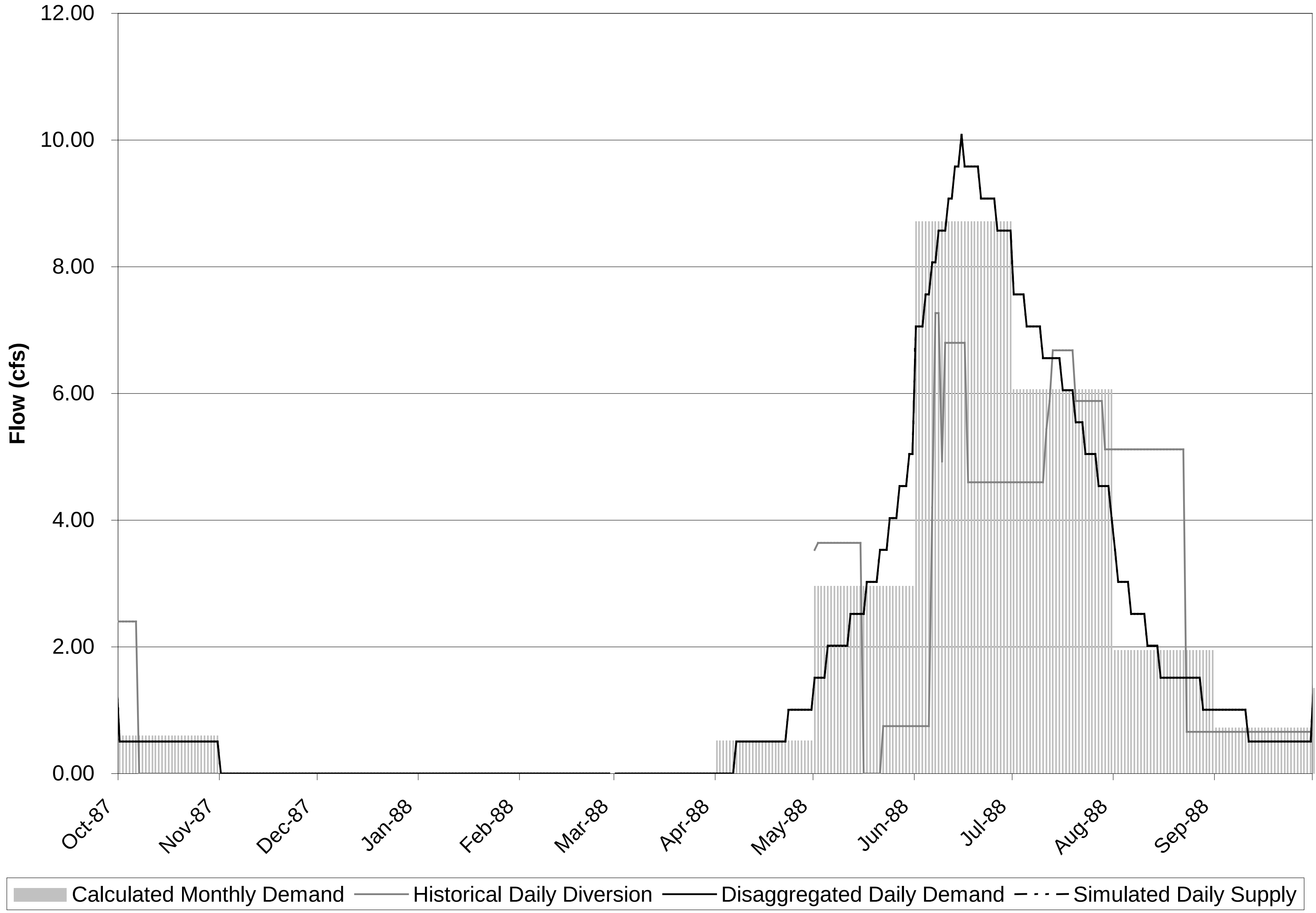

Figure 65 - Historical Diversion versus Simulated Daily Demand and Supply for Water Year 1988, Nickell Ditch