CALIFORNIA TROUT

APPENDIX B: UNIMPAIRED STREAMFLOW ESTIMATES FOR SPROUL CREEK

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SEPTEMBER 1, 2017

This memorandum is an appendix to the *Sproul Creek Site Specific Instream Flow Study* (main report). This appendix describes the methods and results for the preparation of an unimpaired streamflow data set for Sproul Creek for use in subsequent instream flow and water demand analyses. Two specific uses of the data (both required in our Grant Agreement Scope of Work) are:

- Prepare a set of unimpaired daily average annual hydrographs for a period of record (e.g., more than 20 water years) for use in the Physical Habitat Simulation (PHABSIM) time-series methodology, to compute an index of habitat abundance for different water year types (extremely wet, wet, normal, dry, extremely dry). [Scope Task 4.2]
- Evaluate the impacts of water demand and prepare estimates of unimpaired streamflow based on assessments of daily water demand by the general public. {Scope Task 5.2]

We assume "unimpaired flows" are the natural, ambient streamflows for a watershed, un-altered by any form of regulation or extraction, and thus represent the contemporary total daily and annual water supply available for instream and appropriative water uses. Unimpaired flows may be affected by past watershed management activities such timber harvest leading to sediment aggradation that may then cause higher sub-surface (hyporheic) flows compared to conditions prior to human influences in the watershed. These land management activities are not considered in our estimation of unimpaired flows for Sproul Creek.

Sproul Creek is a good study watershed within the South Fork Eel River. Sproul Creeks is similar in size to several nearby watersheds, including Bull Creek (Table B-1). Sproul Creek has two main forks of approximately equal size: the West Fork Sproul Creek (8.47 mi^2) is considered unimpaired, whereas the South Fork Sproul Creek (7.1 mi^2) has twenty homesteads in the upper headwaters (see Appendix K: Water Demand Analysis). In addition, numerous small tributaries at different locations and aspects within the Sproul Creek watershed offered the opportunity to measure streamflow throughout the spring/summer recession and compare anecdotal unit runoff (cfs/mi^2) measurements.

Table B-1. List of watersheds and sub-watersheds sampled in the Sproul Creek study, along with USGS reference gauged watersheds in the South Fork Eel River basin.

Location	USGS Gage Number	Drainage Area (mi^2)	Period of Record
Bull Creek near Weott USGS Gage	11476600	28.1	USGS (1961-present)
Elder Creek near Branscomb USGS	11475560	6.5	USGS (1968-present)
South Fork Eel River near	11475500	43.9	USGS (1946-1970
South Fork Eel River at Leggett	11475800	248	USGS (1965-present)
Lower Sproul Creek at Sprowel		24.0	CalTrout (May 2015 to
Upper Sproul Creek at CalTrout		17.0	CalTrout (April 2016 to
West Fork Sproul Creek		8.47	CalTrout (May 2015 to
South Fork Sproul Creek		7.10	CalTrout (May 2015 to
Upper South Fork Sproul Creek		4.99	CalTrout (April 2016 to
West Branch South Fork		1.10	CalTrout (April 2016 to
Cox Creek		1.50	CalTrout (April to Nov
Little Sproul Creek		3.90	CalTrout (April to Nov
Warden Creek		1.6	Ungaged
Dry Trib (Unnamed Tributary to		0.6	Ungaged

Developing Unimpaired Annual Hydrographs for Sproul Creek

The Lower Sproul Creek gaging station, installed by CalTrout near the confluence with the SF Eel River at the Sproul Creek Road Bridge, was the primary gage used to develop unimpaired flow estimates. The Lower Sproul (LSC) gage was installed in WY2015 and thus provide two years of seasonal recession and low-flow streamflow estimates available for our analysis.

A full description of all streamflow gages, rating curve development, and flow estimates installed by CalTrout in Sproul Creek are described in Appendix C.

One of the only available methods for estimating unimpaired flows for an ungaged watershed, and the method chosen for this study, is the formula recommended by the SWRCB (Mann et al. 2004), which incorporates a drainage basin area-ratio for statistical transfer, as well as a precipitation ratio to account for differences in precipitation between watersheds:

$$\textbf{Sproul Creek Streamflow = Bull Creek Streamflow * } (DA_{Sproul}/DA_{Bull}) * (MAP_{Sproul}/MAP_{Bull})$$

where DA=drainage area in square miles, and MAP=Mean Annual Precipitation in inches.

To determine the best USGS data record for use in developing Sproul Creek unimpaired annual hydrographs, we examined the Bull Creek and Elder Creek USGS gages because they were closest in drainage area to Sproul Creek and had long periods of record. Daily average streamflow for Bull Creek and Elder Creek were plotted with the Lower Sproul Creek streamflow estimates for WY 2016 (Figure B-1). The Sproul Creek data more closely resembled the Bull Creek gage in the overall pattern of streamflow recession and unit runoff (cfs/ mi^2). Elder Creek is known to have a higher summer baseflow unit runoff relative to other watersheds in the SF Eel River, which was evident in our recession comparisons. Because we were more interested in the spring recession and low flow period, we chose Bull Creek as a model data set for developing Sproul Creek unimpaired hydrographs.

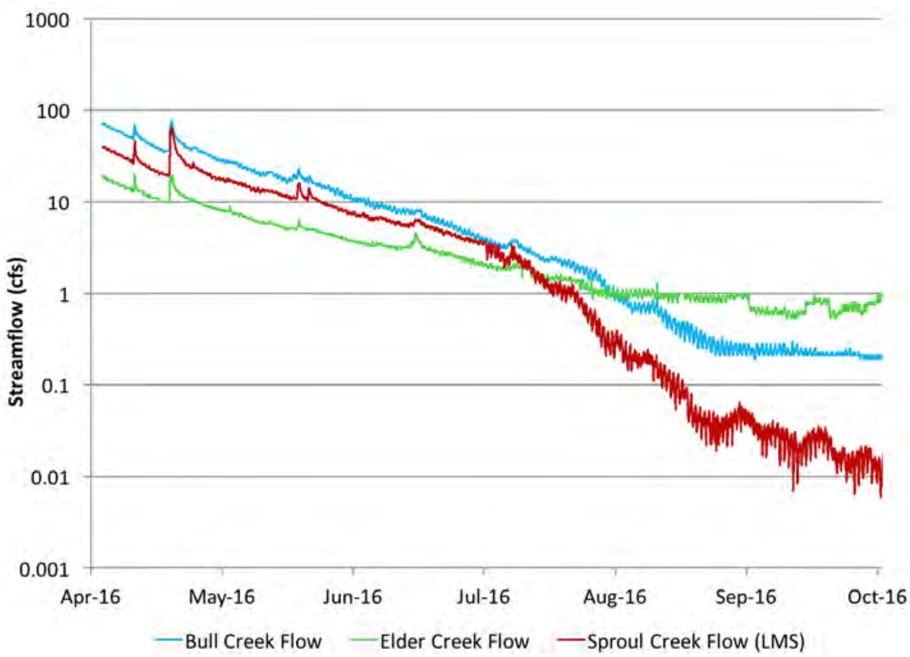


Figure B-1. Streamflow recession hydrographs for the USGS Bull Creek and Elder Creek gages in WY 2016 plotted with the CalTrout Lower Sproul Creek gage data. The Sproul Creek data more closely resembled the Bull Creek gage in pattern of streamflow recession.

The 49-year period of record from Bull Creek extends from WY 1968 to WY 2016. To convert Bull Creek data to Sproul Creek, The following formula was used:

Sproul Creek Streamflow = Bull Creek Streamflow * (24.0/28.1)*(69.4/99.7) = 0.59

We refined the conversion of Bull Creek data to Sproul Creek for flows less than 2 cfs using a polynomial regression of estimated Sproul Creek vs. Bull Creek daily average streamflows (Figure B-2) computed in MS Excel. Thus, for flows above 2 cfs, the drainage area and rainfall ratio of 0.59 was used, and for flows below 2 cfs, the regression equation was used to refine the estimate.

Once Bull Creek gaging data were converted to Sproul Creek, the data was then converted to the 1D and 2D modeling sites for use in the PHABSIM analyses based only on drainage area. The Upper South Fork Sproul Creek has a 5.0 mi^2 drainage area, the upper mainstem Sproul Creek has a 17.0 mi^2 drainage area.

Annual hydrographs for Sproul Creek were sorted by water year class (i.e., Extremely Wet, Wet, Normal, Dry, and Extremely Dry) based on the total annual yield in acre-feet (Table B-2). There are 10 years of data for each of the water year classes except the Wet water year class, which only has nine. Characteristics of the different water year classes, such as differences in magnitude of flow event, and the variability in flow between water years within a given class, can be visualized by plotting all hydrographs for the entire period of record, color-coded by water year class (Figure B-3).

