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<u>Arizona State Land Department - Salt River Rebuttal:</u>
Hydrology
Jonathan Fuller, ASLD Expert

Part 1:
What is the "Right" Flow Data for the Salt River?

During testimony before ANSAC, the opponents of navigability expended considerable effort trying to discredit some of the types of hydrology or flow data used in the ASLD reports. In fact, the ASLD reports and presentation included a wide variety of flow data, in stark contrast to the very limited data types used by the opponents of navigability. The flow estimates used by ASLD brackets the range of numbers presented by other experts, making the entire argument somewhat pointless. Nevertheless, the criticisms raised by the opponents of navigability must be addressed in order to assist ANSAC in making its determination. The flow estimate are important because they are used with rating curves to estimate flow depths, as well as determining how frequent boatable flows occur.

The first step in determining what the "right" hydrology is to decide what types of hydrologic data should be considered. The following types of flow data have been presented to ANSAC by the various experts in this case:

1. Mean Annual Flow Rate (a.k.a., average annual flow rate)
2. Median Annual Flow Rate
3. Median Daily Flow Rate (for the entire year)
4. Median Daily Flow Rate (for each day of the year)
5. Annual Flow Duration Statistics (10%, 50%, 75%, 90%) (for entire year)
6. Boating Season Flow Duration Statistics
7. Mean Monthly Flow Rate
8. Minimum and Maximum Monthly Average Flow Rates
9. Flood discharge estimates based on statistical analysis of USGS gage data
10. Actual flow measurements on specific days at USGS gages
11. Canal diversion data (long-term averages, maximum capacities)
12. Estimates based on summaries in published USGS Reports
13. Estimates based on all USGS flow data listed on USGS websites
14. Estimates based on USGS flow data listed on USGS websites, but limited to a period purported to be representative of long-term average flow rates (i.e., ordinary and natural conditions)
15. Estimates based on US Bureau of Reclamation Reports
16. Estimates based on tree-ring studies
17. Estimates based on ground water modeling studies
18. Estimates based on reconstructed, pre-development published studies
19. Estimates based on assumed well pumping, irrigation usage, return flows, and mine production rates
20. Estimates of base flow
21. Defined range of ordinary, natural flow
22. Normal seasonal fluctuation of flow

To add to the complexity of all these types of data, discharge estimates have been presented in acre-feet, acre-feet/year, miner's inches, inches of rainfall and/or runoff, cubic feet per second, and second-feet. In the ANSAC hearings, streamflow is most commonly described in cubic feet per second (cfs). Therefore, cfs will be used throughout this discussion.

Almost all of these data types are legitimate ways of describing flow conditions on the Salt River. The non-navigability experts have been highly critical of the use of median *annual* flow estimates, preferring to use median *daily* flow data. However, mean annual flow has been frequently used to describe and compare rivers in prior communications from various parties as well as in ANSAC hearings, probably because it is a readily available number for most rivers. Opponents also fail to properly acknowledge that the single value of median daily flow data they now seem to prefer fails to capture the ordinary seasonal fluctuations of flow in the river (See Figure 1 for example of the variance between ordinary seasonal flow fluctuations and the median daily discharge). Note that while the opponents of navigability agree that the median daily discharge is their preferred number, they each computed slightly different estimates of that number and used different data sets to perform their calculations. In contrast, ASLD chose to rely on peer-reviewed published data wherever possible for the flow estimates presented to ANSAC, rather than introduce the uncertainties and potential biases that may accompany new analyses and use of partial data sets. Experts from GRIC and SRP have been particularly critical of the use of the median annual flow rate presented by ASLD for Segment 6. The value used by ASLD is exactly the value presented in the peer-reviewed, unbiased publication by the United States Geological Survey (USGS), and that value has been a part of the ASLD reports since the first reports were submitted to ANSAC in 1993.

SRP's and GRIC's experts frequently refer to the flow estimates as "Mr. Fuller's numbers" as if Mr. Fuller had computed them himself. Again, **the numbers presented in the ASLD reports are those published by the United States Geological Survey (USGS) or in other peer-reviewed journals**. They were not computed by Mr. Fuller, unlike many of the flow estimates touted by the SRP, GRIC or FMI experts.

So what are the "right" numbers to estimate the ordinary and natural flow conditions on the Salt River? The starting point for the answer to that question is the things that all the hydrology experts agree on, which include the following:

1. The stream gauge records of the USGS are the best source of systematic, long-term flow data for the Salt River.
2. The Salt River is perennial. There is no scientific evidence that the Salt River has ever dried up in its ordinary and natural condition.[1] Therefore, whatever the "right" number is, it should indicate that the river was always flowing.
3. The Salt River experiences regular seasonal fluctuations in flow that ordinarily cause higher flow rates in late winter and spring (February-May), and seasonal lows in summer (June-July).

