Stillaguamish River Instream Flow Study & Hydrology
Exceedance Hydrograph Development

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northwest hydraulic consultants, inc.
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Introduction

This document summarizes a hydrologic evaluation of river and stream flows in the Stillaguamish River basin, Water Resource Inventory Area 5. The work was authorized and funded by the Washington Department of Ecology, which is proposing to promulgate an instream resources protection rule in the Stillaguamish River basin in conjunction with the Stillaguamish and Tulalip Indian Tribes and other agencies. A concurrent evaluation of biological information and instream flow characteristics was performed by Steward and Associates.

Study Objective

The objective of the hydrologic evaluation was to provide hydrographs showing the 5, 10, 20, 50, 80, and 90 percent daily exceedance values for each of fourteen instream flow study sites defined in a previous study by the U.S. Geological Survey (USGS)[1]. Note that while flows vary along the reaches due to tributary inflows, for purposes of the hydrological evaluations a single instream flow control point was identified by Ecology to represent each of the fourteen reaches. A list of the 14 control points, and a map showing their locations, is provided on Exhibit 1.

Methodology

Flow exceedance curves were based on an analysis of USGS records of historical flow data at rivers and streams within the Stillaguamish River basin. However, streamflow records are not available for all of the proposed instream flow control points, and the flow record length is too short to reliably determine flow statistics at many of the USGS streamgage sites. The methodology adopted for this study was to develop representative "master" exceedance curves based on an analysis of flow data at sites with relatively long periods of record, and to transpose those curves to control point sites, considering basin areas and available site-specific flow records. Basin areas tributary to the control points were determined by ArcView GIS processing of basin Digital Elevation Models.

[1] U.S. Geological Survey, 1987, Water-Resources Investigations Report 86-4326, "The Relation of Streamflow to Habitat for Anadromous Fish in the Stillaguamish River Basin, Washington." Prepared in cooperation with the Stillaguamish Indian Tribe.

The USGS has collected and published streamflow data for a total of 19 sites in the basin. Of these, data for 11 sites were analyzed after screening for record length and proximity to control point locations. A list of the 11 USGS sites used in the analysis, and a map showing their locations, is provided on Exhibit 1.

Long-term records sufficient for determining reliable flow exceedance characteristics are available from three of the Stillaguamish basin gages: 1) N.F. Stillaguamish River near Arlington (76 years); 2) S.F. Stillaguamish River near Granite Falls (53 years), and 3) Pilchuck Creek near Bryant (49 years). The remaining gages were operated for relatively-short periods of record including gages on the tributary streams of Jim Creek (21 years) and Canyon Creek (5 years) for which instream flow studies were performed. Except for the Boulder River, the USGS has collected and reported at least one year of streamflow data for each of the streams for which exceedance hydrographs are being developed. Available data for the Boulder River consists of only four months of data recorded near Oso in June through September 1950. These data were not used in the hydrograph development due to insufficient record length.

A three step process was used to develop exceedance hydrographs for the instream flow sites. First, "master" sets of exceedance hydrographs were developed for the three USGS gage sites with long periods of record. Second, the master exceedance hydrographs were transposed to the locations of short-record USGS sites, based on an evaluation of the available recorded data. Finally, hydrographs for specific control points were determined based on a simple area-based transposition of the data for the USGS station which best represented each instream flow study location. This process is described below in greater detail.

Daily exceedance hydrographs for each of the three long-term stations were determined by sorting the recorded mean flow values for each day of the year, and extracting the values corresponding to the desired exceedance levels. These served as master hydrographs for estimating exceedance characteristics at other locations. The computed exceedance hydrographs for USGS stream gage 12167000, North Fork Stillaguamish River near Arlington, were used as the master hydrographs for all seven control points within the North Fork basin. The computed exceedance hydrographs for USGS stream gage 12161000, South Fork Stillaguamish River near Granite Falls, were used as the master hydrographs for all five control points within the South Fork basin. A combination of the data from these two gages was used develop master hydrographs for the control point on the mainstem Stillaguamish River. Exhibit 1 includes a summary of the USGS stream gages which were used for hydrograph development at each control point.

The master hydrographs were transposed directly to four of the control point sites, and indirectly to the remaining 10 sites. In the direct transposition, computed hydrographs were multiplied by a single area correction factor equal to

the ratio of the basin areas between the control point and stream gage site. In the indirect transposition, master hydrographs were first transposed to the location of a closer (more-representative) short-record stream gage prior to applying an area correction factor. Area correction factors were not applied when the control point basin area, computed by GIS techniques, was within 2% of the gage site basin area published by the USGS.

Two methods described below were used for the transposition of master hydrographs to other sites with relatively short periods of record.

1. In cases where the short-record destination site had more than 10 years of record, a 50% exceedance curve was determined directly for the destination site. Then, for each day of the year, the ratio was determined between the master 50% curve and the destination 50% curve. Day-specific ratios were applied to each of the (5% through 90%) master exceedance curves to produce curves for the destination site. This method allowed development of a full family of curves which included the 50% curve as determined directly from the destination site data.

2. In cases where the destination site had fewer than 10 years of record, transpositions of all hydrographs were based on the ratio of average flows, for each day of the year, for periods of common record. For example, if the ratio of average daily flows for July 3 for years of common record was 0.453, then each of the 5 through 90 percent master hydrographs for July 3 were multiplied by 0.453, with different multipliers being computed and applied for each day of the year.

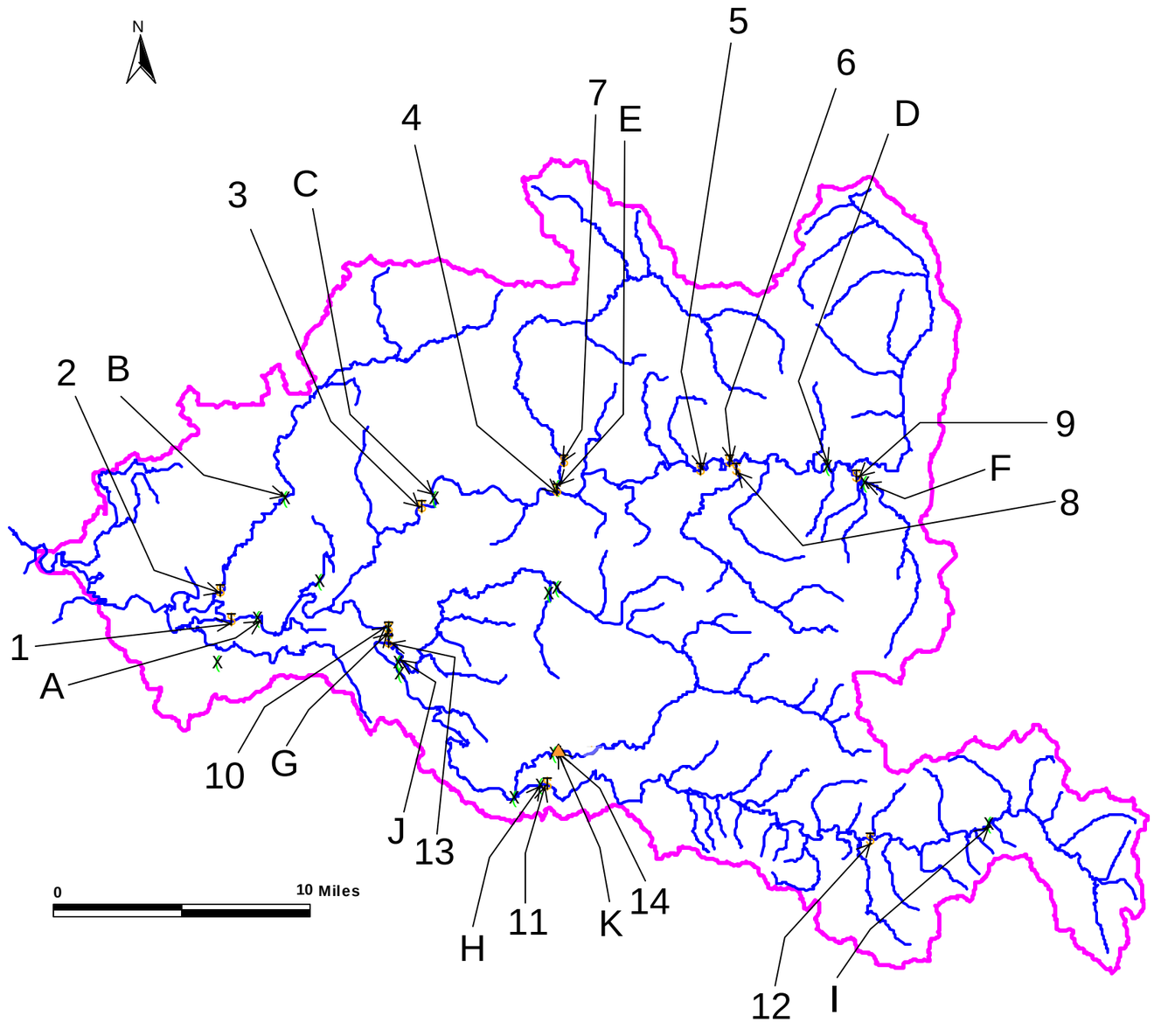
Hydrographs representative of flows in the main stem Stillaguamish River were developed by summing the daily flow hydrographs for the long-term stations on the North Fork and South Fork channels for periods of common record. The combined record was then transposed downstream by applying an adjustment factor based on basin areas and a further correction to match the annual flow volumes for one year of available stream gage data on the main stem channel. Exceedance curves for the main stem Stillaguamish River control point were computed directly from the 52-year record of combined and transposed daily flow data.

Results

Exceedance hydrographs for each of the 14 proposed instream flow control points are presented in Figures 1 through 14, corresponding to the station list presented on Exhibit 1. The plotted exceedance curves were smoothed by averaging the daily values over 30 days. A paired set of Figures, 1A through 14A show the same exceedance curves plus one year of daily streamflow data, with no smoothing, to demonstrate actual streamflow variability. The plotted daily streamflow data show USGS published values after adjustment for area

correction factors between the gage site and control point. The years selected to illustrate actual streamflow variability use consistent years where concurrent records exist, but were otherwise chosen at random.

It should be recognized that the accuracy of the flow exceedance curves presented here is constrained by the available streamflow data and the assumptions made in the transposition of the curves. Of the computed curves, the median (50% exceedance) curves are considered to be the most reliable and the high-flow (5% exceedance) curves are considered to be least reliable. This is because a median flow is exceeded every other year, on average, and can be reliably estimated with a relatively short period of record. In contrast, a 5% exceedance flow is exceeded only once in 20 years and requires a very long period of record to be estimated at all. If further refinement to the flow exceedance curves is desired, there are additional analysis techniques which could be employed in a follow-on assessment. Appropriate additional techniques would include a more rigorous regional analysis of coincident flows and of basin elevation effects.



Proposed Control Point Locations

Map ID	Control Point	River Mile	Latitude	Longitude	Basin Area sq. mi.	USGS Gages Used
1	Stillaguamish Mainstem	11.1	48 11 51 N	122 12 32 W	560.6	A, C, H
2	Pilchuck Creek	0.6	48 12 49 N	122 13 06 W	78.6	B
3	North Fork at Wiersma Bar	6.5	48 15 37 N	122 02 45 W	264.0	C
4	North Fork near Oso	14.3	48 16 05 N	121 55 51 W	172.5	C
5	North Fork near Hazel	22.3	48 16 41 N	121 48 37 W	138.3	D, C
6	North Fork at Blue Slough	24.2	48 16 58 N	121 47 04 W	110.2	D, C
7	Deer Creek	1.4	48 17 03 N	121 55 33 W	65.6	E, C
8	Boulder River	0.5	48 16 41 N	121 46 46 W	25.9	F, C
9	Squire Creek	0.7	48 16 24 N	121 40 39 W	25.6	F, C
10	South Fork near Arlington	21.1	48 01 31 N	122 04 34 W	250.1	G, H
11	South Fork near Granite Falls	35.0	48 06 12 N	121 56 38 W	117.3	H
12	South Fork at Gordon Creek	54.0	48 04 12 N	121 40 14 W	55.4	I, H
13	Jim Creek near Mouth	0.0	48 11 04 N	122 04 32 W	46.8	J, H
14	Canyon Creek	3.4	48 07 18 N	121 56 15 W	59.8	K, H

USGS Stream Gages Used in Exceedance Hydrograph Development

Map ID	USGS Gage #	Gage Name	Basin Area sq. mi.	Record Begins	Years of Data
A	12167700	Stillaguamish River near Silvana	557.0	1974	3
B	12168500	Pilchuk Creek near Bryant	52.0	1929	49
C	12167000	North Fork Stillaguamish River near Arlington	262.0	1928	76
D	12165500	North Fork Stillaguamish River near Darrington	82.2	1950	8
E	12166500	Deer Creek at Oso	65.9	1917	15
F	12165000	Squire Creek near Darrington	18.8	1950	20
G	12164500	South Fork Stillaguamish River near Arlington	251.0	1929	8
H	12161000	South Fork Stillaguamish River near Granite Falls	119.0	1928	53
I	12158500	South Fork Stillaguamish River at Silverton	37.2	1929	4
J	12164000	Jim Creek near Arlington	46.2	1937	21
K	12161500	Canyon Creek near Granite Falls	59.8	1929	5