Plots of the Sproul Creek estimated hydrographs derived from Bull Creek are presented in Figure B-4 for each water year, along with those derived from Elder Creek for comparison purposes.

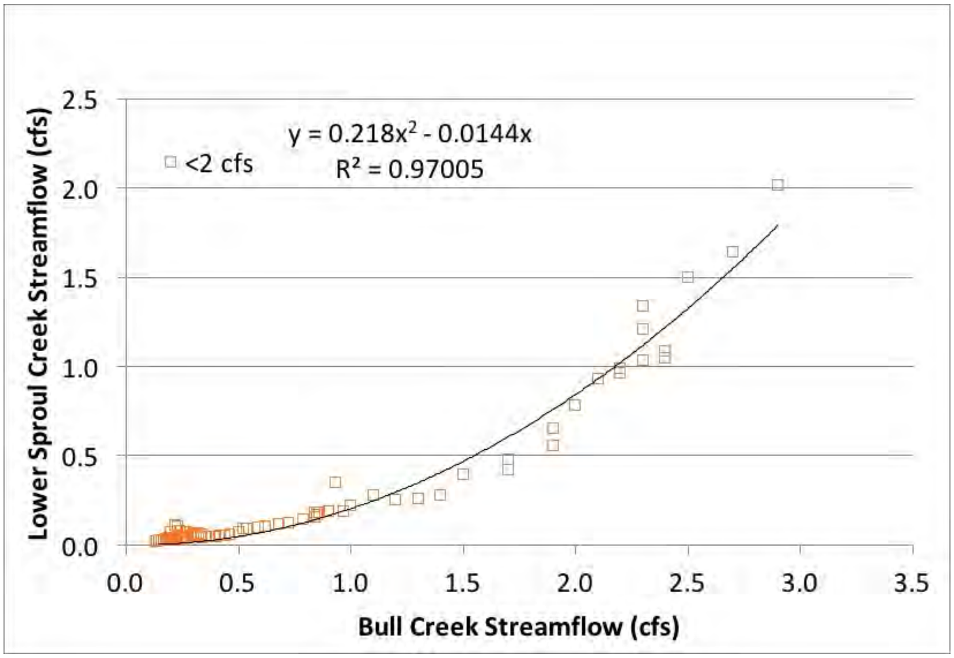


Figure B-2. Polynomial regression comparing the USGS Bull Creek daily average flow to the CalTrout Lower Sproul Creek gage for the period July 13, 2016 when Sproul Creek flows dipped below 2 cfs.

Literature Cited

Mann, M. P., Rizzardo, J., and Satkowski, R. 2004. Evaluation of methods used for estimating selected streamflow statistics, and flood frequency and magnitude, for small basins in north coastal California: U.S. Geological Survey Scientific Investigations Report, 2004–5068, 92 p.

Table B-2. Water Year classifications assigned to the estimated unimpaired Sproul Creek data (whole watershed), based on annual water yield.

WATER YEAR	UNIMPAIRED ANNUAL YIELD (af)	RANK	EXCEEDANCE PROBABILITY	WATER YEAR CLASSIFICATION
1968	61,400.0	22	45%	Normal
1969	100,474.6	6	12%	Extremely Wet
1970	75,530.9	13	27%	Wet
1971	69,349.8	14	29%	Wet
1972	53,869.5	28	57%	Normal
1973	52,897.4	29	59%	Normal
1974	133,294.7	2	4%	Extremely Wet
1975	69,121.4	15	31%	Wet
1976	39,276.2	38	78%	Dry
1977	5,079.6	49	100%	Critically Dry
1978	115,516.4	3	6%	Extremely Wet
1979	29,291.9	42	86%	Critically Dry
1980	68,263.5	16	33%	Wet
1981	39,039.5	39	80%	Dry
1982	108,906.9	4	8%	Extremely Wet
1983	153,273.9	1	2%	Extremely Wet
1984	80,291.3	10	20%	Extremely Wet
1985	42,873.5	34	69%	Dry
1986	83,610.6	9	18%	Extremely Wet
1987	39,357.0	37	76%	Dry
1988	34,347.2	40	82%	Critically Dry
1989	46,054.2	31	63%	Dry
1990	27,984.1	44	90%	Critically Dry
1991	20,854.4	47	96%	Critically Dry
1992	25,796.5	45	92%	Critically Dry
1993	61,030.7	23	47%	Normal
1994	29,134.1	43	88%	Critically Dry
1995	95,844.0	7	14%	Extremely Wet
1996	67,815.9	18	37%	Wet
1997	79,499.2	11	22%	Wet
1998	93,361.2	8	16%	Extremely Wet
1999	68,081.0	17	35%	Wet
2000	57,474.4	25	51%	Normal
2001	23,878.3	46	94%	Critically Dry
2002	56,454.5	26	53%	Normal
2003	79,434.0	12	24%	Wet
2004	58,078.1	24	49%	Normal
2005	54,152.7	27	55%	Normal
2006	102,596.3	5	10%	Extremely Wet
2007	41,717.1	35	71%	Dry
2008	43,828.7	32	65%	Dry
2009	32,672.7	41	84%	Critically Dry
2010	62,386.0	21	43%	Normal
2011	66,467.0	19	39%	Wet
2012	40,361.8	36	73%	Dry
2013	46,688.5	30	61%	Dry
2014	11,890.5	48	98%	Critically Dry
2015	43,506.6	33	67%	Dry
2016	65,972.6	20	41%	Normal
Average Annual Yield (af)		**60,369**		