[1] Note that SRP's expert Bob Mussetter opined during cross examination that even though the Salt River was perennial, it probably dried up under ordinary and natural conditions. Although the scientific definition of the term perennial does allow for occasional dry conditions, it is not the common use of the term. Dr. Mussetter's basis for his opinion was not any systematic or professional flow measurement that demonstrated zero flow in the river, but rather on later-life recollection of Carl Hayden's childhood from a time period after the Salt River had been depleted of flow, as reported by the City of Tempe's history expert, Jack August. Dr. August did not introduce any documented evidence that supported his opinion. In contrast, the Kent Decree, Arizona's first major water rights adjudication, declared that Segment 6 of the Salt River never fell below 300 cfs. The scientific evidence regarding perennial flow is discussed in more detail below.

4. Flow rates on the Salt River above Granite Reef Dam increase in the downstream direction due to the contributions from tributaries, springs, and subsurface inflows as the size of the watershed increases.
5. Some stream flow is lost to the subsurface in Segment 6, but much of it returns at Tempe Butte where bedrock forces groundwater to the surface again. The amount of the loss and return was computed in a published USGS study.
6. Human alterations of the watershed, dam construction, groundwater withdrawals, and irrigation diversions have reduced the amount of flow in the river, particularly in Segment 6 where man-made diversions began completely drying up the river in the years prior to statehood. In its ordinary and natural condition, the Salt River had higher flow rates than it does today.[2]

Therefore, the right numbers should indicate that the river was perennial and subject to seasonal fluctuations. That is why the ASLD report included different types of flow estimates, such as the following:

- Annual Flow. Both the median and mean annual values were presented to facilitate comparison with other rivers and to allow use of a single number to depict river conditions.[3]
- Flow Range. No natural river has a constant or static flow rate. The ordinary and natural flow occurs within an expected range. Therefore, the ASLD reports included flow duration data that depict the median within the ordinary range of flow.
- Seasonal Flow. The ASLD reports include depictions of monthly (a.k.a., seasonal) flow rates. These data included not just average monthly flow rates, but also the average monthly highs and lows, to help constrain the range of flows possible.
- Pre-Development, Natural Flow. The ASLD reports specifically note that pre-development flow rates would be higher than indicated by long-term modern records, and relied on tree-ring studies, historical descriptions and archaeological records to describe natural flow rates prior to modern depletions. Given that the ASLD depth estimates indicated that boatable conditions existed with the modern flow rate estimates, there was no need to quantify a specific estimate of the loss due to human-caused depletions in Segments 1 to 5, since that would only result in higher, more boatable flow depths and river conditions than currently exist today. For Segment 6, the ASLD Reports had already provided a pre-development flow estimate obtained from USGS published studies.

The differences in flow estimates for Segments 1-4 are not that significant, when apples-to-apples comparisons are made. The differences in flow estimates for Segments 5 and 6 are a bit larger, but even those differences fall within the range of the ordinary seasonal flow fluctuations, and thus make little practical difference for a navigability determination.

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[2] In Segment 5, the seasonality of high and low flow has changed due to water storage and releases from the dams, but the flow magnitudes have generally decreased, particularly during the late fall to early spring period.

[3] Use of only the median daily discharge to represent the entire year, as proposed by the opponents of navigability, can be misleading because it does not adequately capture the significance of seasonal high flow periods. The median daily discharge is a better depiction of flow on a daily basis if the entire year and its ordinary seasonal variance is included.

In an effort to reconcile the testimony of the experts, the following recommended discharges incorporate all of the valid comments, criticisms, and advocacy by all the experts. The recommended discharges are listed in **Table 2** and are illustrated in Figure 1 to Figure 6, and are based on the following assumptions:

- All Segments: Definition of the range of ordinary and natural flow rate (non-flood, non-drought), as dictated by the Winkleman Decision:
    - Low end (non-drought): Defined by the 10% flow duration (median daily) estimate.
    - High end (non-flood): Defined by the 2-year peak discharge. The 2-year flood is generally thought to approximate the bankfull discharge. A common definition of "flood" is flow exceeding the banks of a stream, or inundation of normally dry land, i.e., the area above the stream banks. The USGS (1998) estimate of the 2-year discharge is shown in the figure for each segment. The boundary limits for a title navigability claim are normally established at the ***ordinary*** high water mark. Guidance documents for determining ordinary high water mark in the arid west generally indicate that it has a frequency exceeding the 2-year event. Therefore, using the 2-year flood for the high end of the ordinary flow range is conservative. That is, most guidance documents for determining the ordinary high water mark for streams in the arid west suggest that it associated with floods larger than the 2-year event. Note that the 2-year peak is listed on Figure 1 to Figure 6, rather than depicted graphically to improve the readability of the figures.
- Segments 1 to 5:
    - Mean Annual Flow, Median Annual Flow, and Median Daily Flow (entire year) are all listed in **Table 2** and shown on Figure 1 to Figure 5 as a straight line for each segment based on the entire USGS period of record through 2015.[4] USGS daily flow data are now readily available in digital format from official USGS websites.
    - The 10% and 90% flow duration rates are all listed and shown on Figure 1 to Figure 5 as a straight line for each segment based on entire USGS period of record through 2015.[3]
    - Median Daily Flow (by day) is shown graphically to depict the ordinary and natural seasonal fluctuation in runoff.[5,6]