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EXHIBIT 1

Stillaguamish Basin Location Map

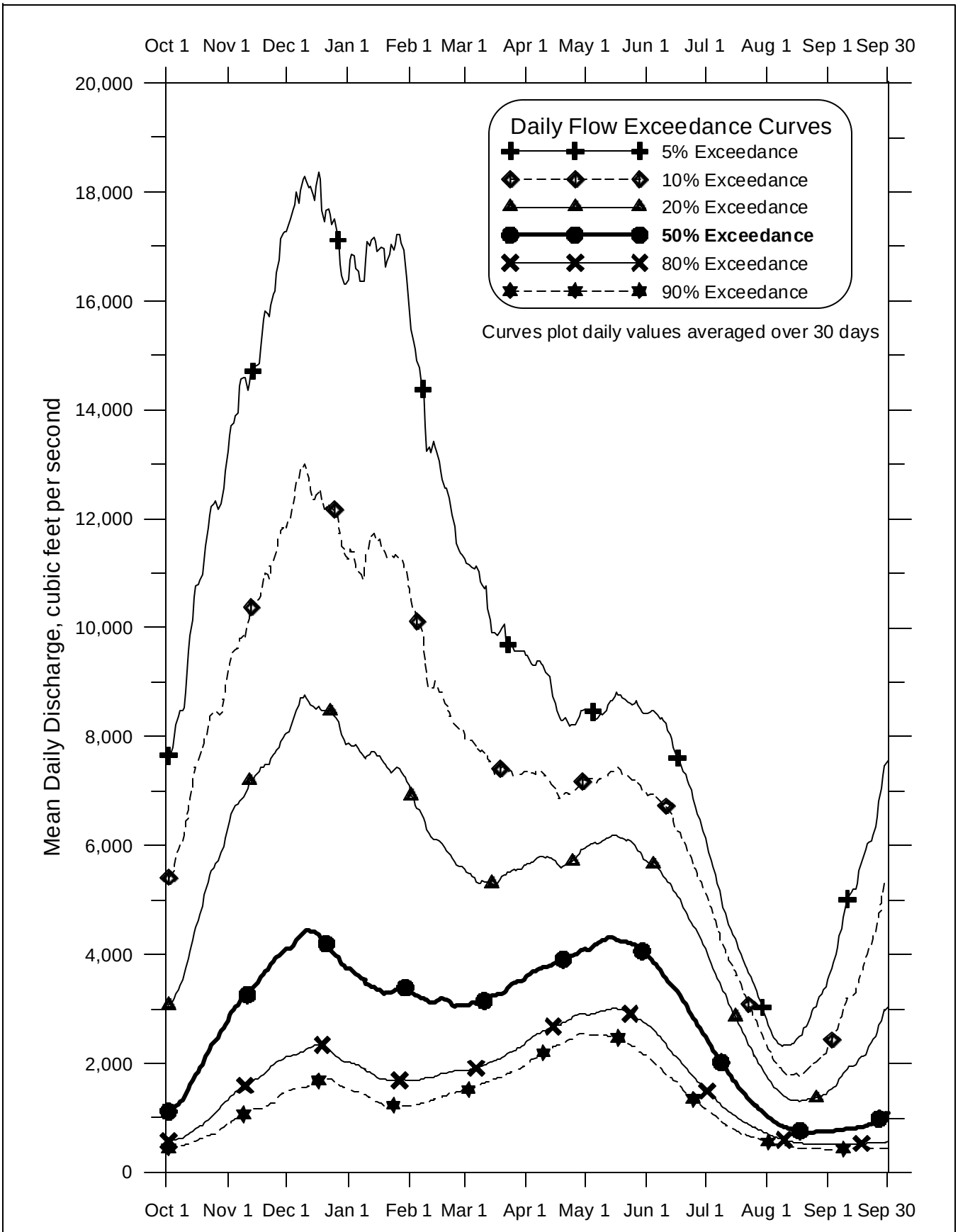

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FIGURE 1
Stillaguamish Mainstem at RM 11.1

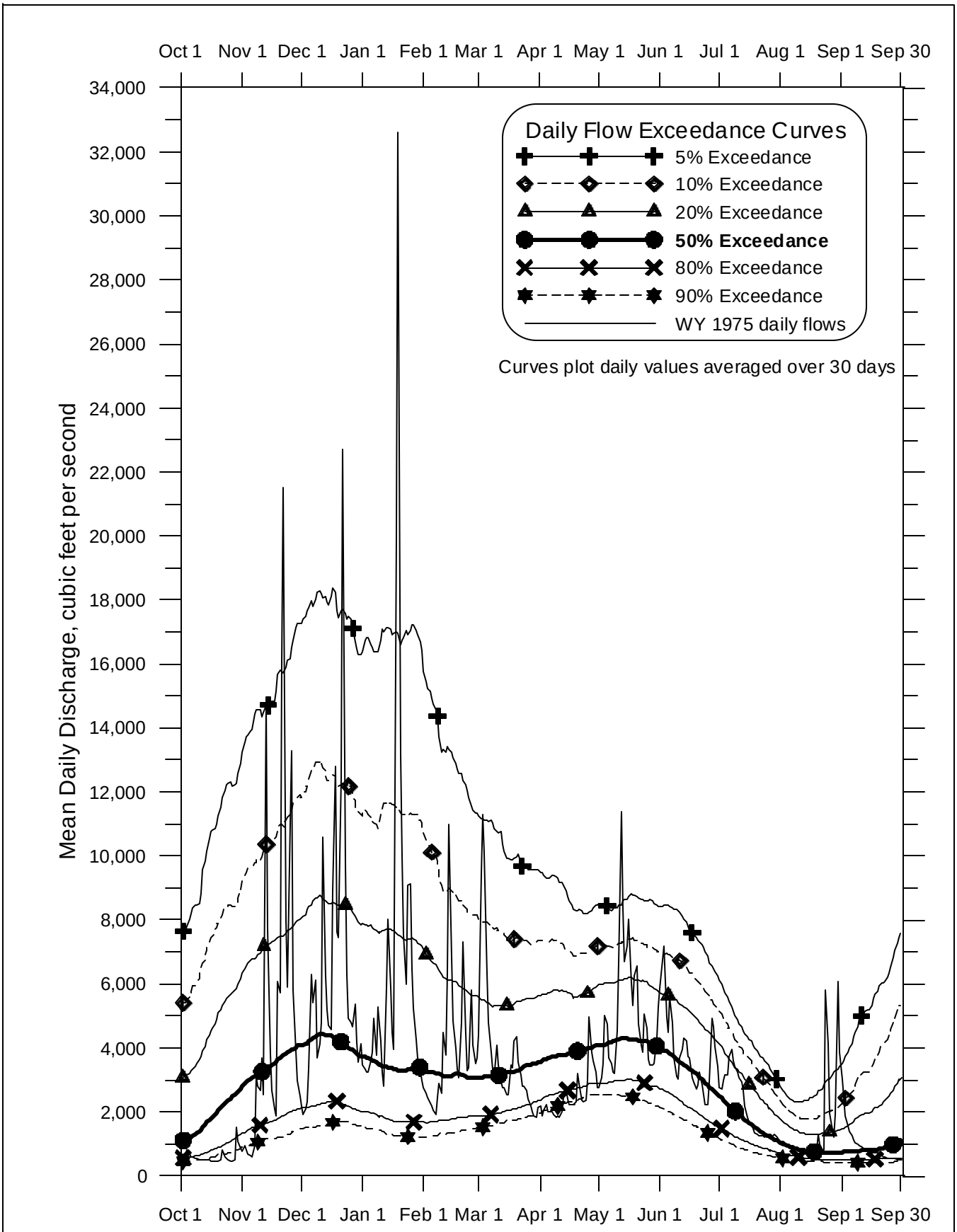

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FIGURE 1A
Stillaguamish Mainstem at RM 11.1

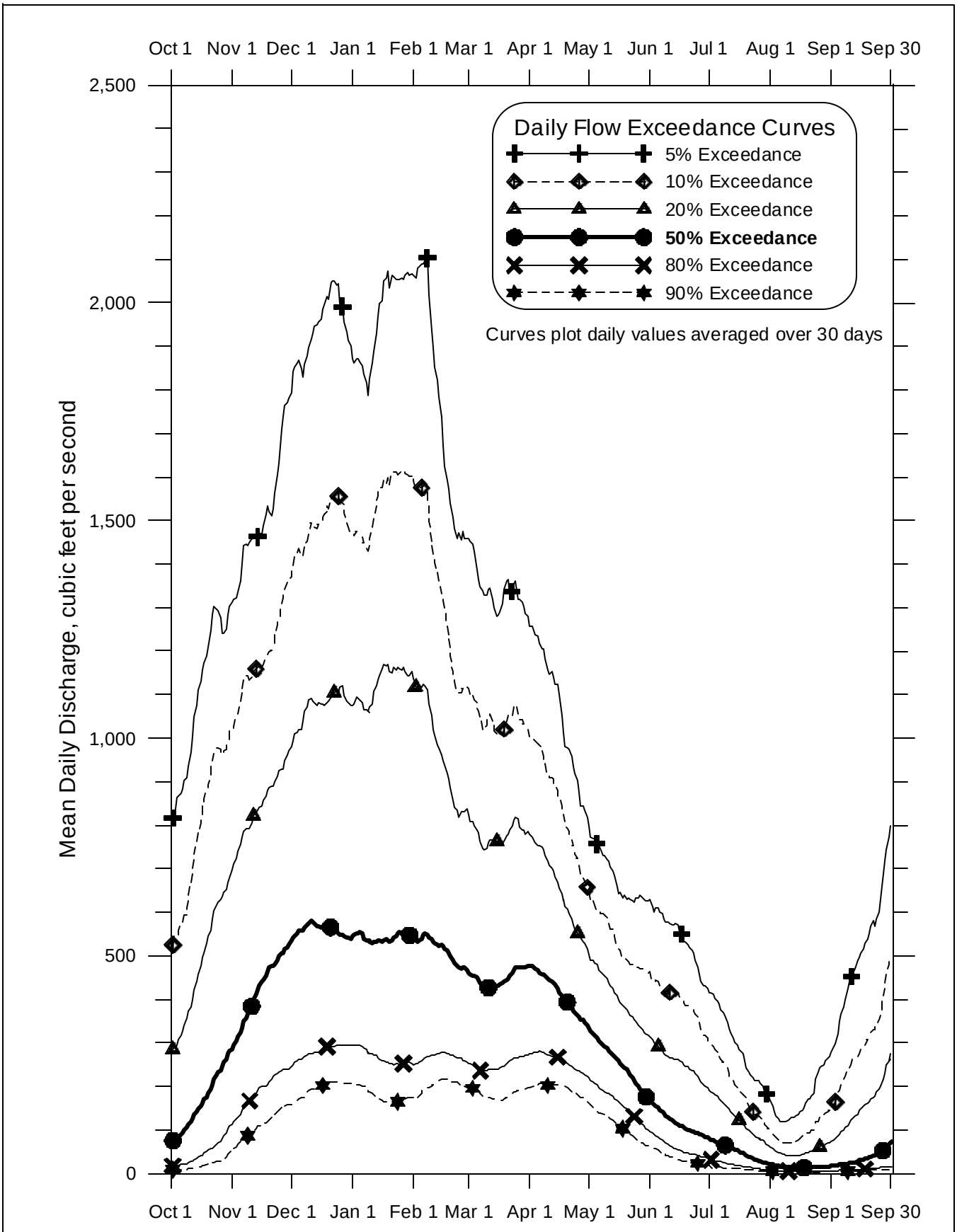

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FIGURE 2
Pilchuck Creek at RM 0.6

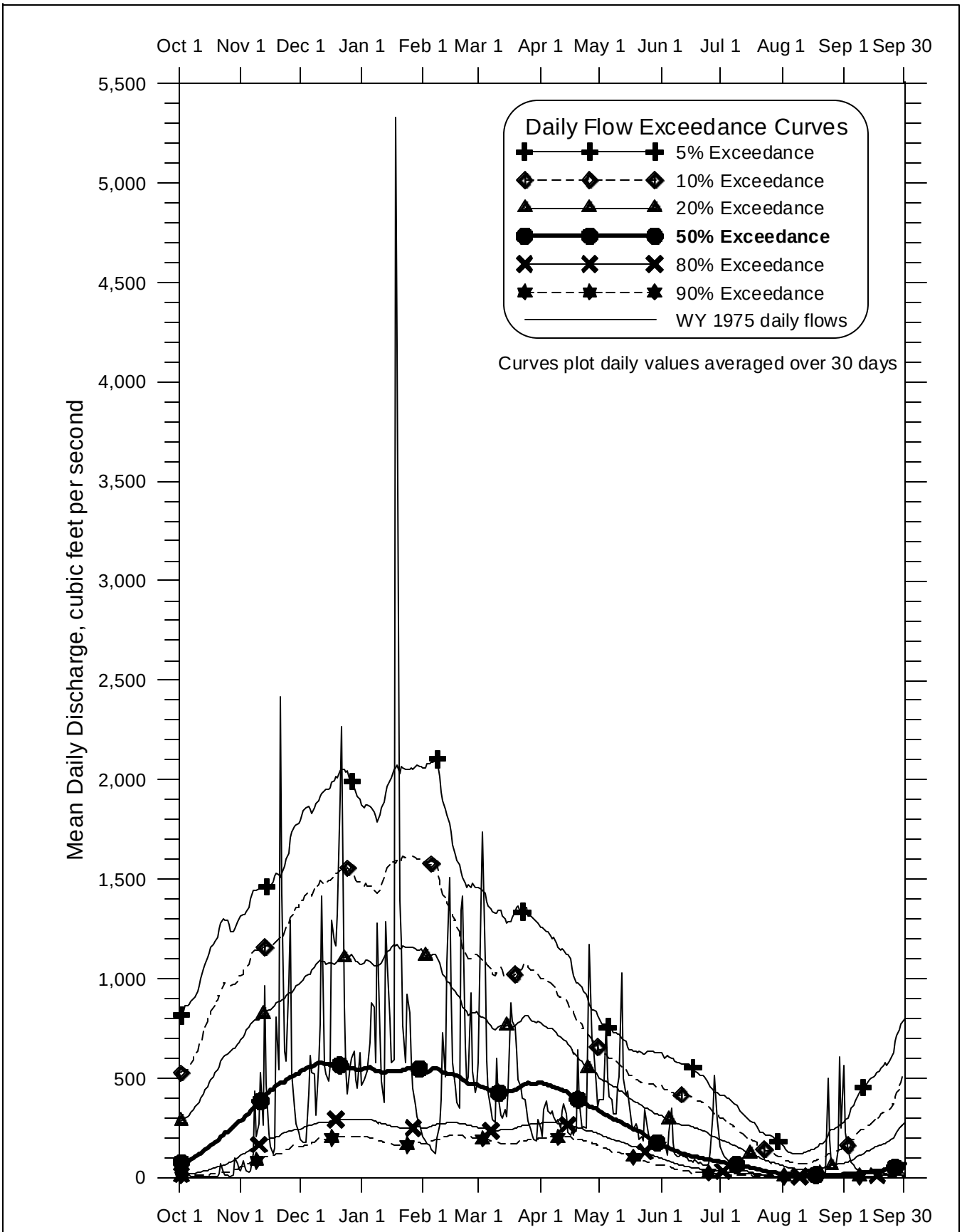

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FIGURE 2A
Pilchuck Creek at RM 0.6