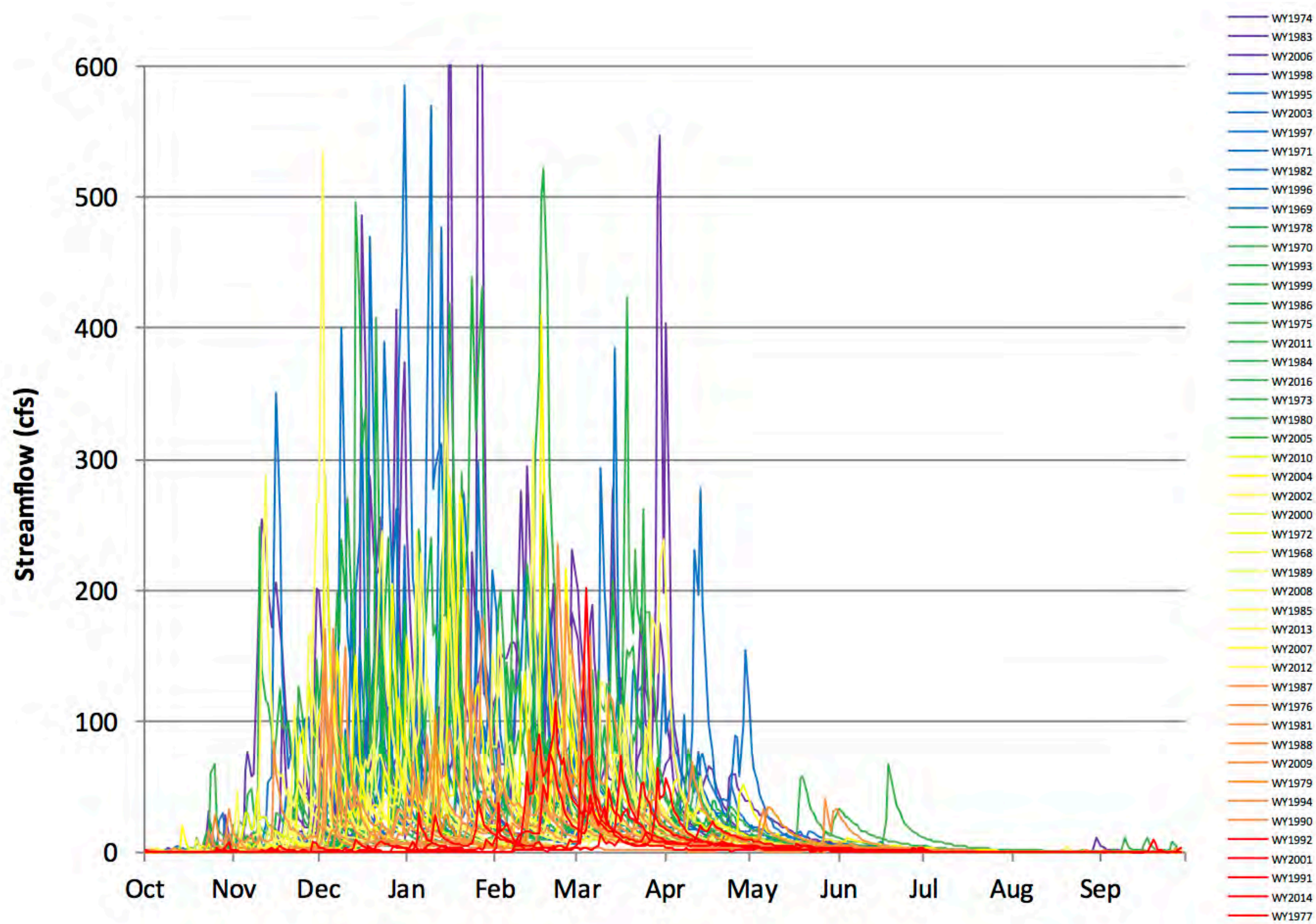
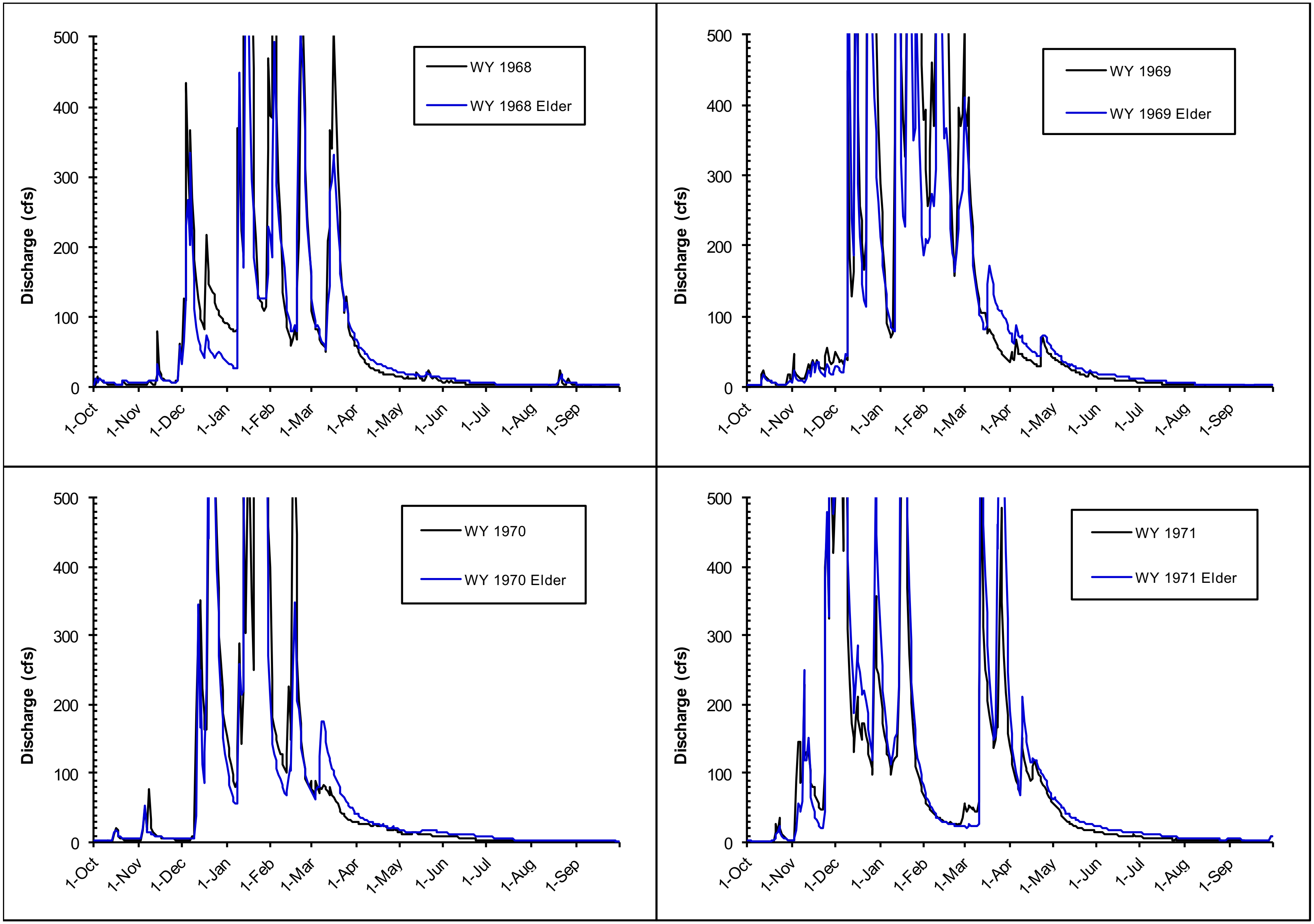
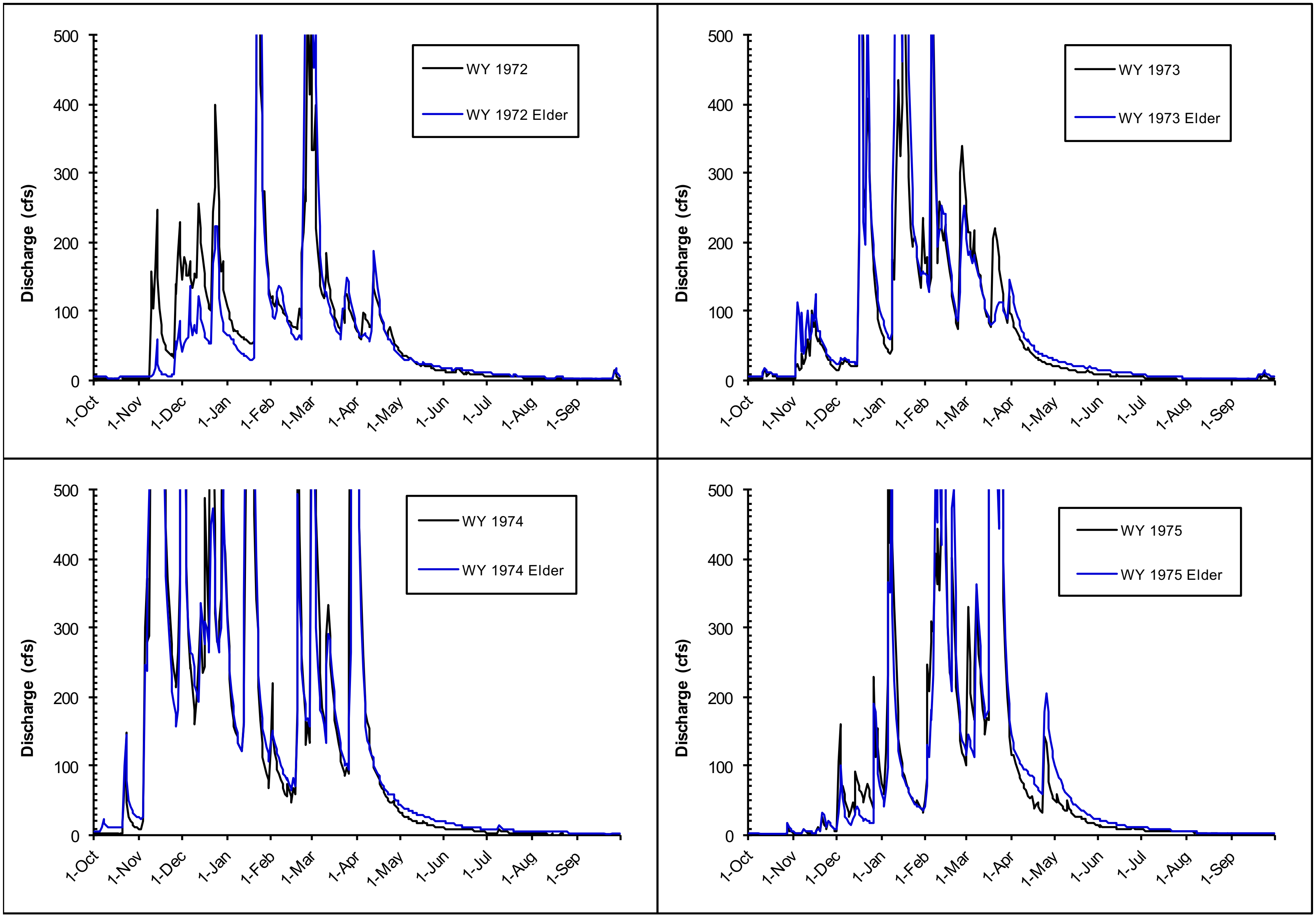


Figure B-3. Annual hydrographs of mean daily flow for the 49-year period of record estimated for the Upper South Fork Sproul Creek instream flow study site (Drainage Area = 4.99 mi^2). The hydrographs are ranked and colored by water year types in five equally weighted exceedance categories.