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[4] Dr. Mussetter was critical of using the USGS' flow data summaries published in 1998 because there are now nearly 20 additional years of record that could be considered. The inclusion of post-1996 data biases the results by adding too many below-average flow years, but the difference is not significant relative to navigability criteria and ASLD is willing to concede to Dr. Mussetter's preference if it will help achieve consensus. Note that inclusion of the full record incorporates many drought years since 1996, and thus leads to slightly lower flow rate estimates (and hence slightly lower depth estimates).

[5] Previously, ASLD used the published mean monthly discharge published by the USGS to illustrate the seasonal fluctuation. The non-navigability experts were critical of using average data (even though low and high average data were also presented), and advocated for using median daily discharges computed for each calendar day. Use of the median daily discharges adequately depicts this seasonal fluctuation and is the preferred dataset (and not coincidentally, lower) of the non-navigability proponents. ASLD is willing to concede to the other side's preference in this matter since it makes no difference to the overall conclusion regarding the navigability of the river, and since daily discharge data are now available in digital format from the USGS web database.

[6] Similar graphs of the 10% and 90% median daily discharge fluctuation by season could be generated but were omitted to minimize the clutter on the charts. The 10% and 90% data show the expected trends about the median, and parallel the median data shown in the charts for each segment.

- The median daily flow rates (annual and daily), and the 10% and 90% flow duration for Segments 2 to 5 are adjusted upward using Mr. Burtell's reconstructed flow rate analysis.[7]
- USGS gage data used for each Segment:[8]
    - Segment 1: Sum of White River (#9490500) and Black River (#9494000)
    - Segment 2: Salt River near Chrysotile (#9497500)
    - Segment 3: Salt River near Roosevelt (#9498500)
    - Segment 4: Sum of Salt River near Roosevelt (#9498500) and Tonto Creek above Gun Creek (#9499000)[9]
    - Segment 5: Add Salt River near Roosevelt (#9498500) and Tonto Creek above Gun Creek (#9499000)[8]

- Segment 6:
    - Mean Annual Flow and Median Annual Flow from Thomsen and Porcello (1991), as published in their peer-reviewed, unbiased USGS report.
    - Median Daily Flow (annual and by day) from USGS gage data (sum of data from Salt-Roosevelt, Tonto-Gun Ck., and Verde-Tangle Ck.), adjusted upward by Mr. Burtell's flow reconstructions for both the Verde and Salt Rivers.[10]
    - Note that SRP expert Bob Mussetter opined that adding the Verde and Salt River gage directly cannot be done because the timing of the seasonal high flow periods differs between the two rivers. However, this opinion is incorrect for the following reasons:
        - There is no seasonality in the annual mean and median daily estimates, and the flow duration estimates, because the values are annualized and explicitly integrate any seasonal variation.
        - The median daily data also incorporate seasonal fluctuations for each calendar day, so any temporal differences in seasonal flow rates are included directly by calendar day.

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[7] Adjustments per Table 7 in Burtell Salt River Declaration (2015): 31 cfs for Chrysotile gage, 68 cfs for Roosevelt gage on the Salt River; and Table 5 in Burtell Verde River Declaration (2014): 183 cfs below Bartlett Dam on the Verde River (Segment 6 only).

[8] Use of a single gage for each segment fails to capture the increase in flow that occurs over the length of Segments 1 to 5. Specifically, use of the White + Black is located upstream of the beginning of Segment 1 and underestimates the flow rates. Use of the Chrysotile gage data for Segment 2 similarly underestimates flow rates in Segment 2 because it is located at the upstream end of the Segment and misses the flow contributions from several perennial tributaries (e.g., Cibeque Creek, Canyon Creek) as well as numerous springs and seeps that discharge into the Creek. The (near) Roosevelt gage is located near the mid-point of Segment, and thus overestimates flow in the upper portion of the Segment 3 and underestimates flow below the gage.

[9] It is noted that use of the Salt River near Roosevelt and Tonto Creek above Gun Creek gages for Segments 4 and 5 misses contributions from approximately 1,300 square miles (~21%) of the total watershed area of 6300 square miles (at the downstream end of Segment 5), including a number springs that discharge directly into the Salt River downstream of the gages, and thus underestimates the actual flow rate, particularly at the low end of the flow duration curve which occurs during summer when depletions would be largest.

[10] Flow depletion estimates by Mr. Gookin for Segment 6 due to groundwater infiltration are relatively insignificant (as computed by Thomsen & Porcello, 1991) and ignore natural return flows in the Segment. The minor depletions at low flows due to channel infiltration are assumed to be offset by differences in flows not accounted for by the use of gage data from sites upstream of the Segment that do not account for the full contributing watershed area, as previously described.