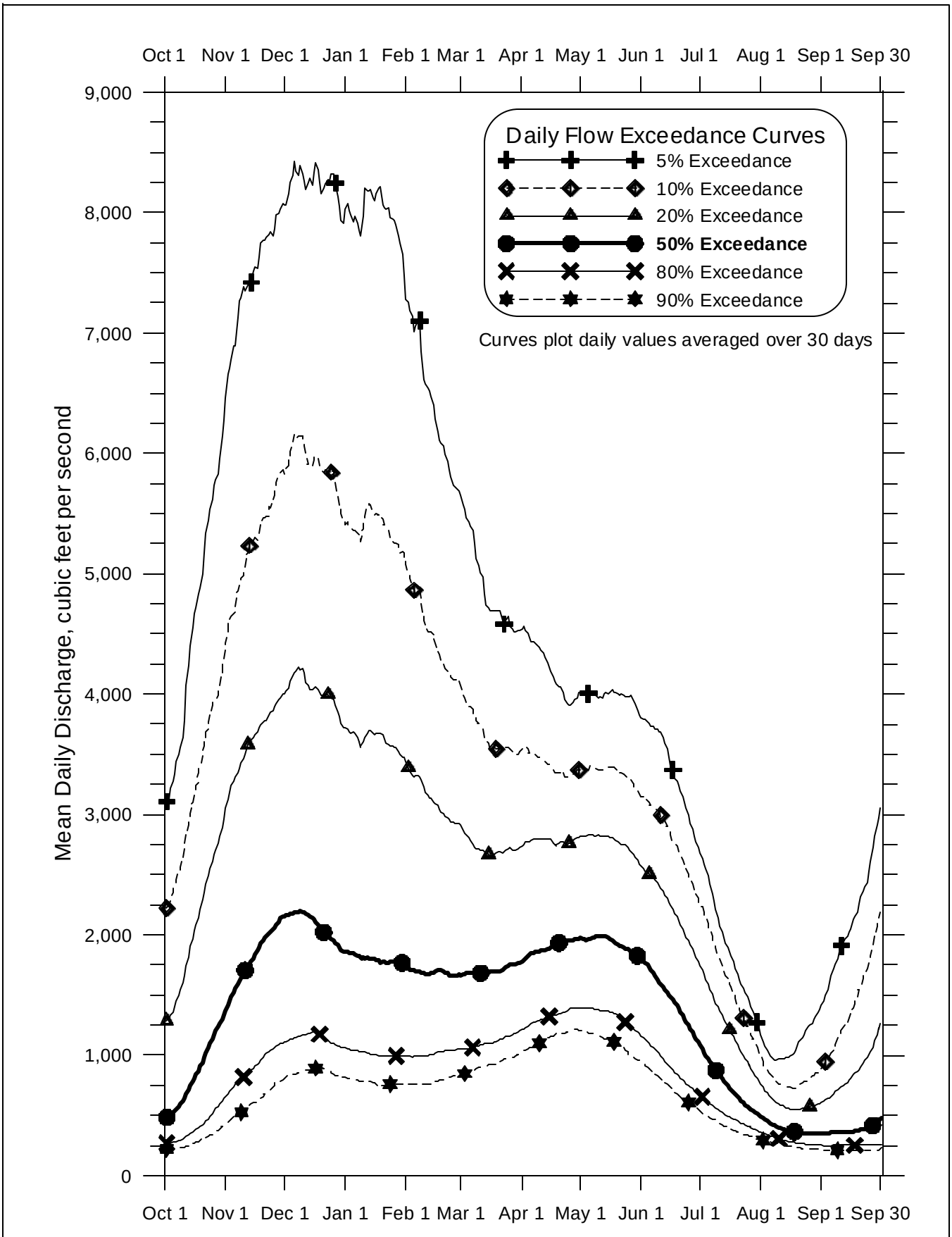

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FIGURE 3
North Fork at Wiersma Bar, RM 6.5

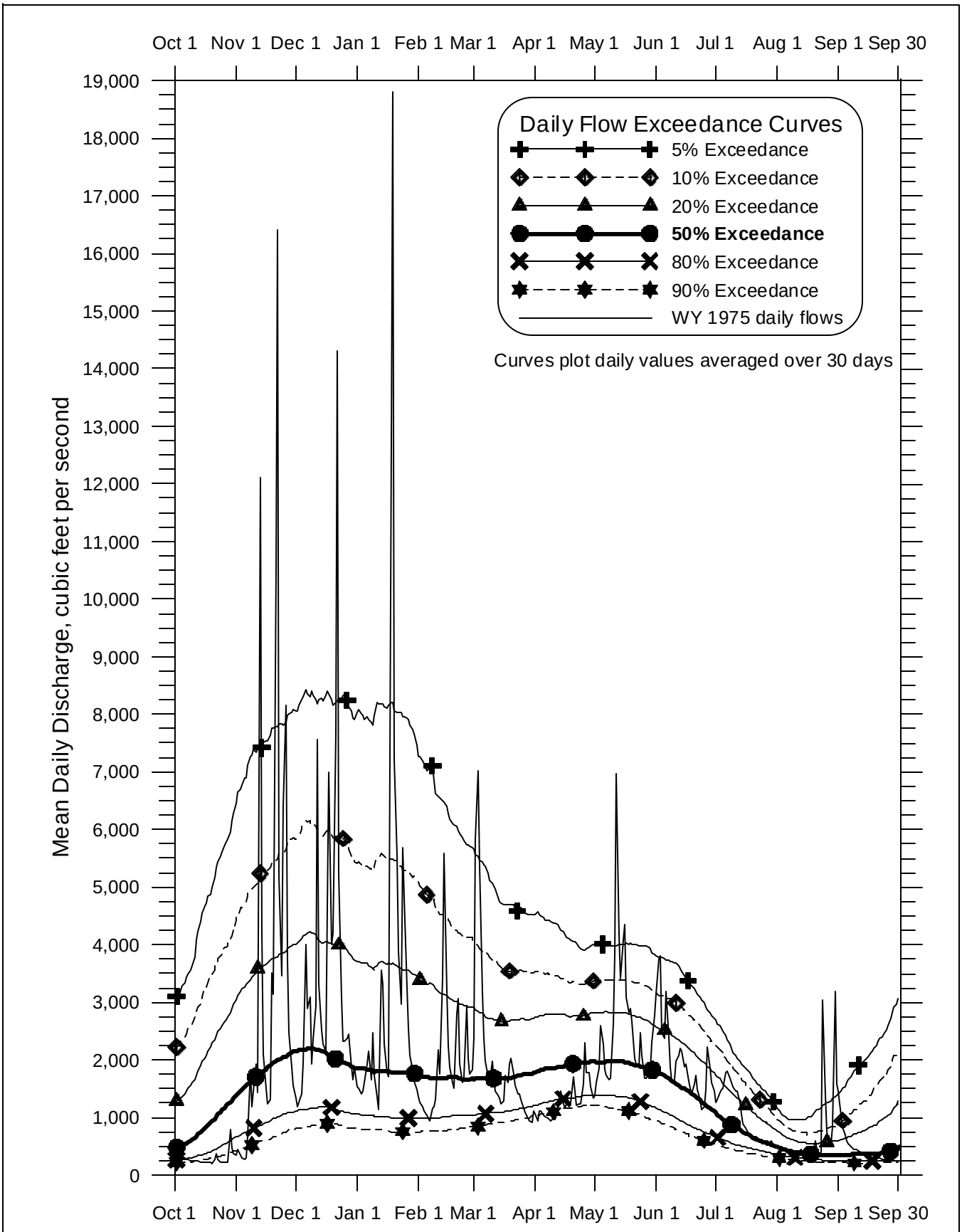

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FIGURE 3A
North Fork at Wiersma Bar, RM 6.5

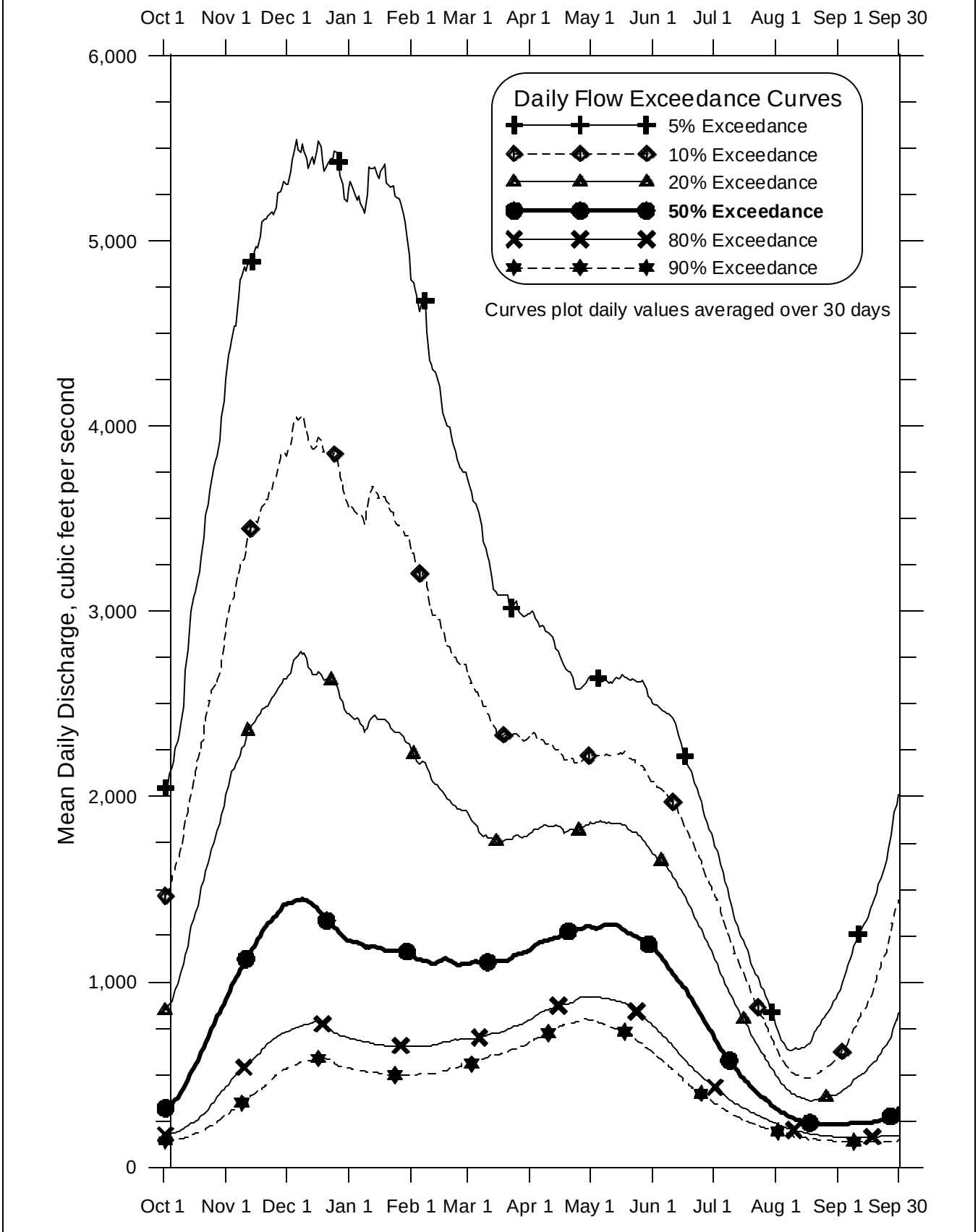

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FIGURE 4
North Fork near Oso at RM 14.3

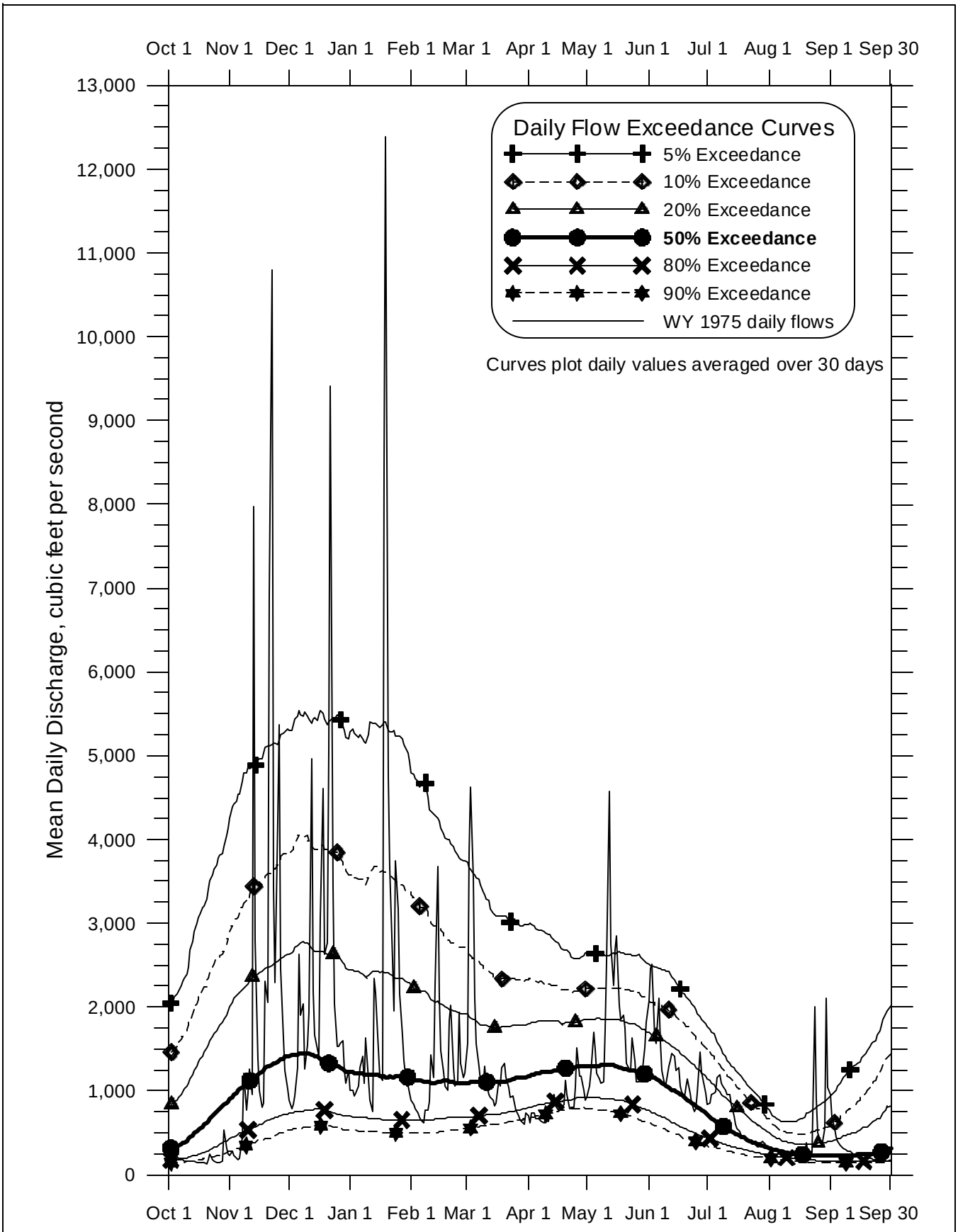

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FIGURE 4A
North Fork near Oso at RM 14.3