Modeled Sproul Creek Hydrographs from USGS Bull Creek and Elder Creek



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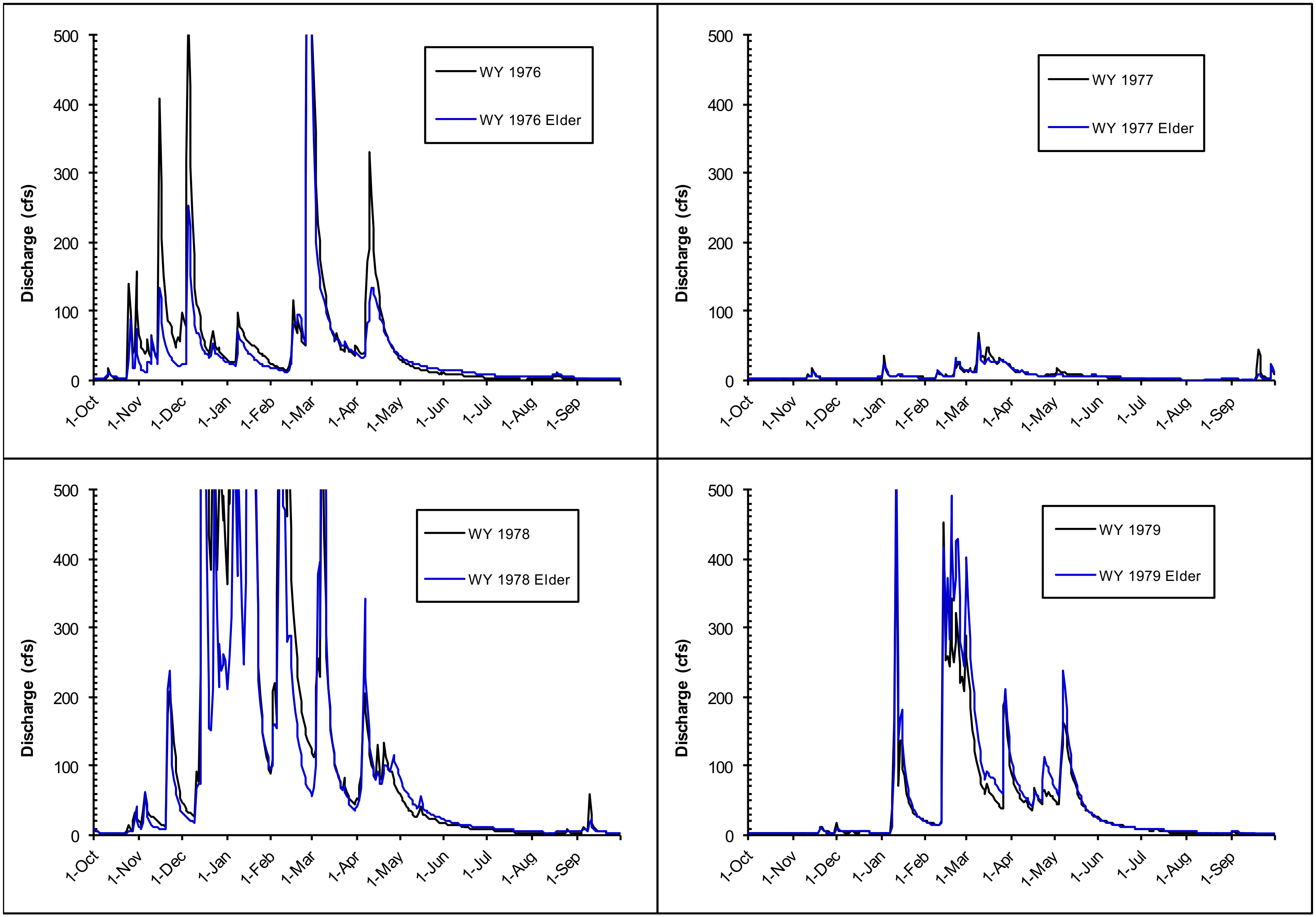

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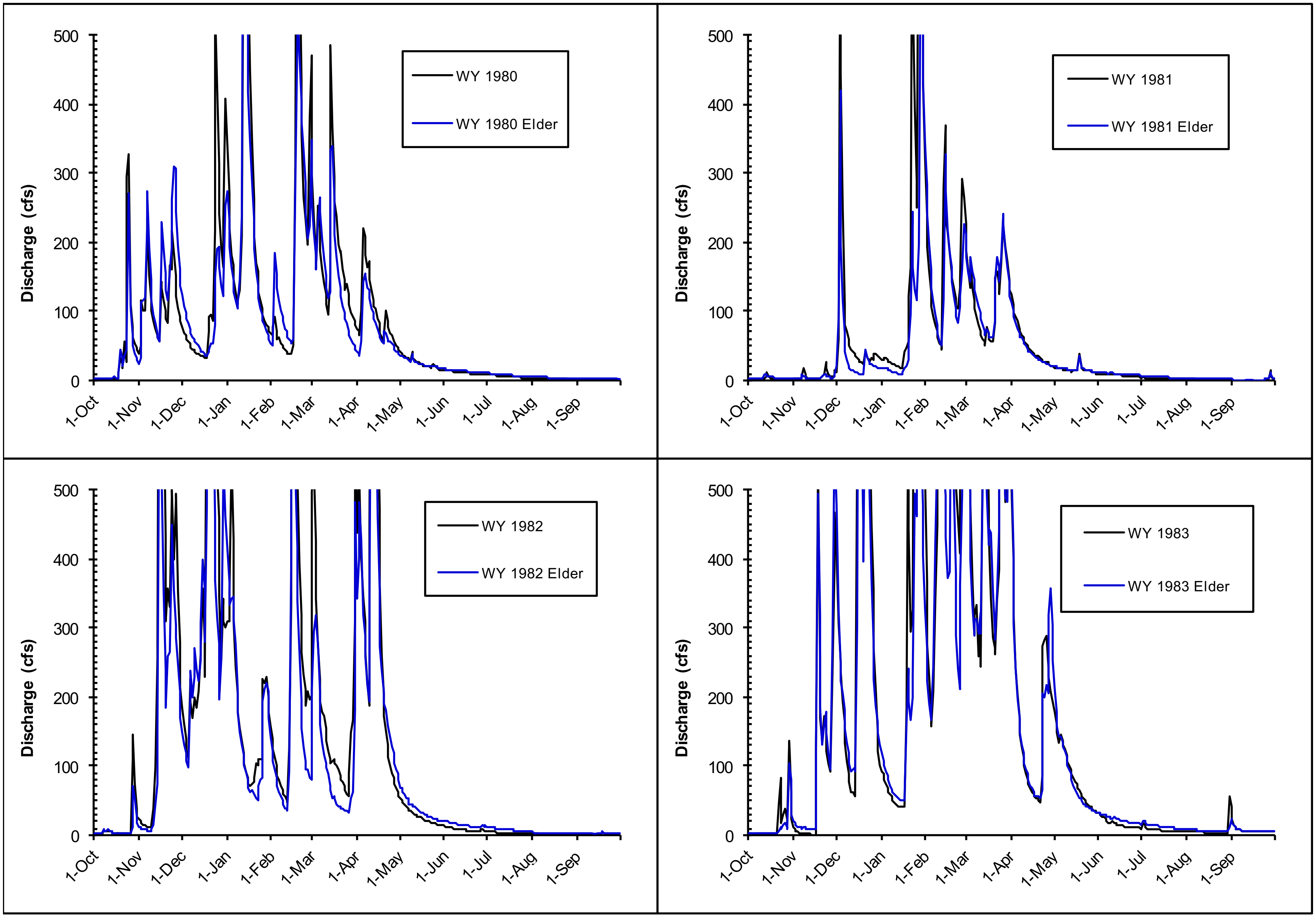