- Dr. Mussetter himself added the Salt and Verde 2-year discharge estimates directly when preparing his analysis of Segment 6.

Table 1. Flow Estimates Previously Reported to ANSAC (not ordinary & natural flows unless specifically noted as such).						
	Flow Duration (Flow Rates Given in CFS)					
USGS Gage (Stream Segment)	**10%**	**25%**	**50%**	**75%**	**90%**	**Notes**
White + Black River (Segment 1)						
Mussetter	-	-	171	-	-	Computations based on USGS data, 1958-2015
Fuller	74	140	199	995	1797	Data published by USGS, 1998
Chrysotile (Segment 2)						
Burtell O&N	-	-	298	623	-	Computed depletions, added to USGS data
Burtell USGS	-	-	267	592	-	Computations based on USGS data, 1924-1939
Mussetter	-	-	246	-	-	Computations based on USGS data, 1925-2015
Fuller	130	180	266	650	1610	Data published by USGS, 1998
Near Roosevelt (Segment 3)						
Burtell O&N	-	-	443	918	-	Computed depletions, added to USGS data
Burtell USGS	-	-	375	850	-	Computations based on USGS data, 1913-1939
Mussetter - Annual	150	200	320	750	2000	Computations based on USGS data, 1914-2015
Mussetter – Rafting Season	280	500	1100	2300	4000	Computations based on USGS data, 1914-2015
Fuller	159	210	341	840	2120	Data published by USGS, 1998
At Roosevelt (Segment 4)						
Burtell O&N	-	-	456	977	-	Computed depletions, added to USGS data
Burtell USGS/USRS	-	-	388	909	-	Computations based on USGS data, 1899-1908
Fuller	164	220	365	900	2381	Data published by USGS, 1998 (nr. Roosevelt+Tonto)
Segment 5						
Mussetter	-	-	348	-	-	Computations based on USGS data, 1913-2015
Fuller	>159	>210	>365	>840	>2120	Data published by USGS, 1998
Fuller – Median Annual O&N			992			Interpretation of USGS data (USGS, 1998; 1991)
Segment 6						
Gookin – Upstream End	296	-	791	-	1956	Computations, various source data
Gookin – Downstream End	86	-	581	-	-	Computations, various source data
Mussetter	-	-	554	-	-	Computations based on USGS data, 1913-2015
Fuller	287	400	605	1280	3323	Data published by USGS, 1998
Fuller – Median Annual O&N			1230			Data published by USGS 1991

Notes:

1. O&N = ordinary and natural condition.
2. Annual = flow data for the entire year, Rafting Season = flow data for February to May (testimony by Mussetter regarding the time period is unclear).
3. Fuller also provided seasonal data for each month of the year and flow duration curves, not listed here. See ASLD Reports.
4. Burtell did not testify on Segment 4 but used Salt River at Roosevelt gage data in his flow reconstruction. That gage is located in Segment 4.

Table 2. Recommended Ordinary & Natural Flow Data for Use by ANSAC in Making Navigability Determinations								
Segment	**Flow Descriptor (cfs)**							
	Mean Annual	**Median Annual**	**10% Duration**	**Median Daily (50%)**	**75% Duration**	**90% Duration**	**2-Year Flood**	**Seasonal Fluctuation**
1	556	410	67	167	468	1,492	>7,500	Use median daily discharge by day – See Chart
2	632	482	158	277	592	1,501	10,200	Use median daily discharge by day – See Chart
3	859	641	221	385	800	1,990	14,400	Use median daily discharge by day – See Chart
4	1,005	727	224	405	858	2,229	>14,400	Use median daily discharge by day – See Chart
5	>1,005	>727	>224	>405	>858	>2,229	>14,400	Use median daily discharge by day – See Chart
6	1,690	1,230	522	819	1,361	3,251	~20,000	Use median daily discharge by day – See Chart

Notes:

1. All flow data obtained from the USGS website for each gaging station.
2. Flow depletion estimates were not added to the mean annual and median annual values listed.
3. Segment 5 values are likely to be underestimated, i.e., they should be higher, because the USGS gages miss significant contributing drainage area (~1,230 mi2) between the Roosevelt and Tonto gages and upstream end of Segment 5. The missed area includes several perennial streams and numerous springs. Therefore, the listed values are shown with the greater than symbol. Estimates may be as much as 20% higher than shown.
4. The Segment 6 mean annual and median annual estimates were obtained from Thomson & Porcello report, published by the USGS.
5. 2-year discharge estimates were obtained from the USGS Water Resources Investigation Report 98-4225 (Pope et. al, 1998). The Segment 1 value is for the Black River only, addition of the White River flood potential would increase the estimate. The Segment 6 value is obtained from the ASLD report for the Lower Salt River.
6. Methodology for determining listed estimates described elsewhere in this document.