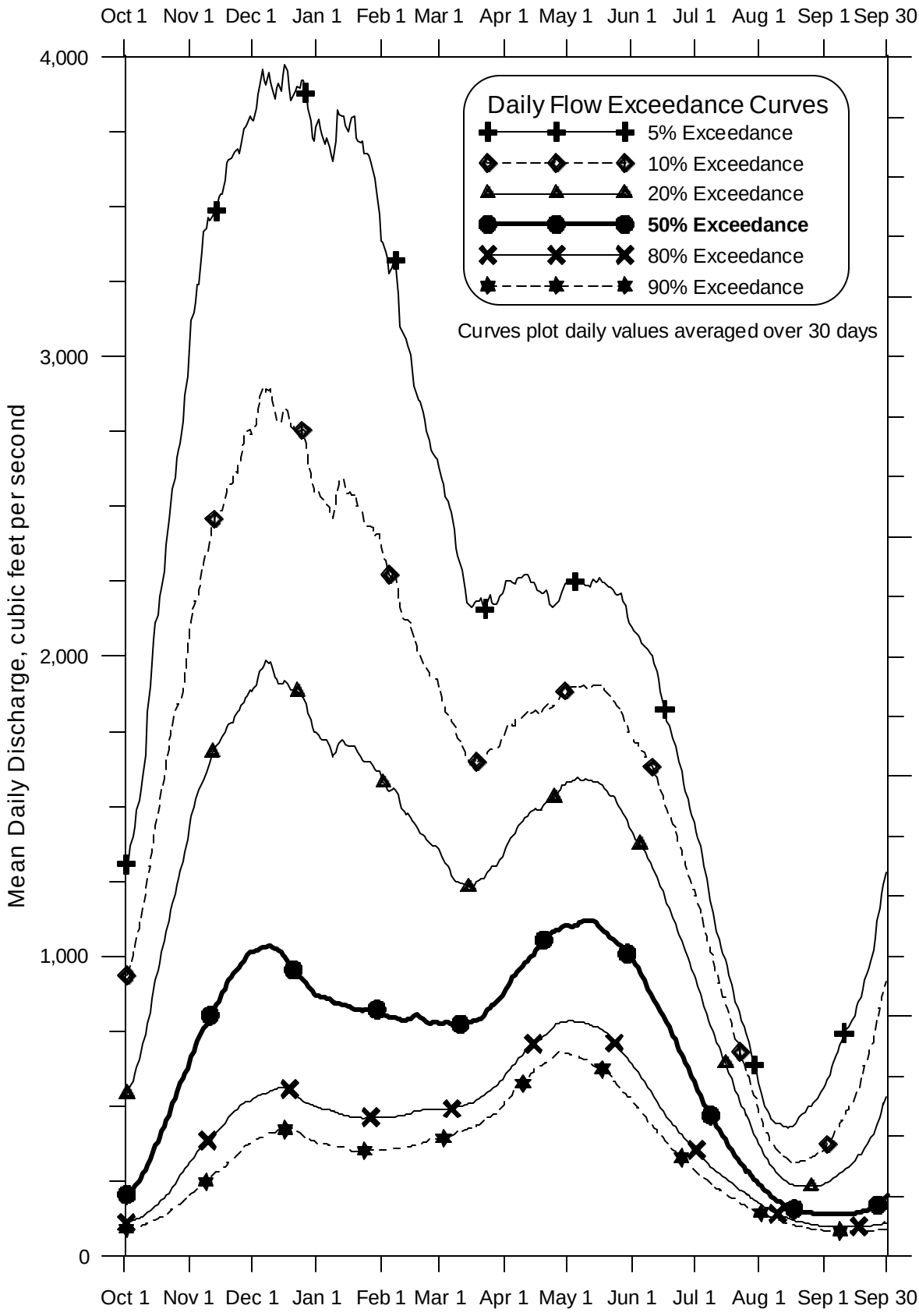

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FIGURE 5
North Fork near Hazel at RM 22.3

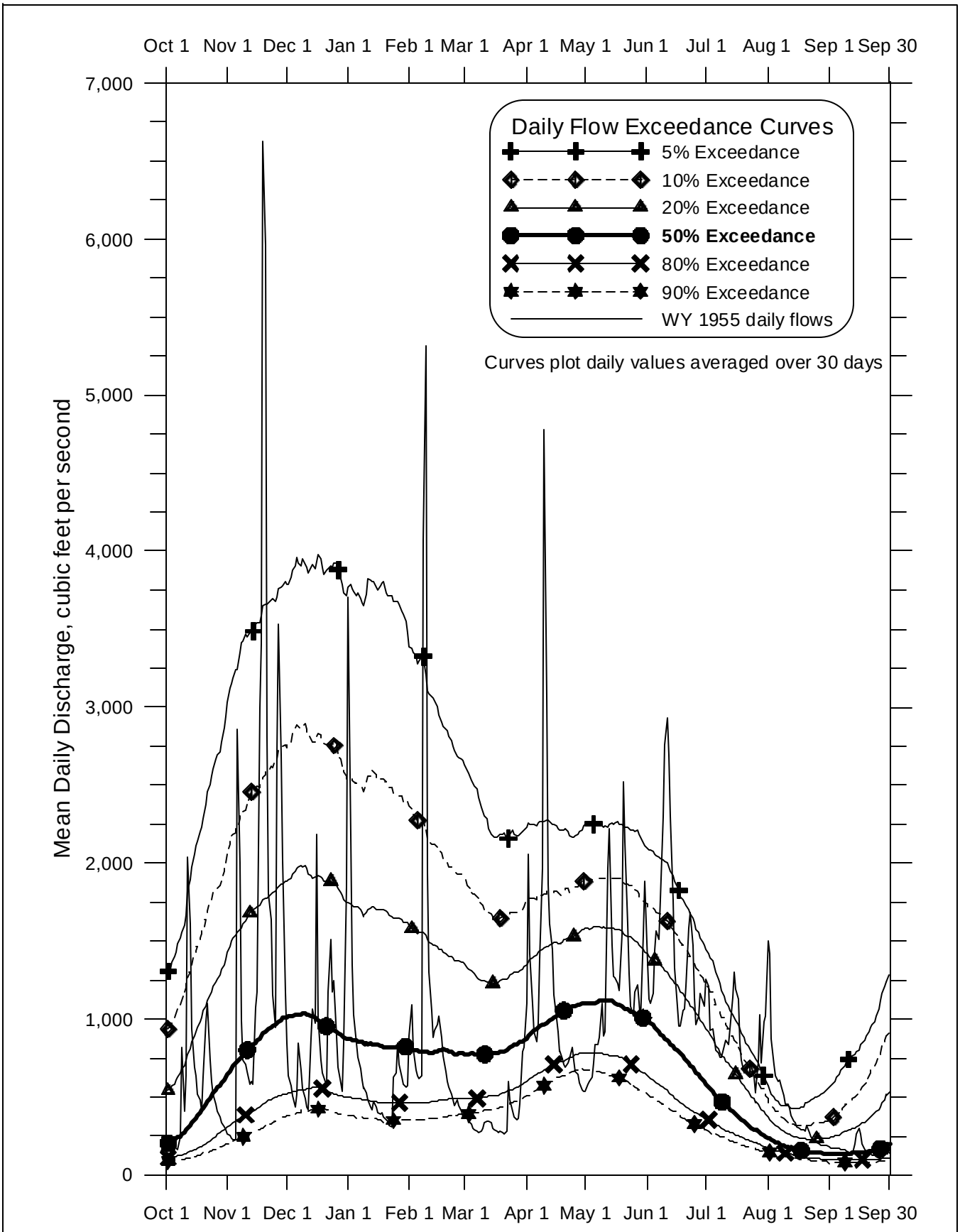

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FIGURE 5A
North Fork near Hazel at RM 22.3

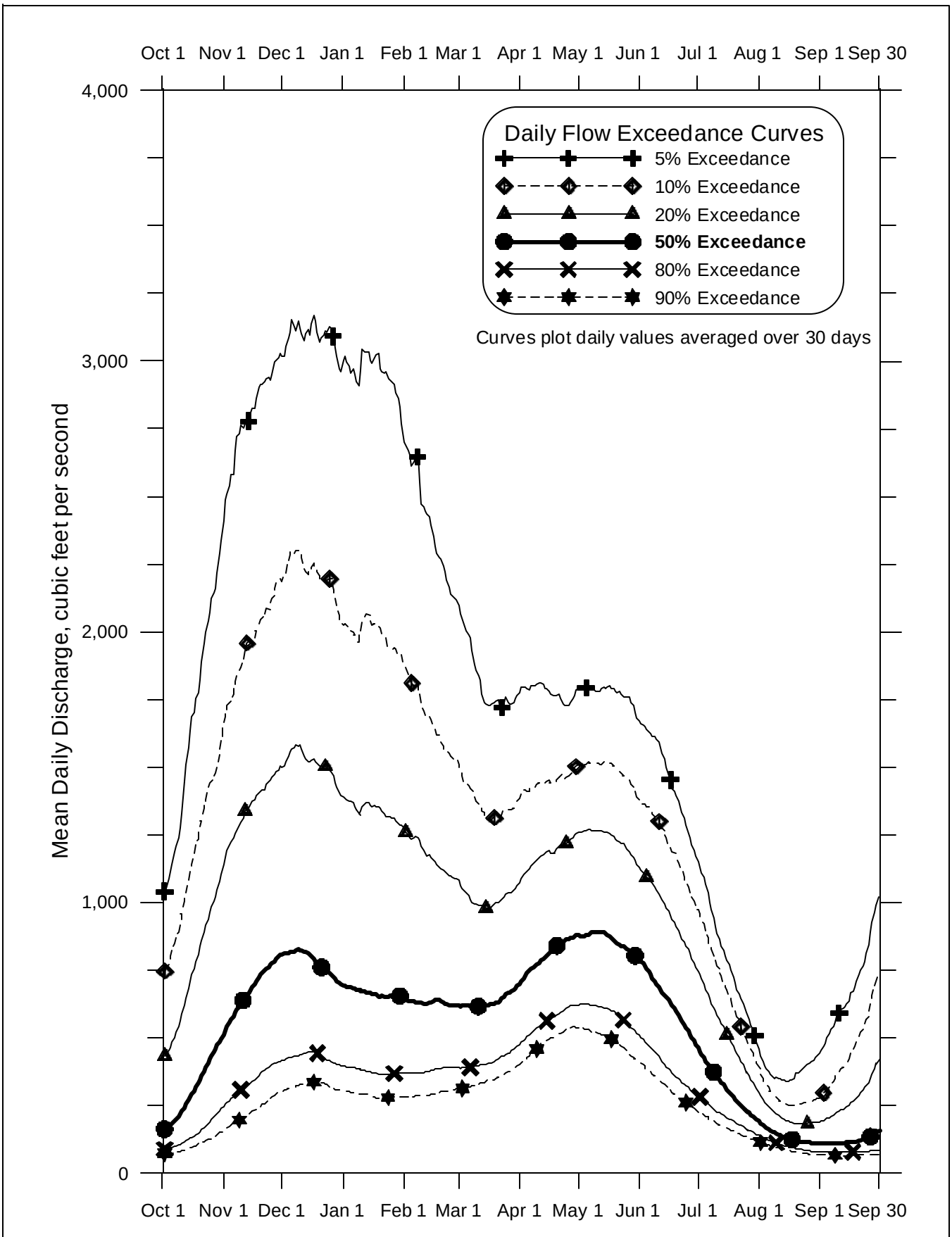

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FIGURE 6
North Fork at Blue Slough, RM 24.2

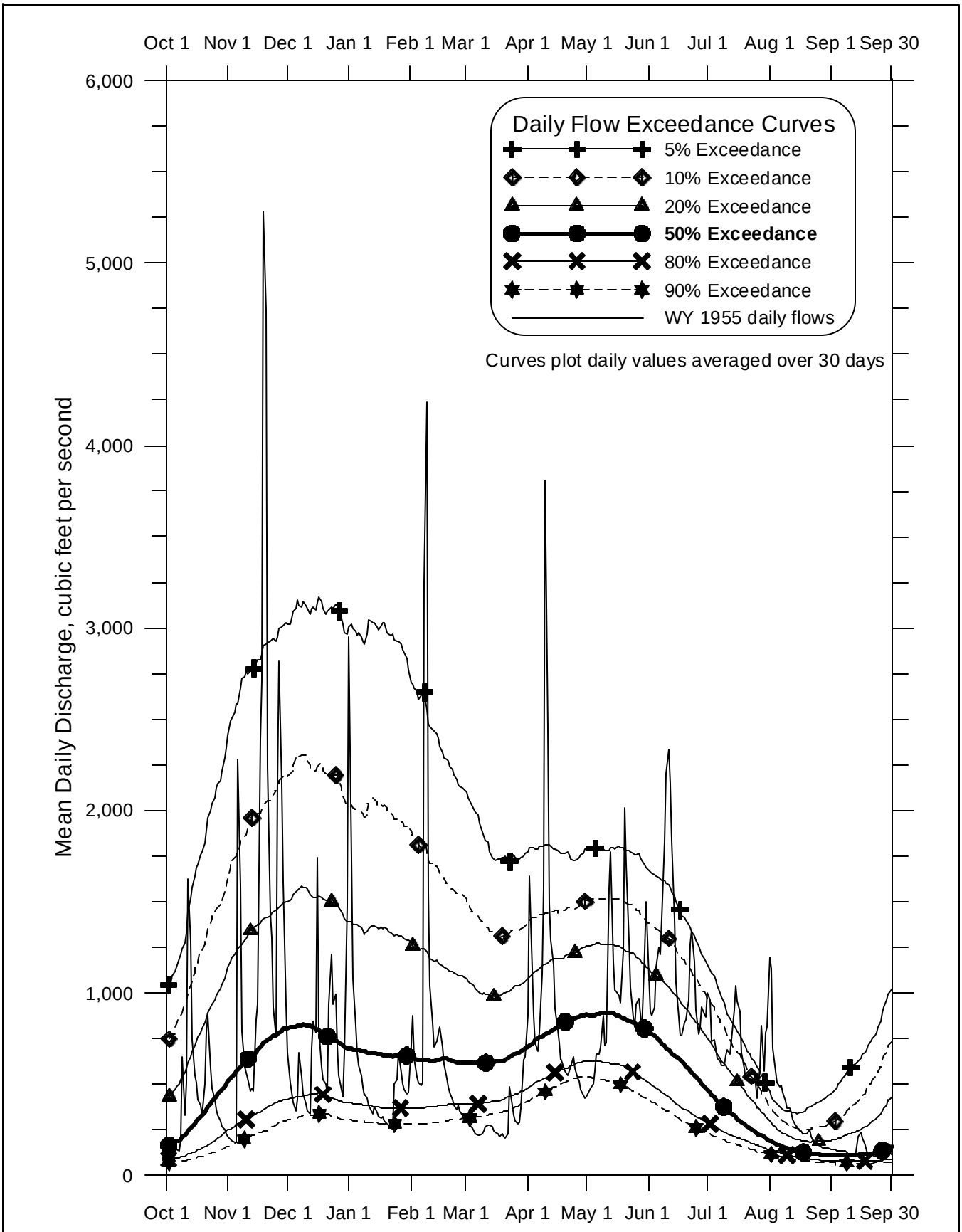

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FIGURE 6A
North Fork at Blue Slough, RM 24.2