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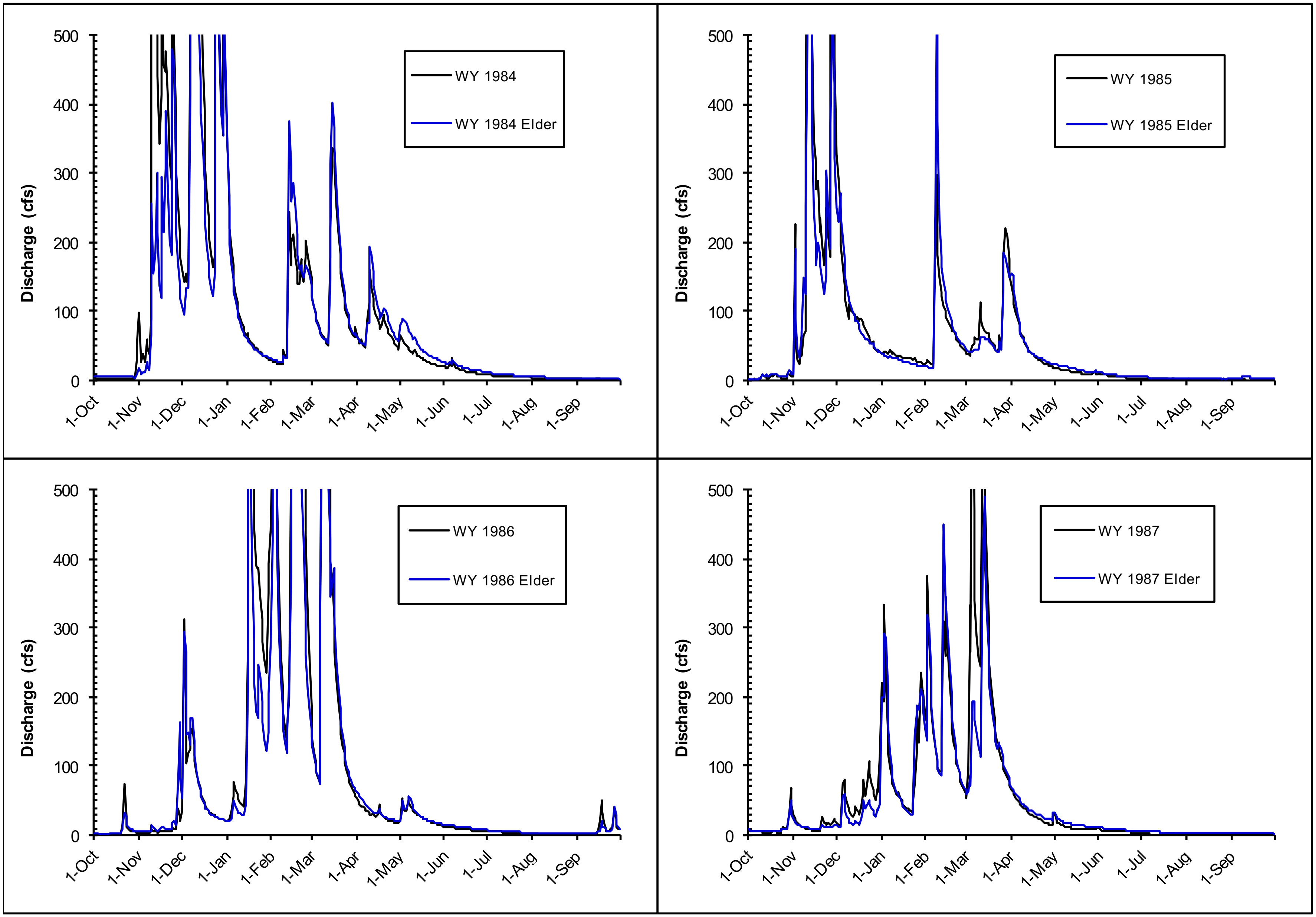

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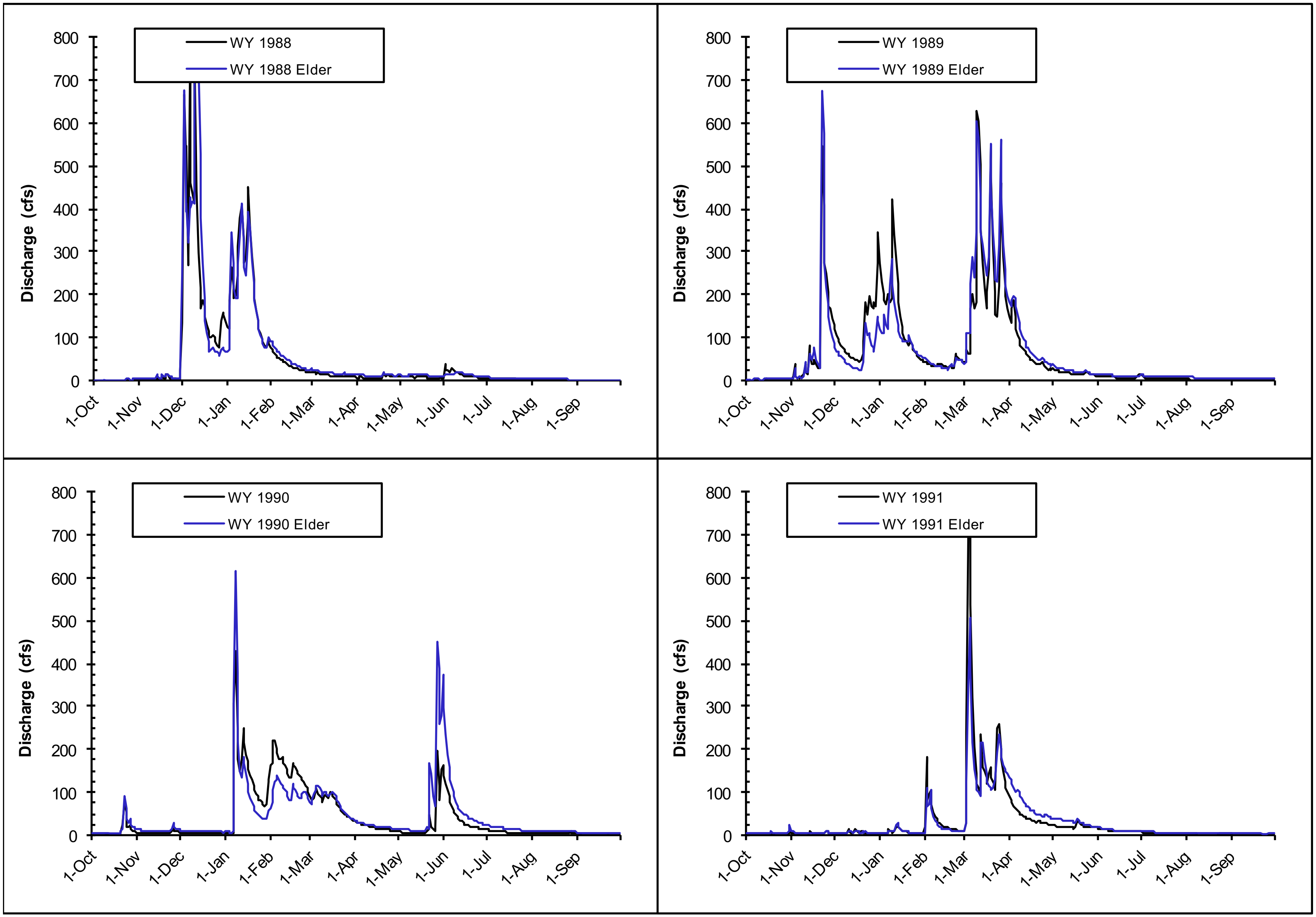