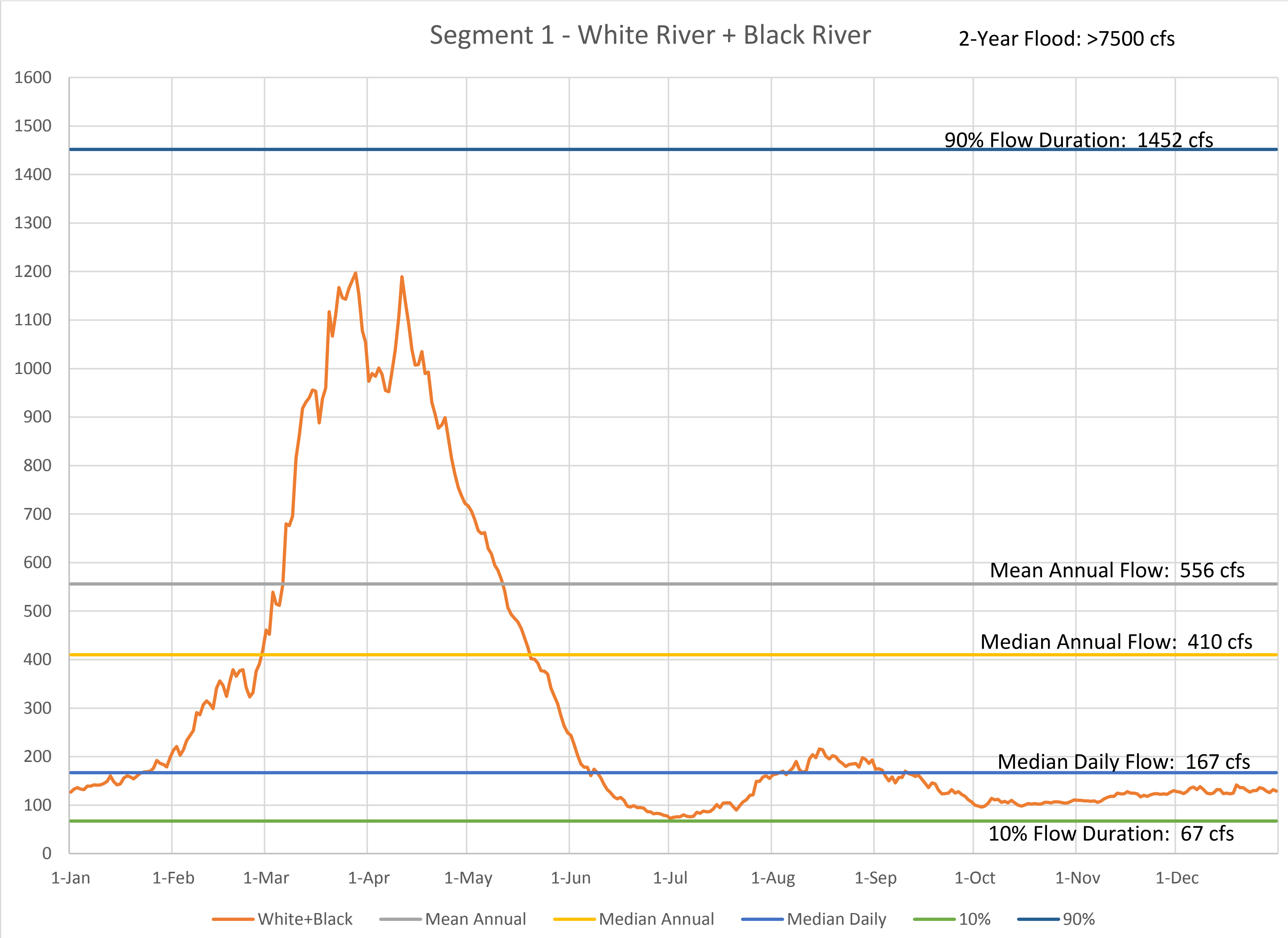

Figure 1. Flow rates for Segment 1.