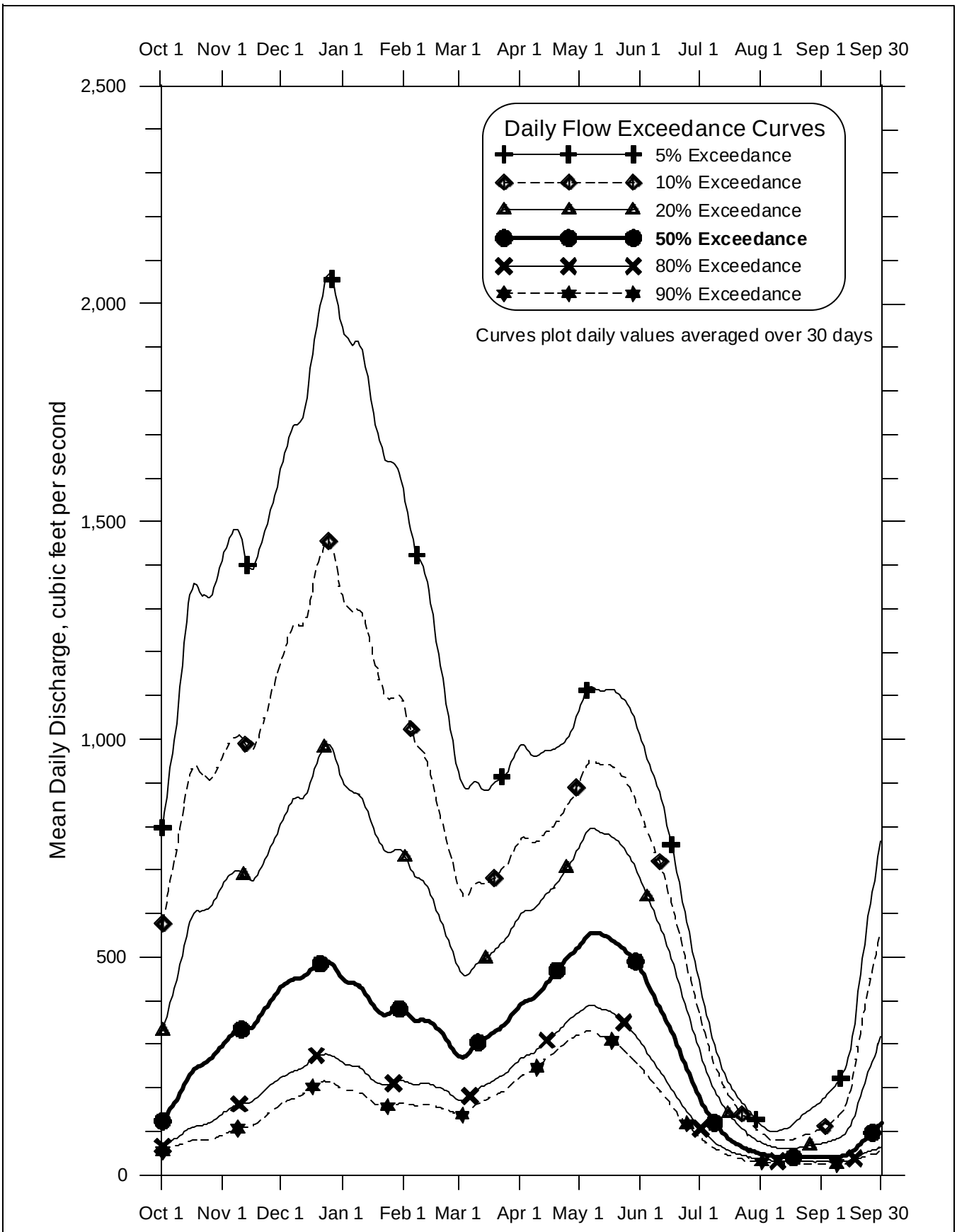

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FIGURE 7

Deer Creek at RM 1.4

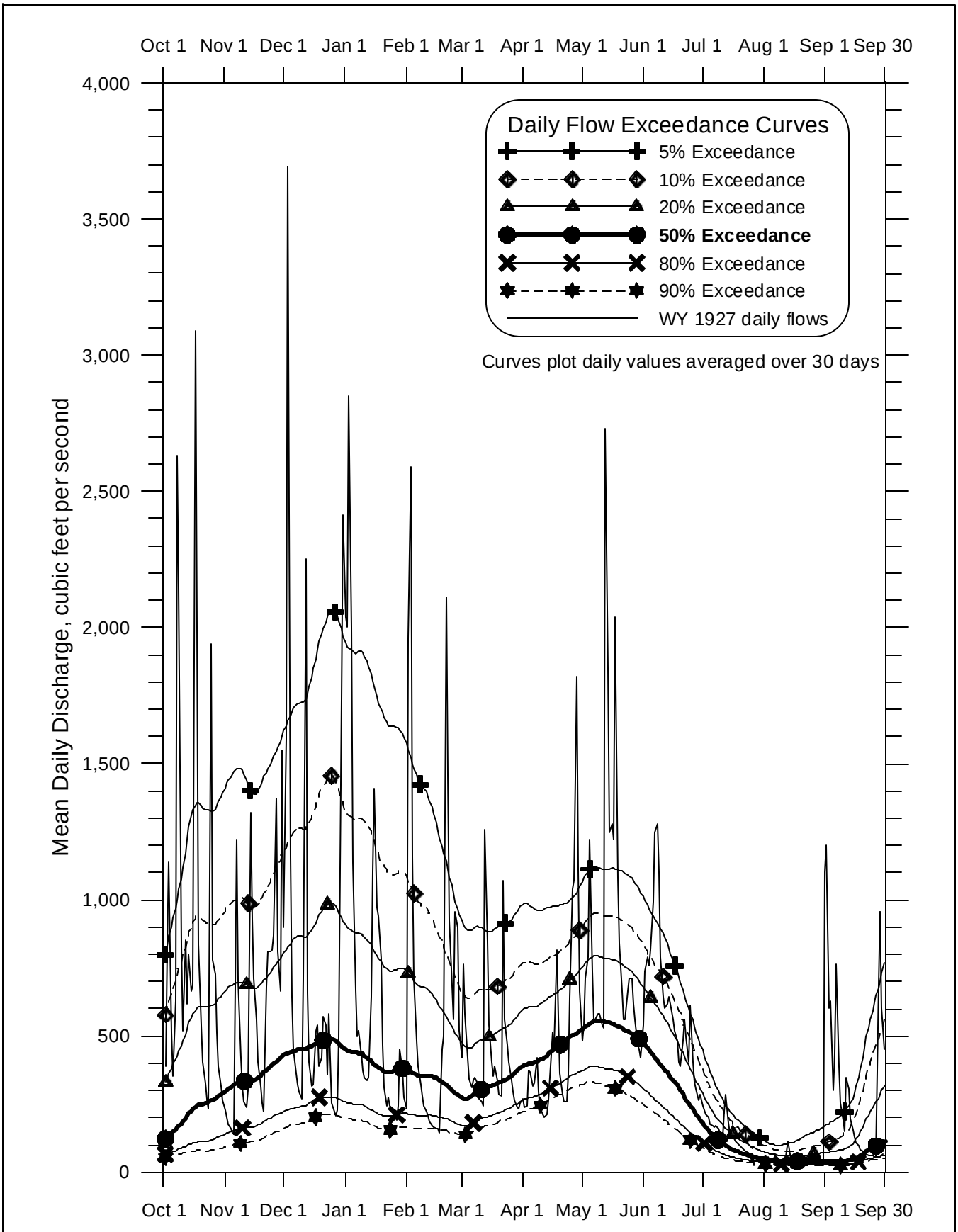

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FIGURE 7A

Deer Creek at RM 1.4

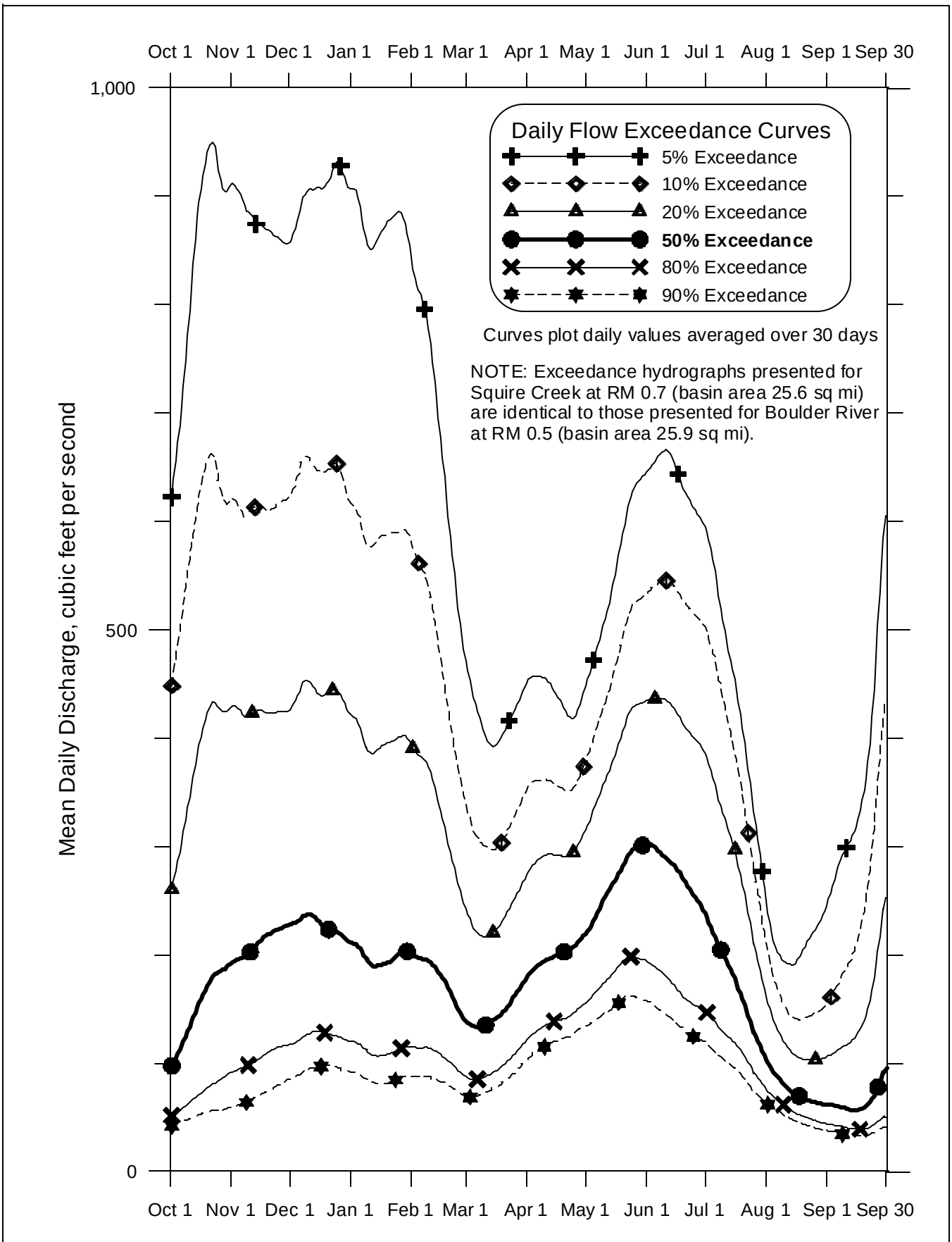

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FIGURE 8

Boulder River at RM 0.5

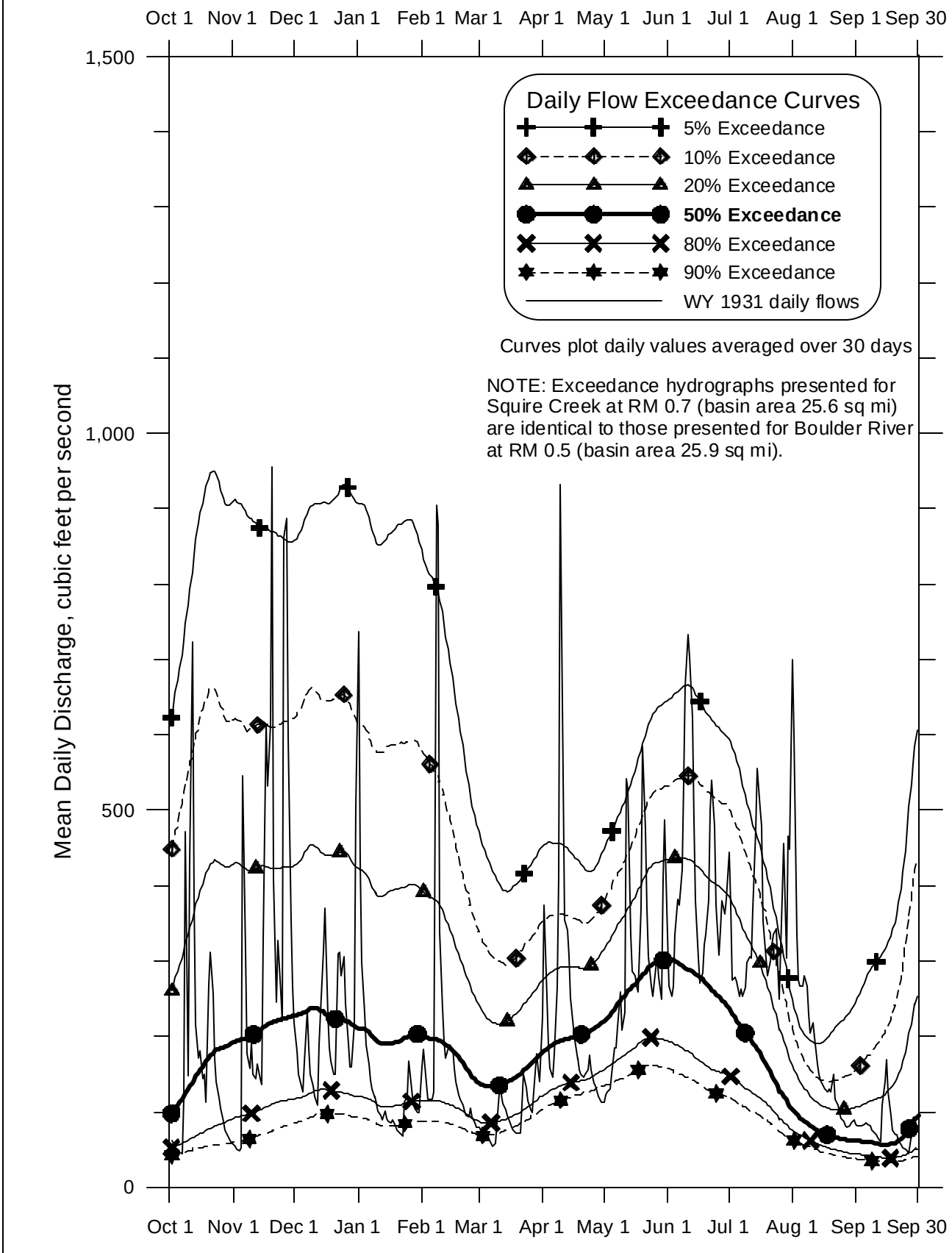

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FIGURE 8A

Boulder River at RM 0.5

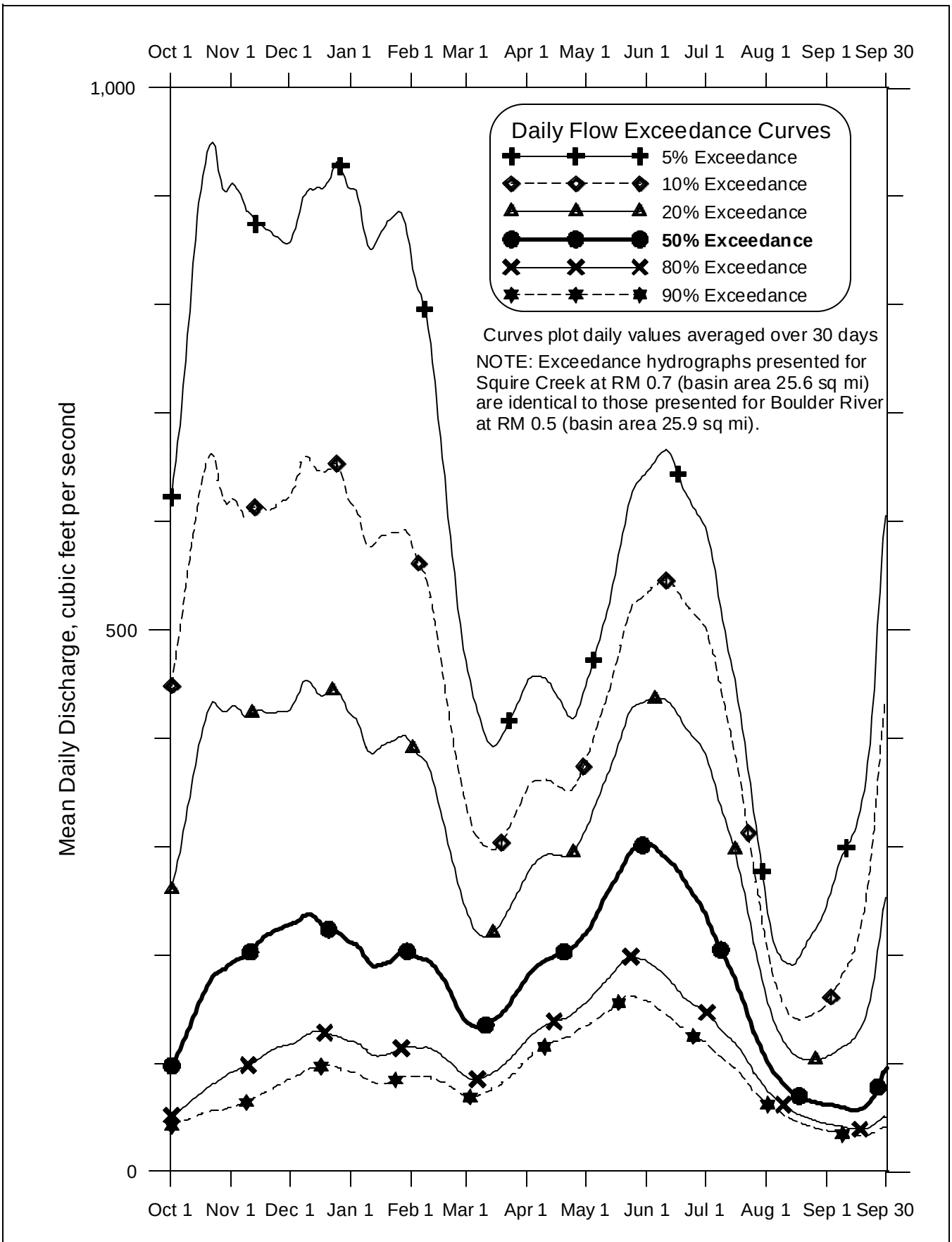