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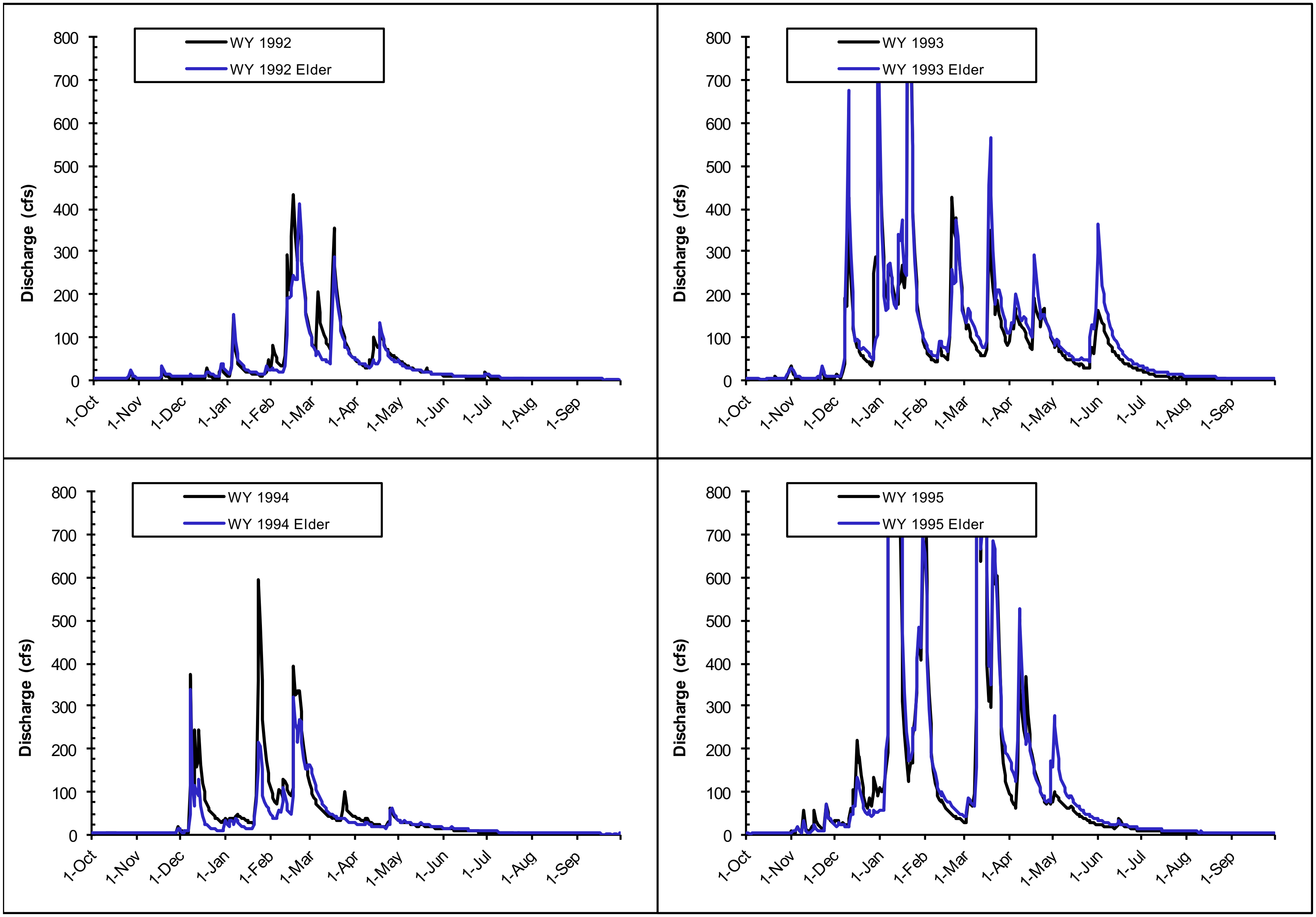

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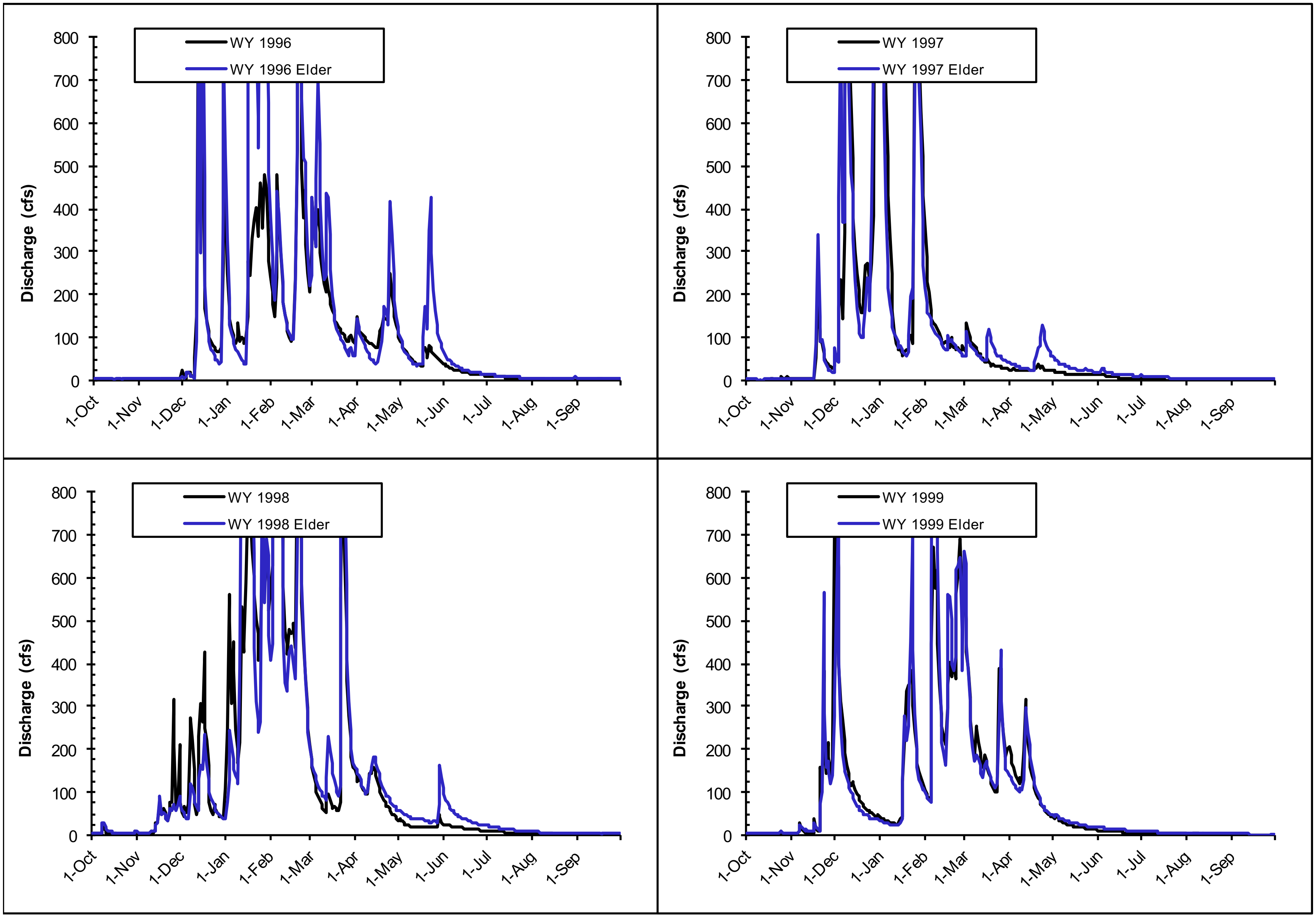

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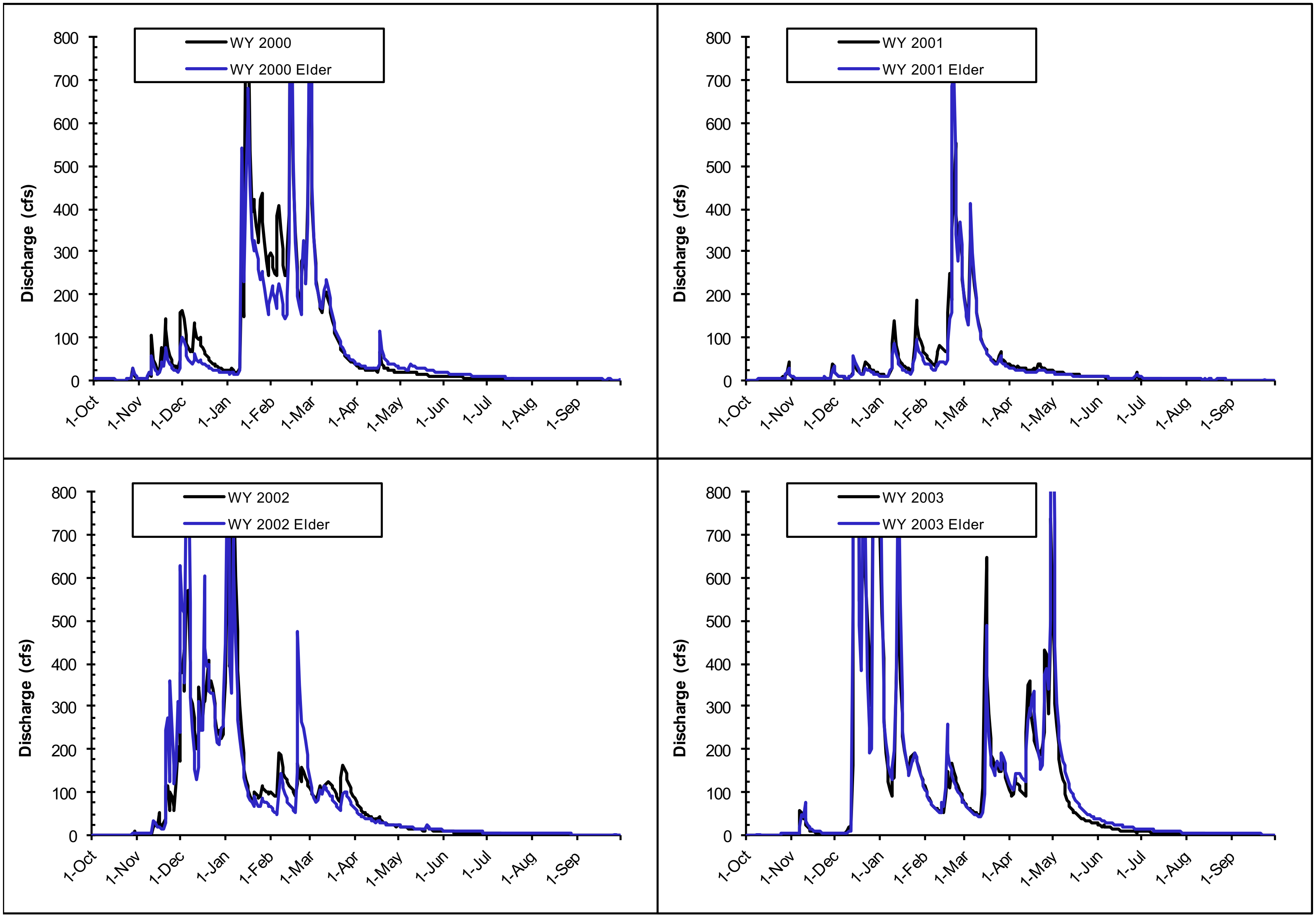