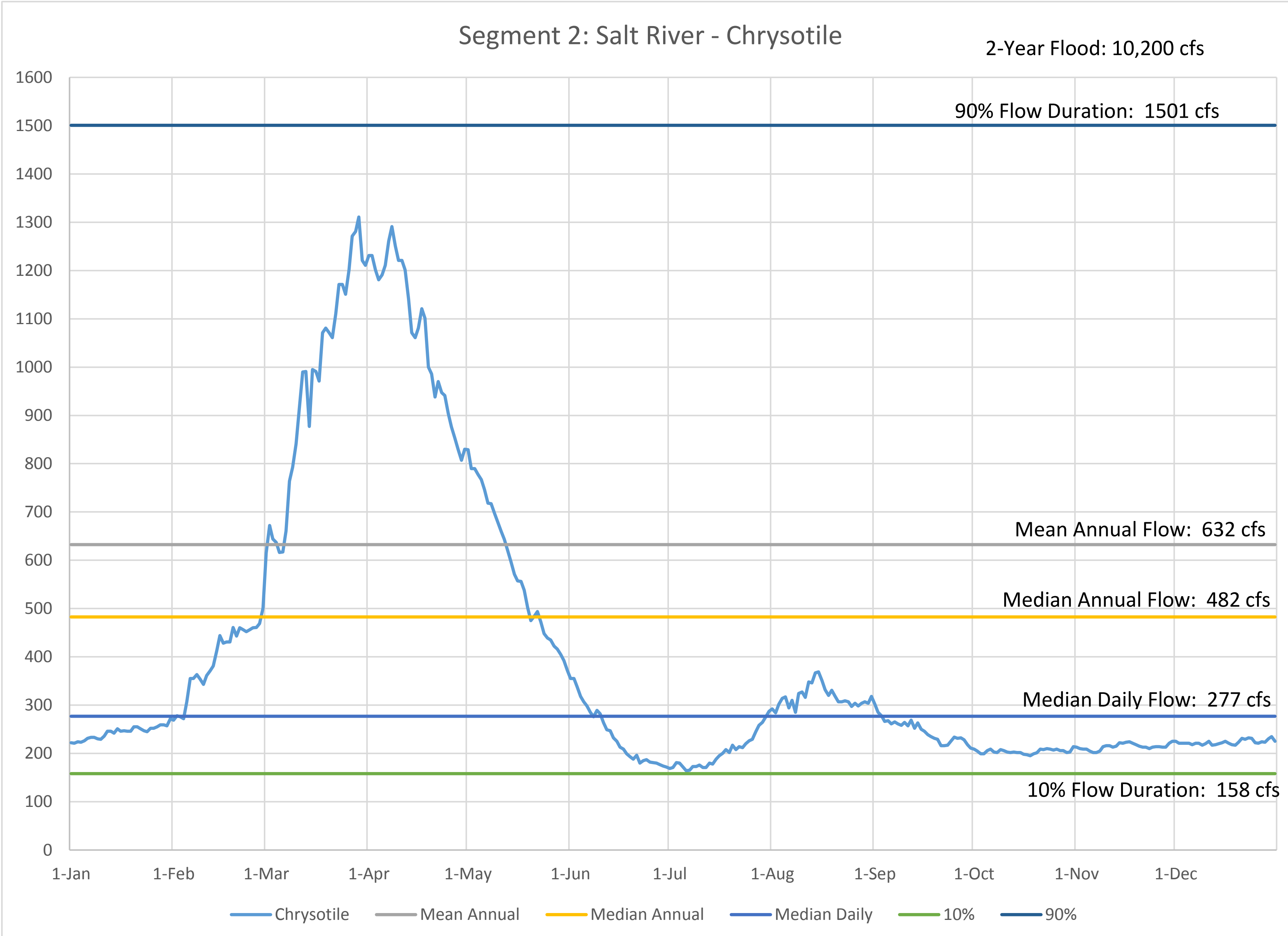

Figure 2. Flow rates for Segment 2.