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FIGURE 9

Squire Creek at RM 0.7

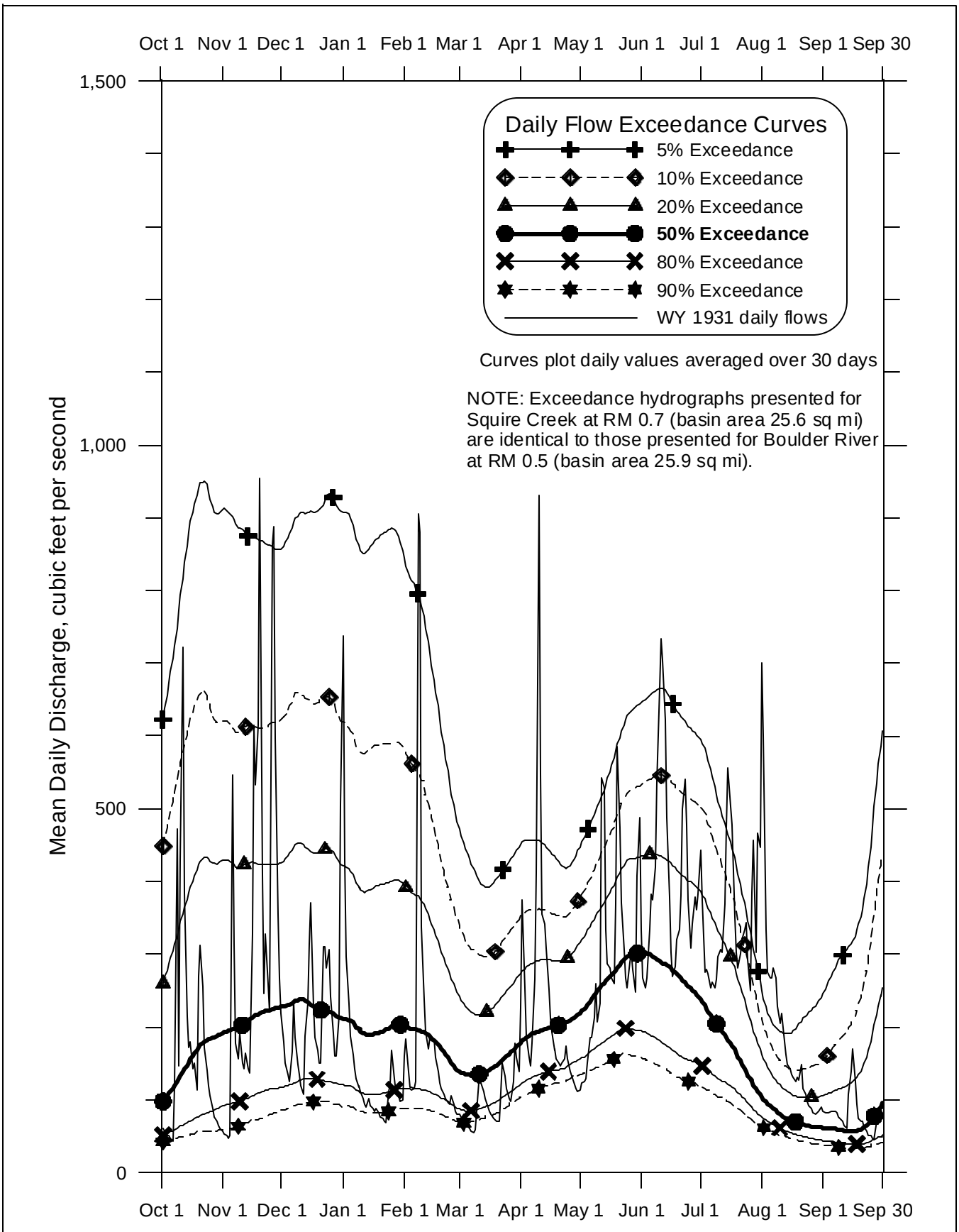

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FIGURE 9A

Squire Creek at RM 0.7

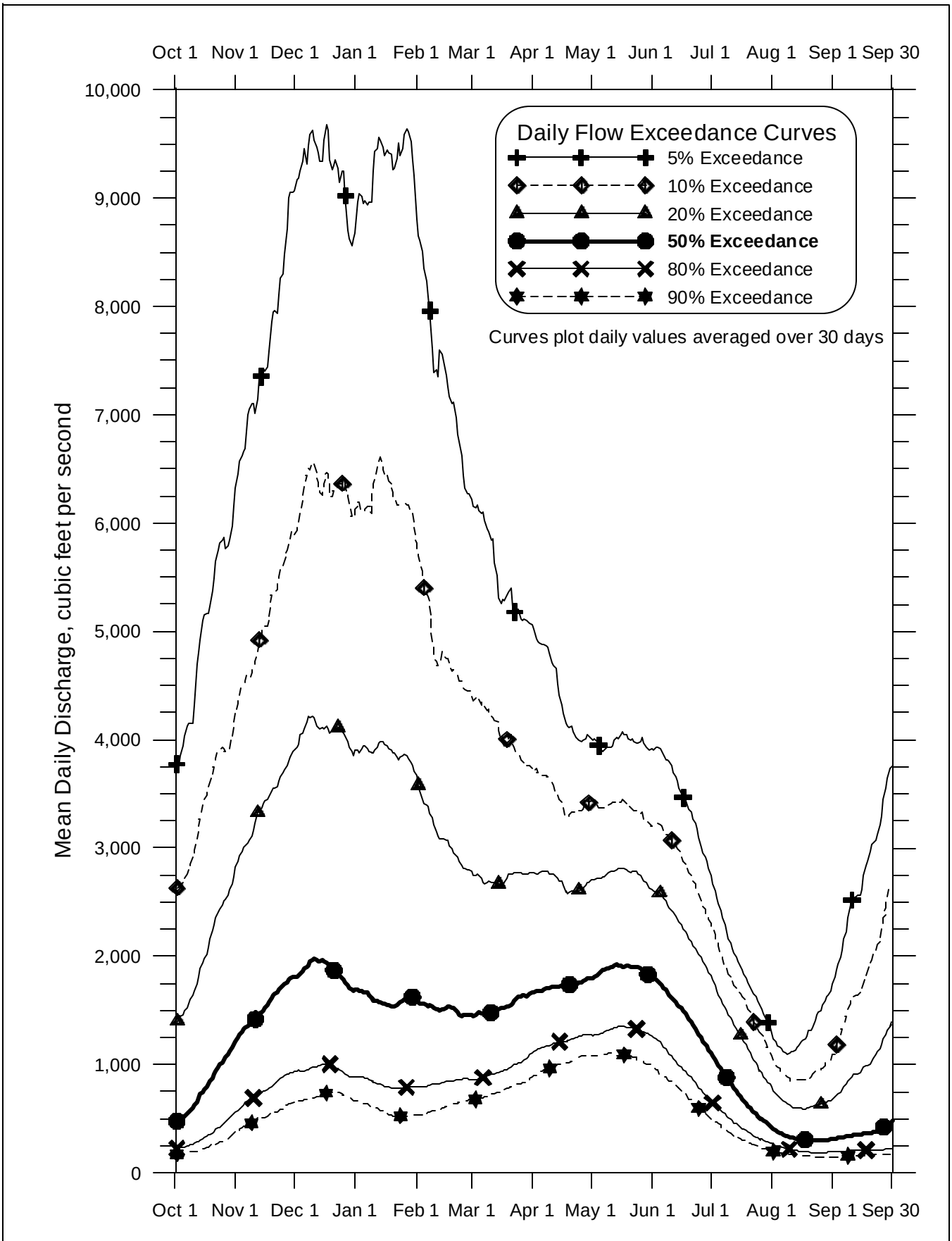

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FIGURE 10

South Fork near Arlington at RM 21.1

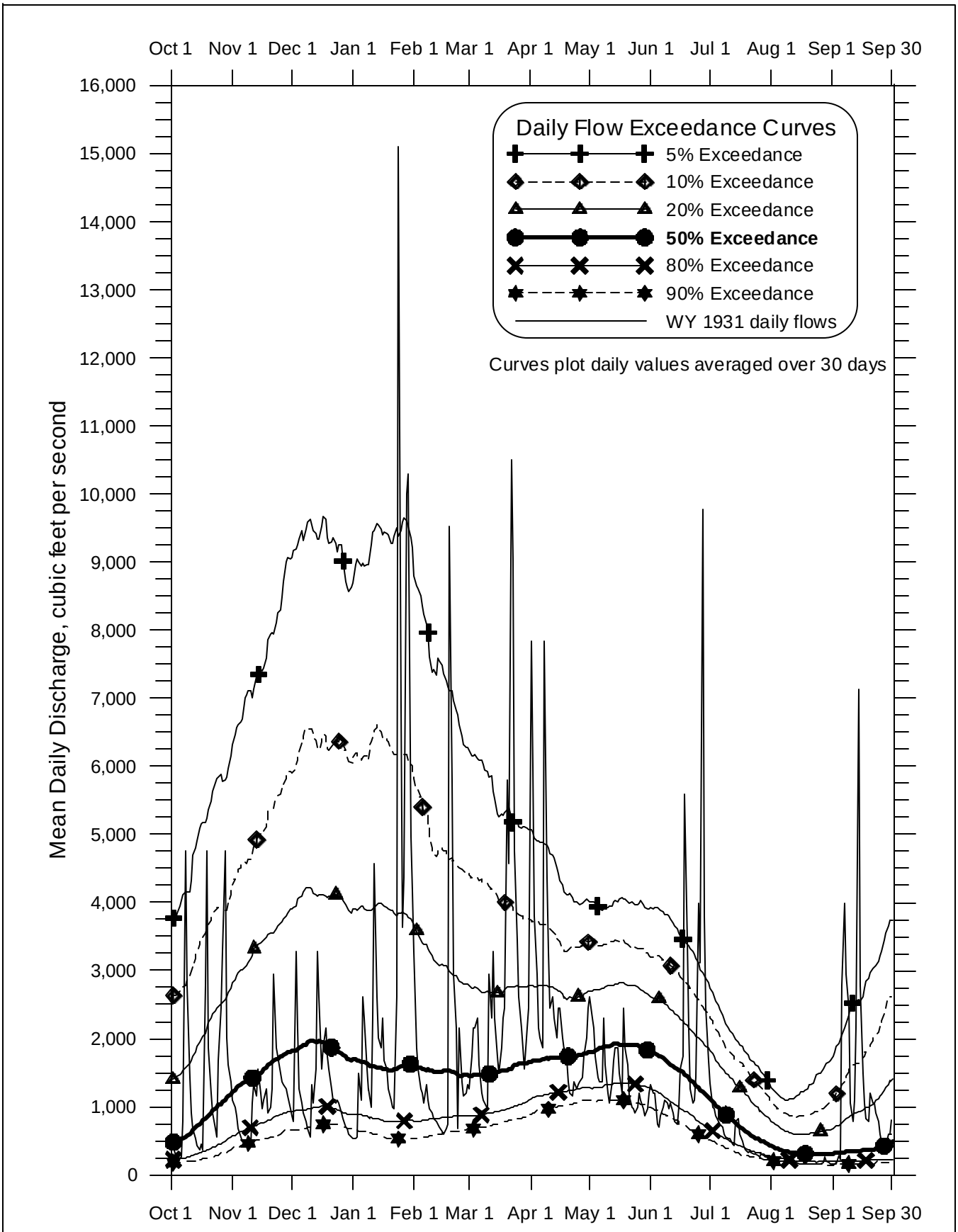

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FIGURE 10A

South Fork near Arlington at RM 21.1

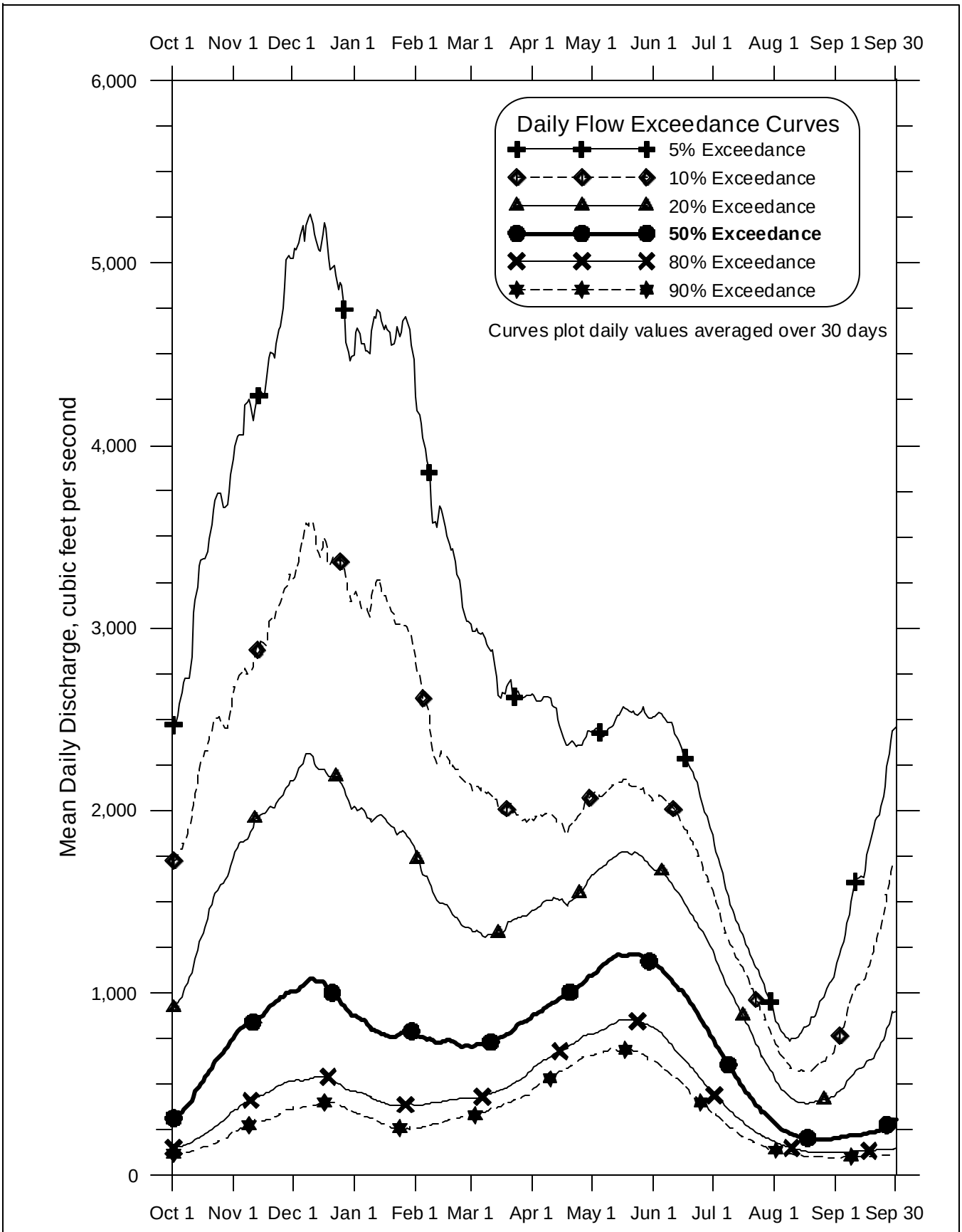