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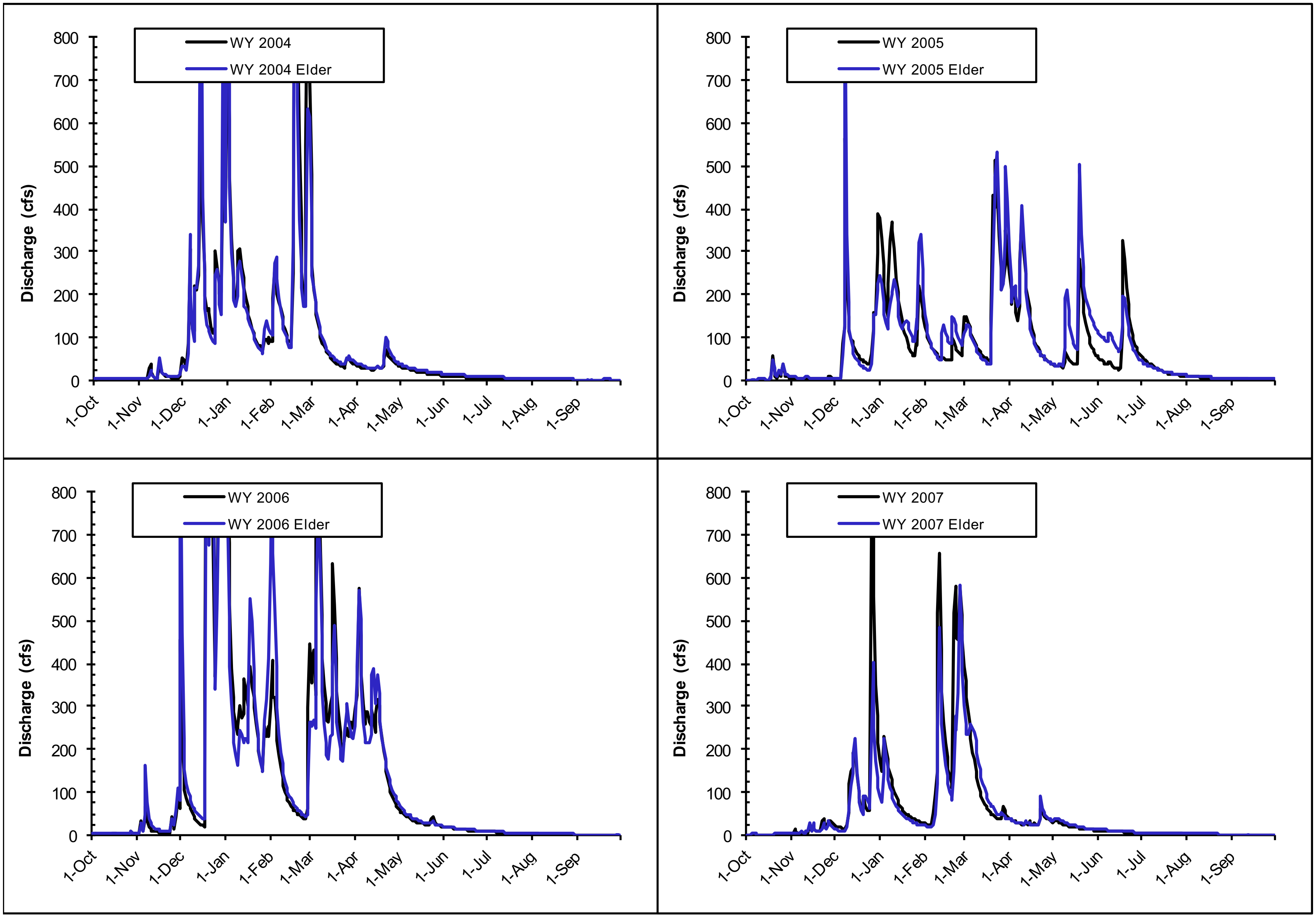

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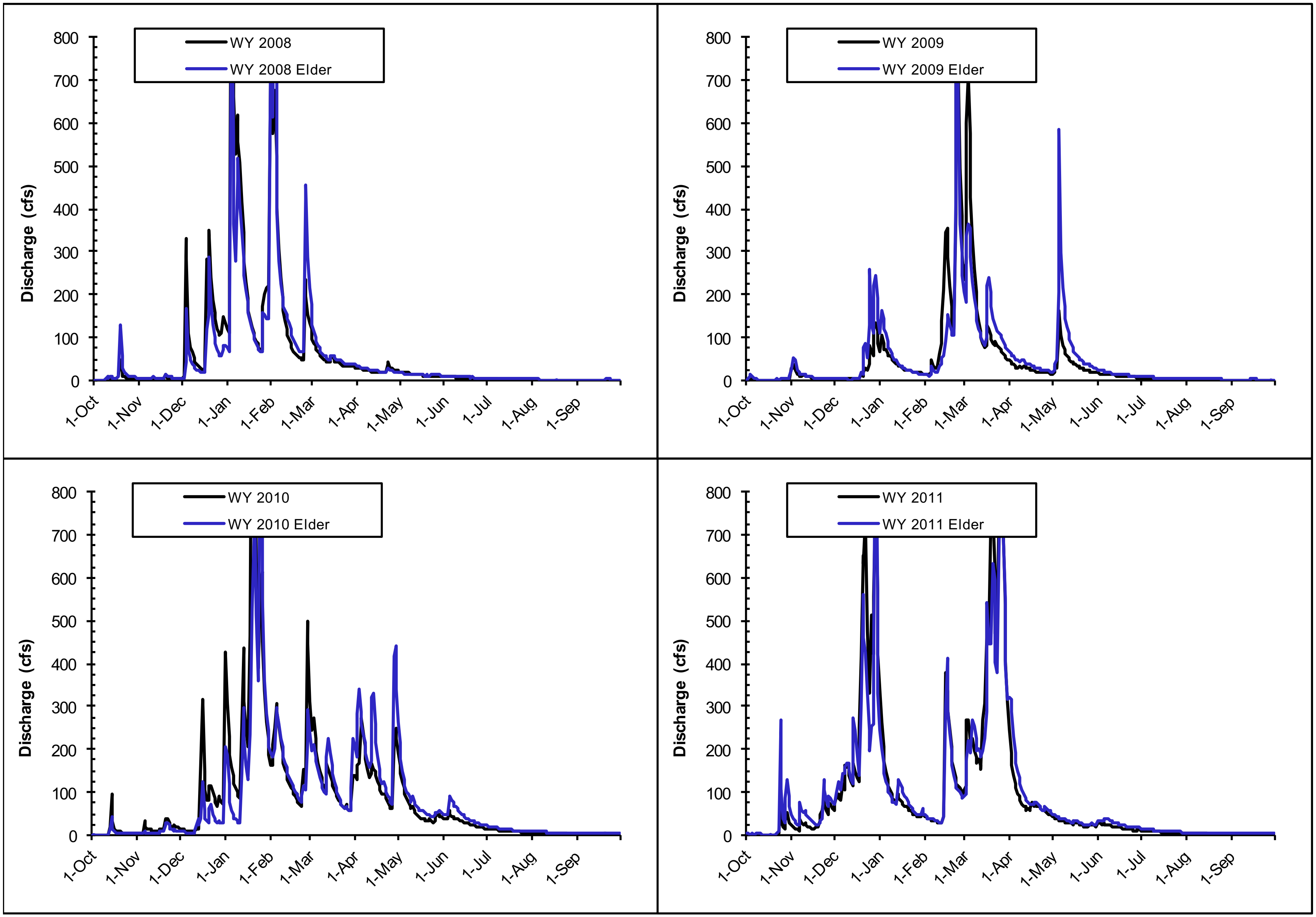