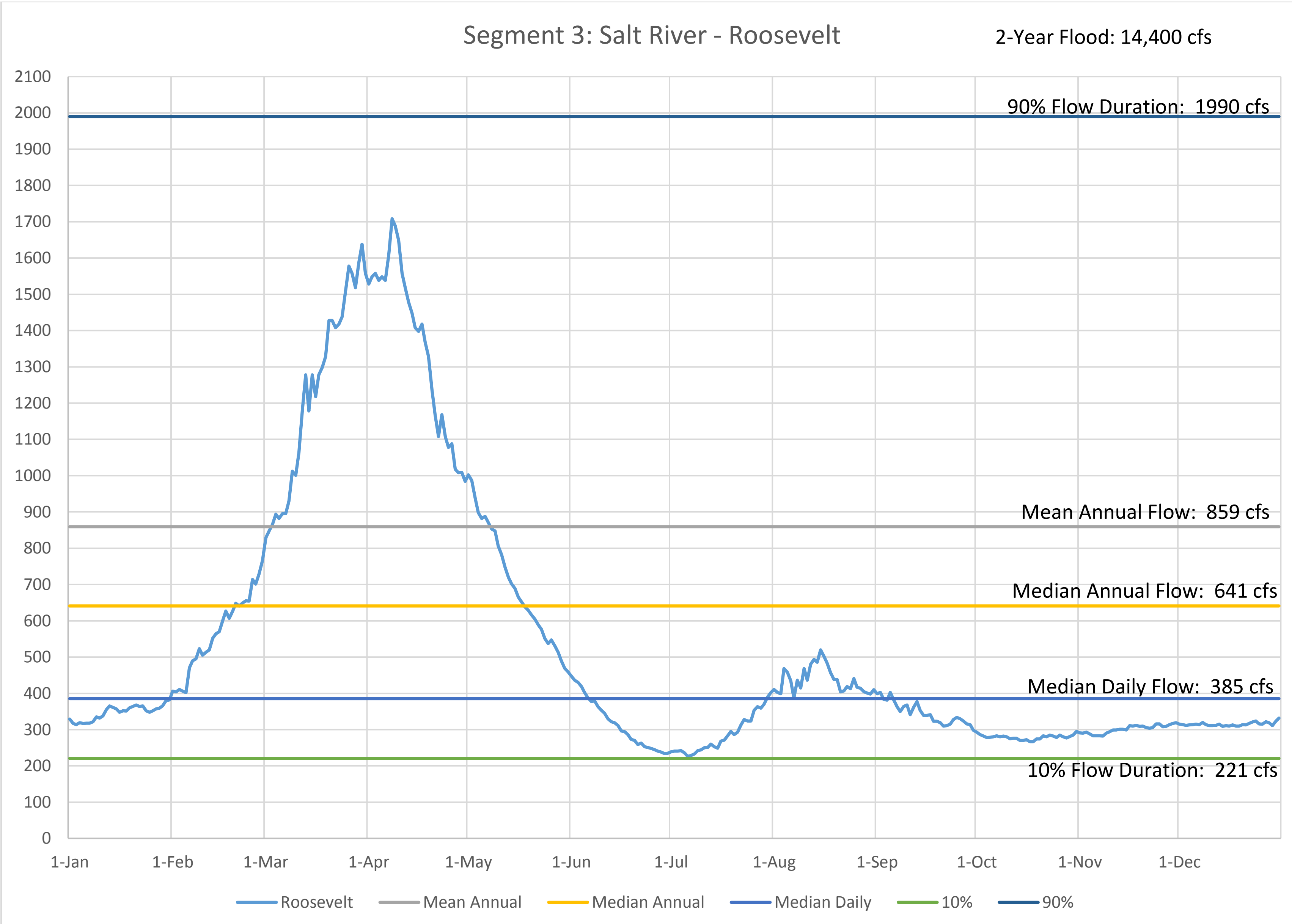

Figure 3. Flow rates for Segment 3.