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FIGURE 11

South Fork near Granite Falls at RM 35.0

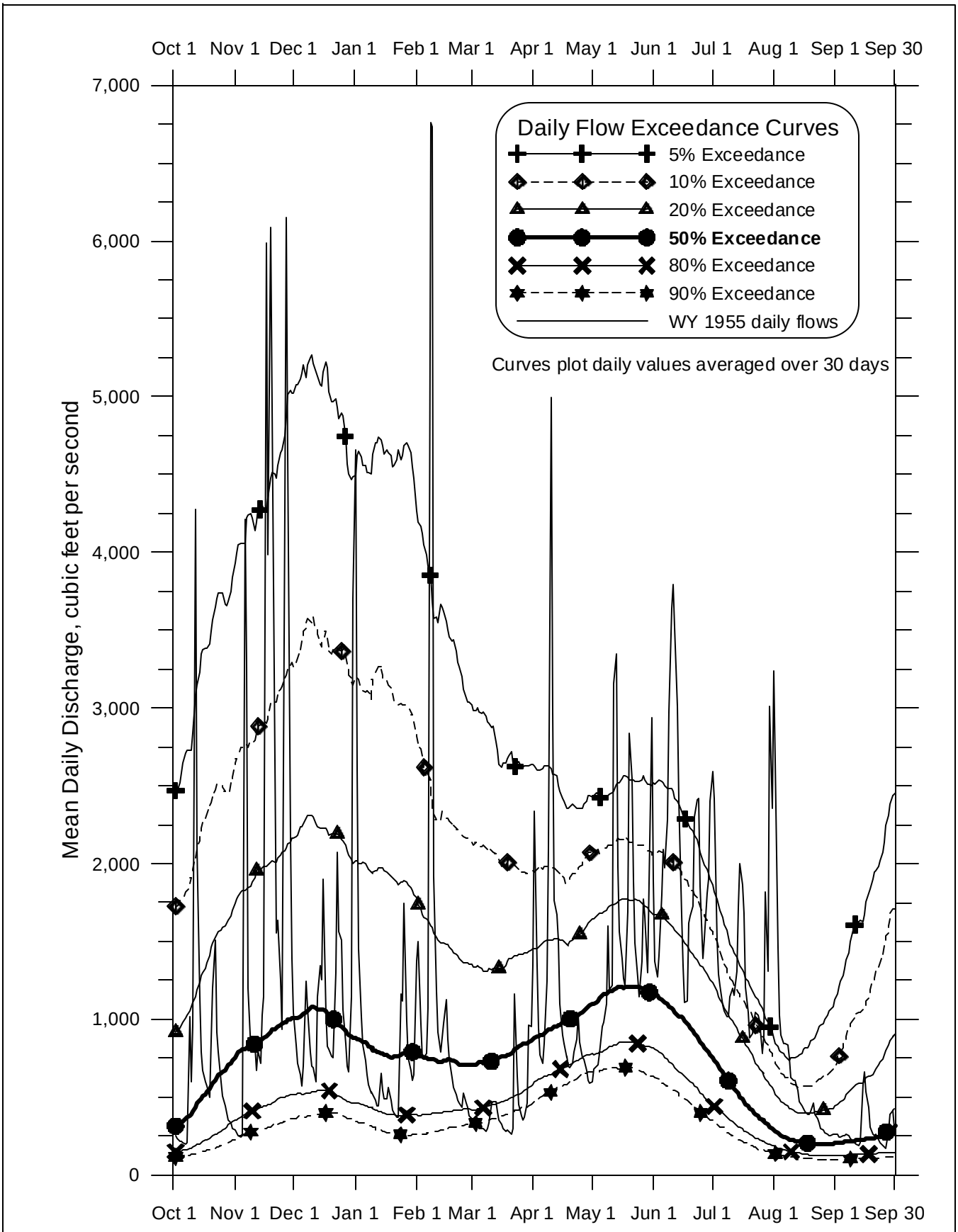

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FIGURE 11A

South Fork near Granite Falls at RM 35.0

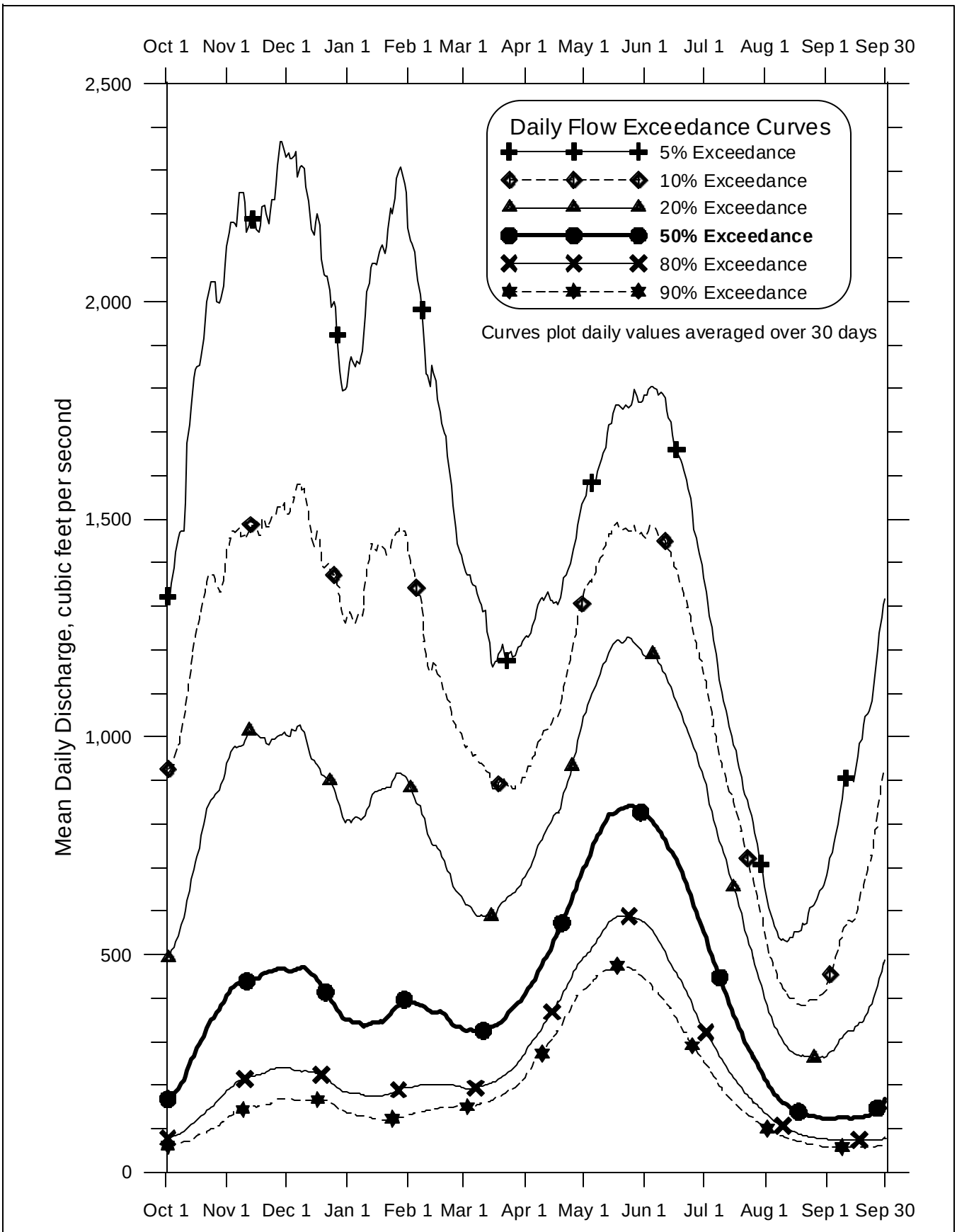

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FIGURE 12
South Fork at Gordon Creek, RM 54.0

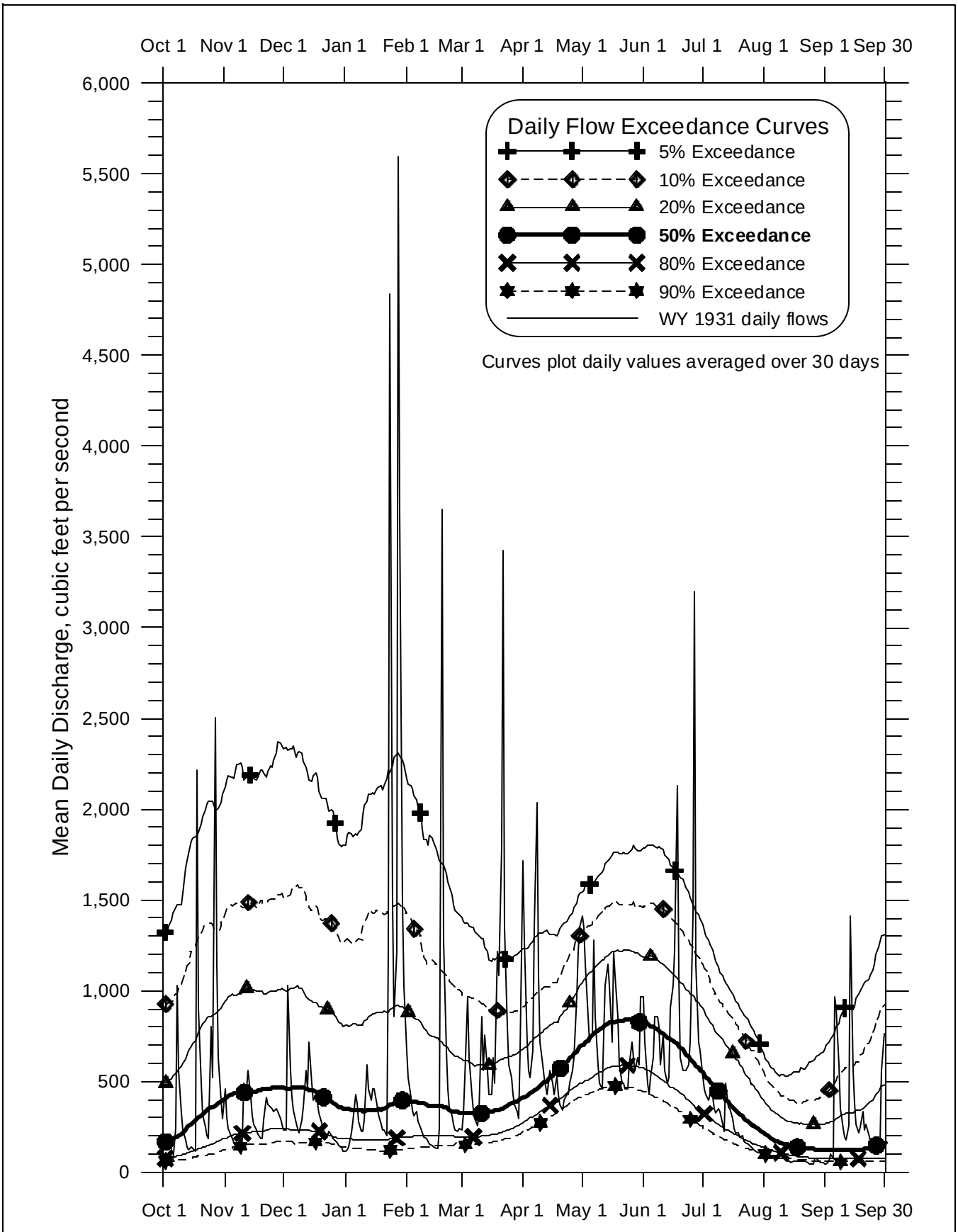

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FIGURE 12A
South Fork at Gordon Creek, RM 54.0