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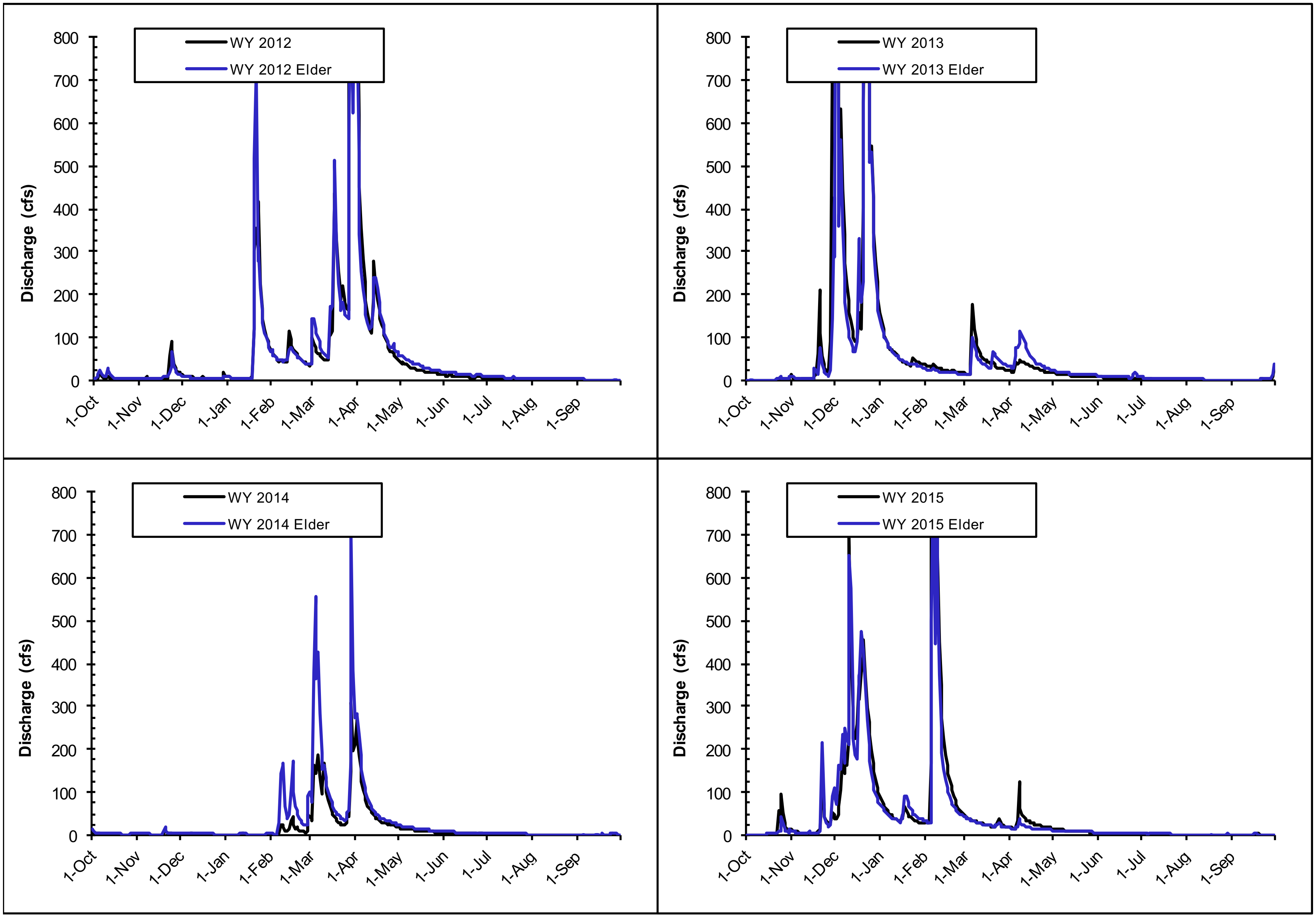

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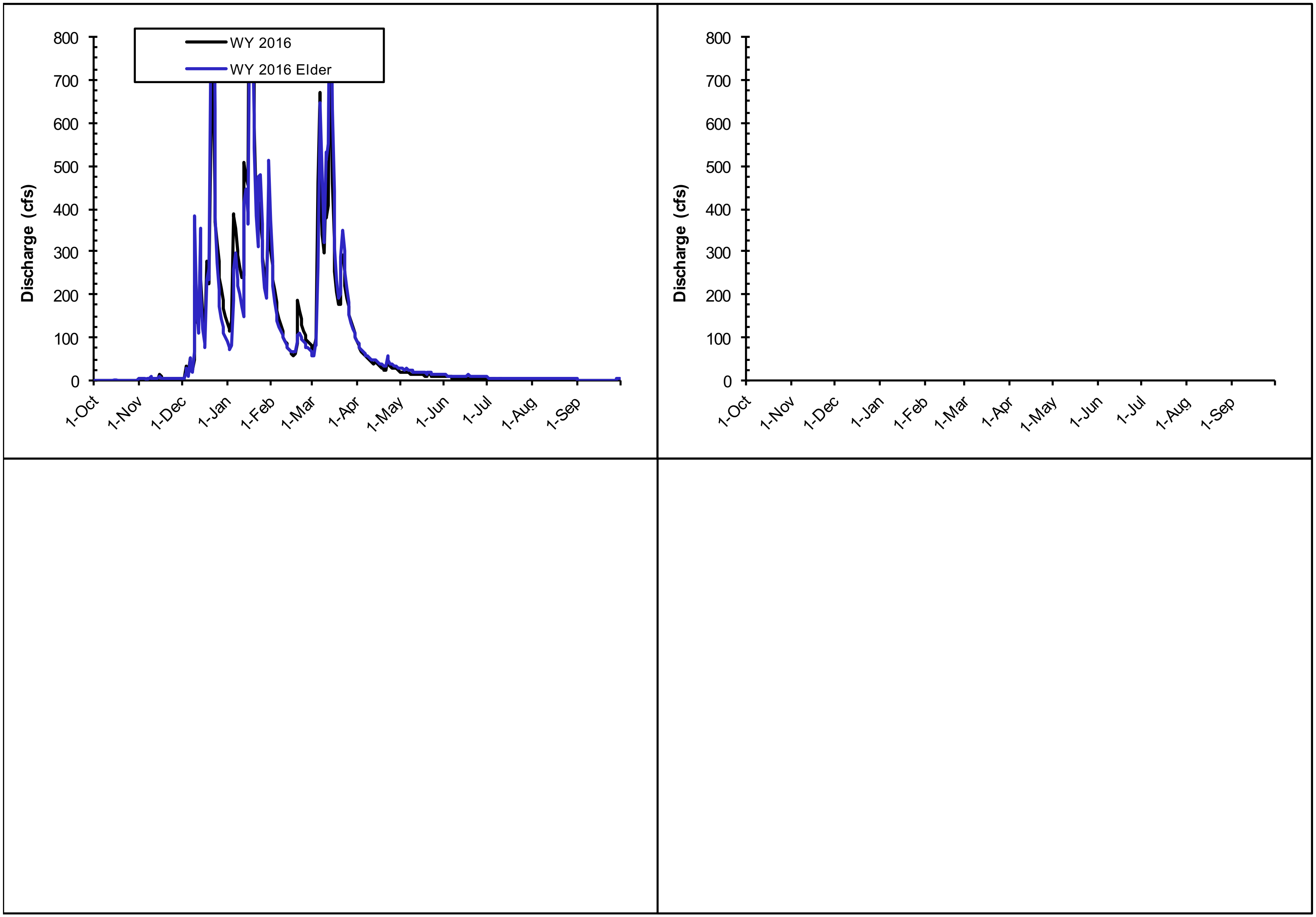

Modeled Sproul Creek Hydrographs from USGS Bull Creek and Elder Creek