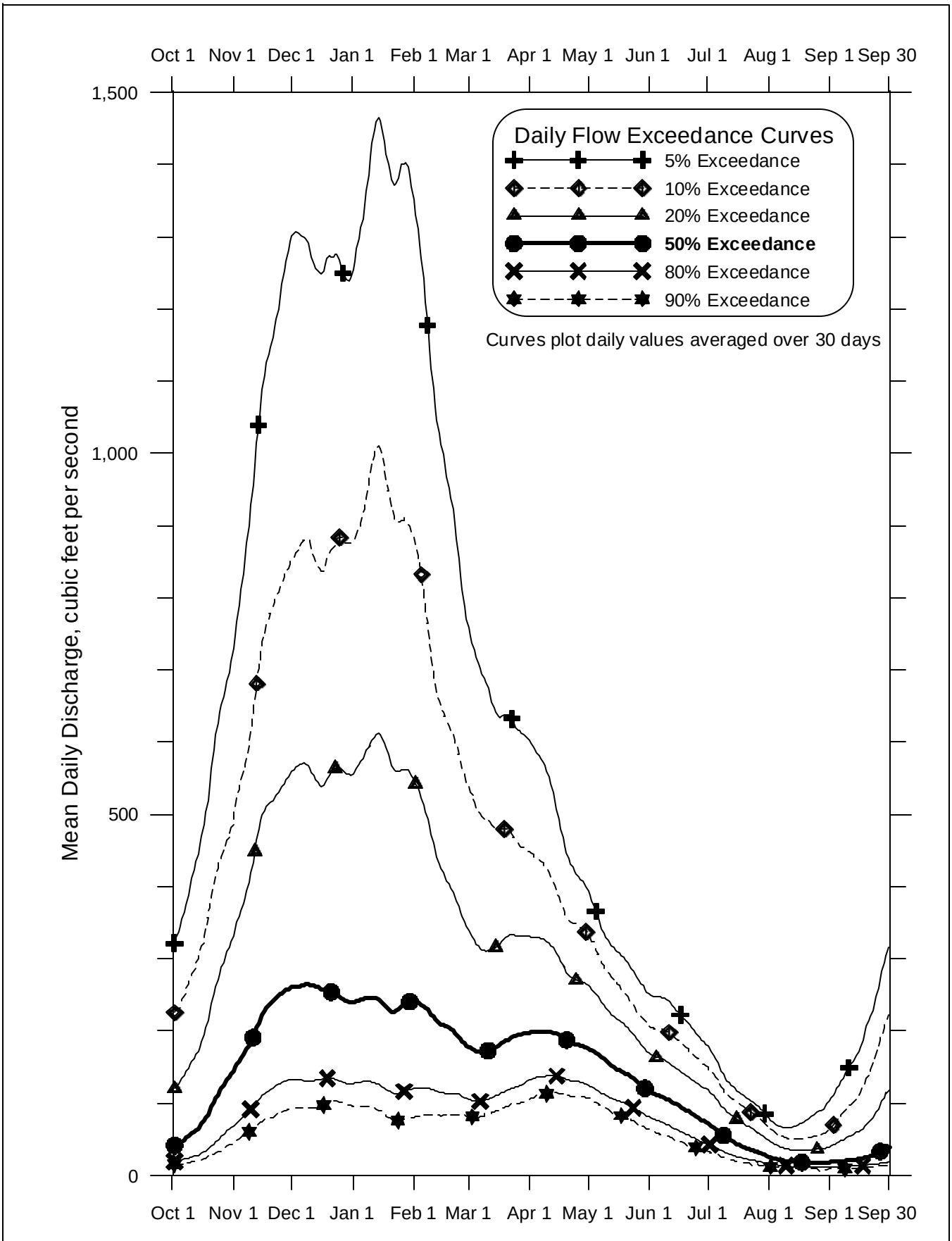

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FIGURE 13

Jim Creek near Mouth, RM 0.0

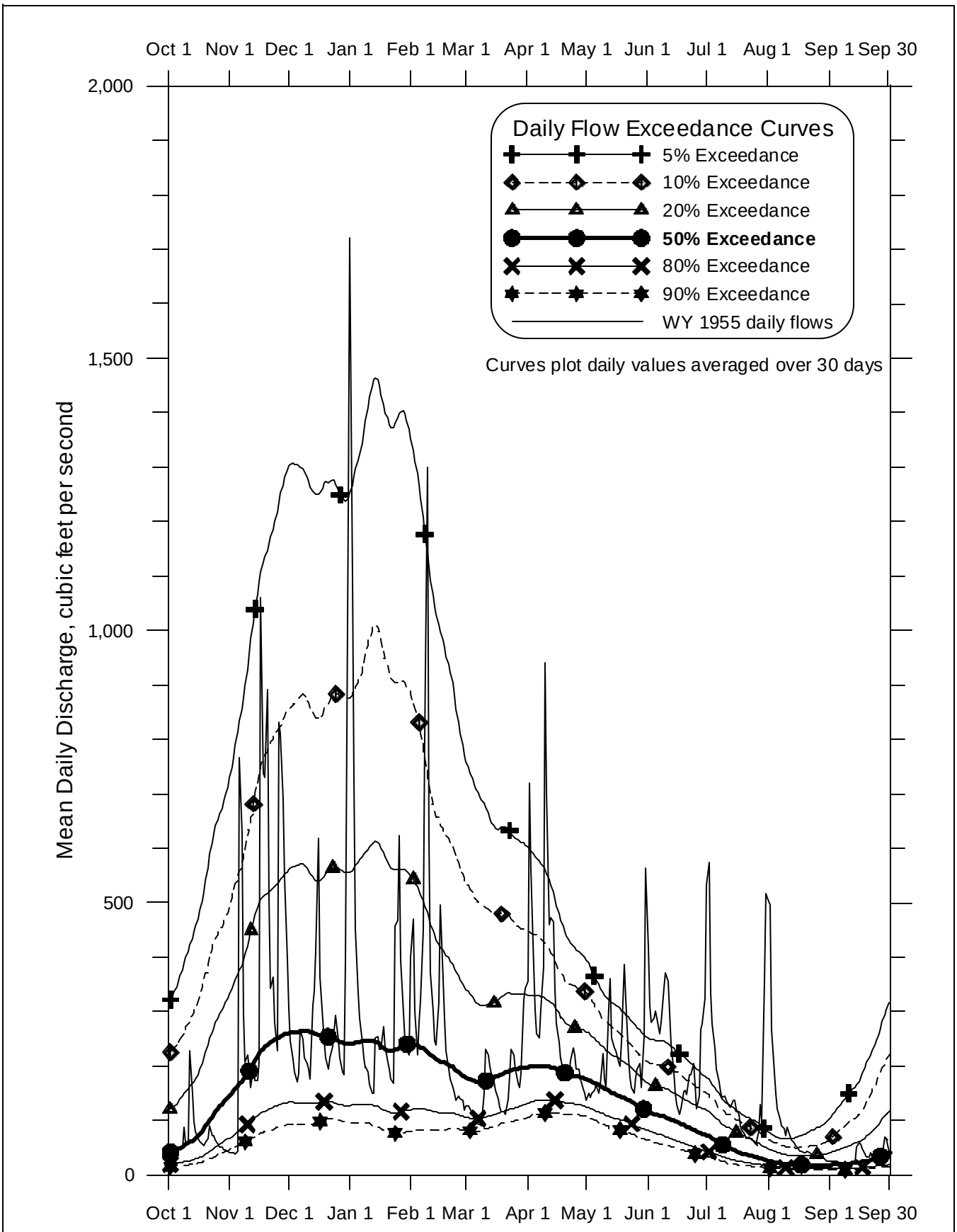

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FIGURE 13A

Jim Creek near Mouth, RM 0.0

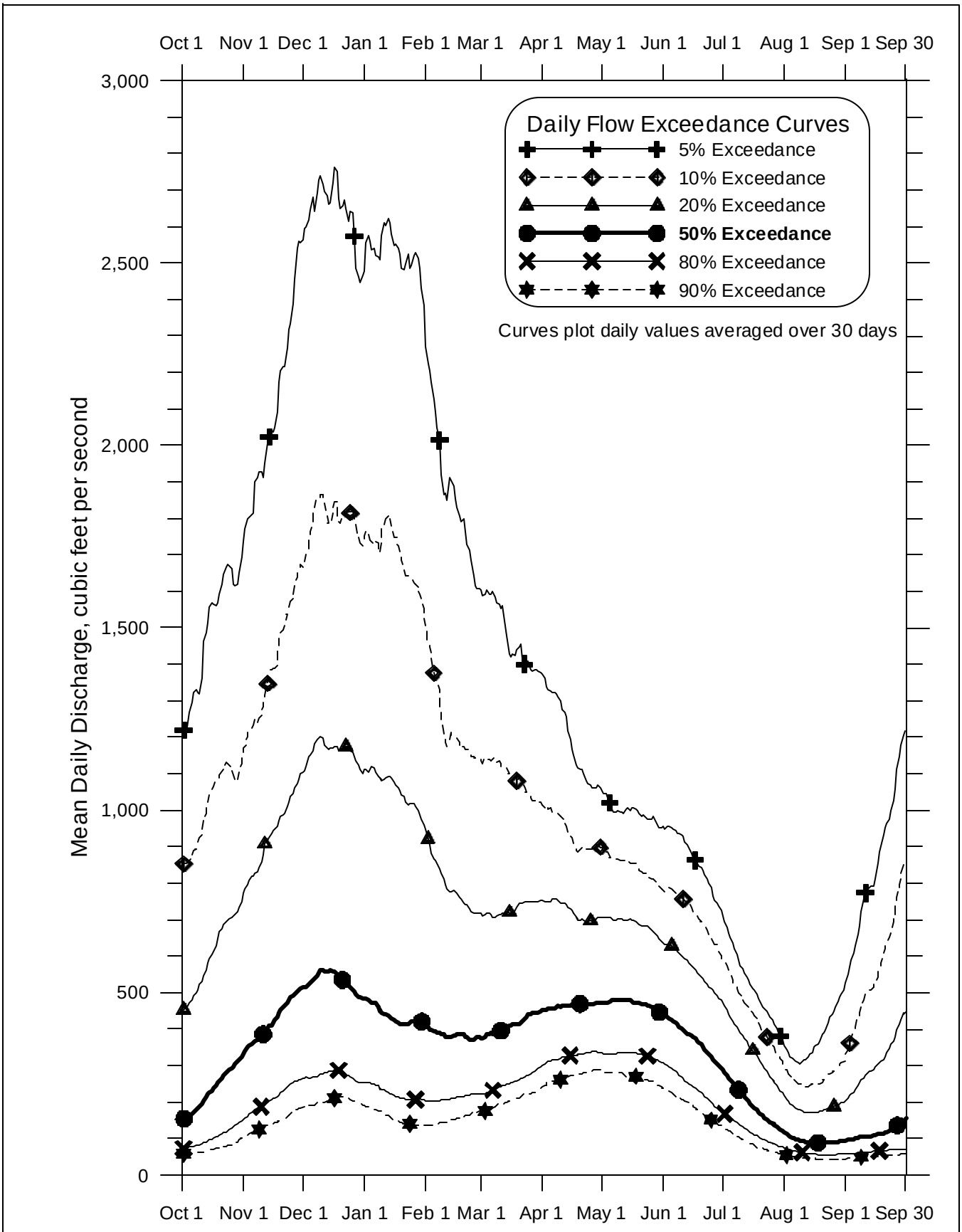

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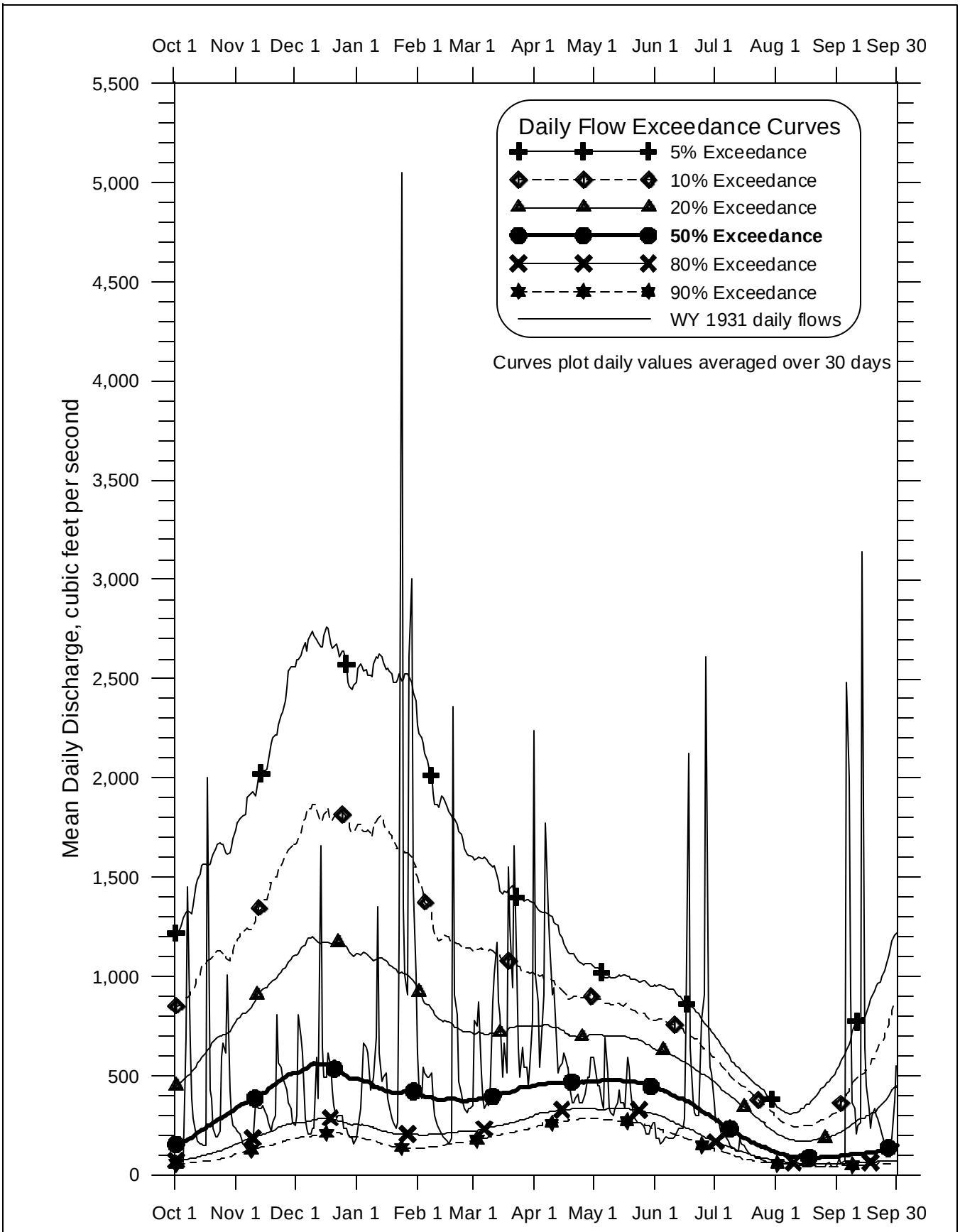
FIGURE 14

Canyon Creek at RM 3.4



Stillaguamish River Basin Instream Flow Study & Hydrology
5, 10, 20, 50, 80, and 90% daily exceedance hydrographs
northwest hydraulic consultants, September, 2003

FIGURE 14A

Canyon Creek at RM 3.4