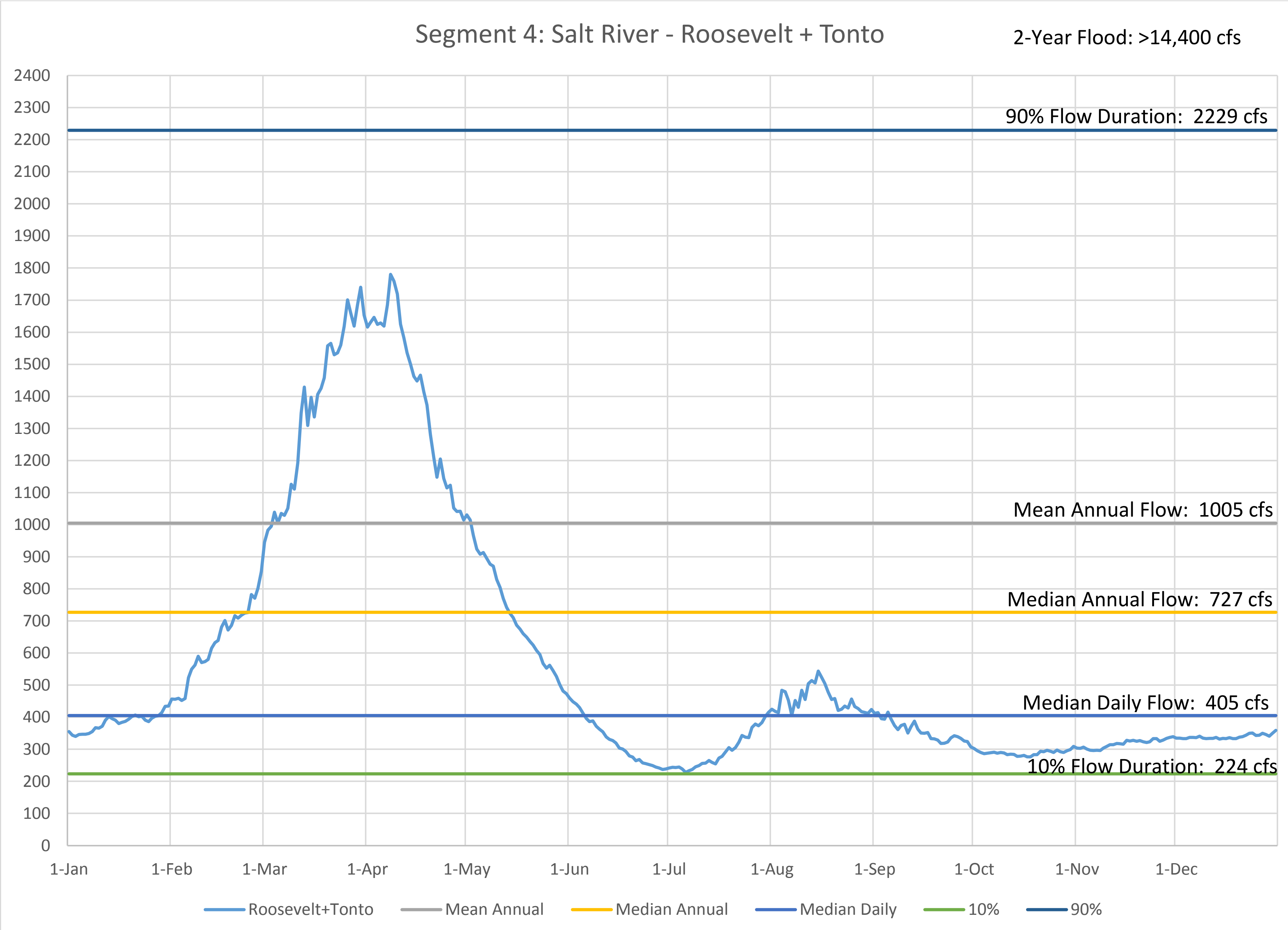

Figure 4. Flow rates for Segment 4.

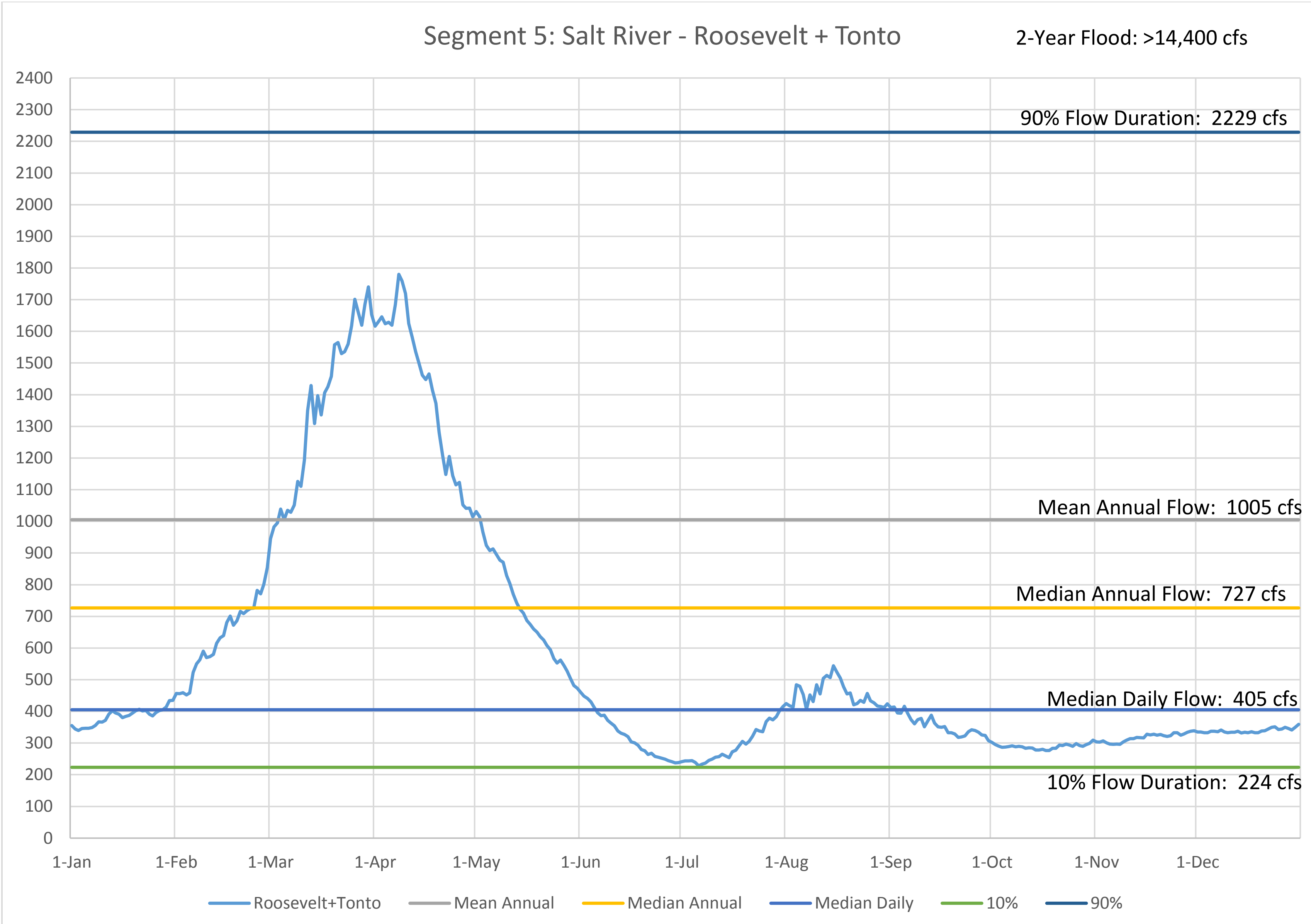

Figure 5. Flow rates for Segment 5.

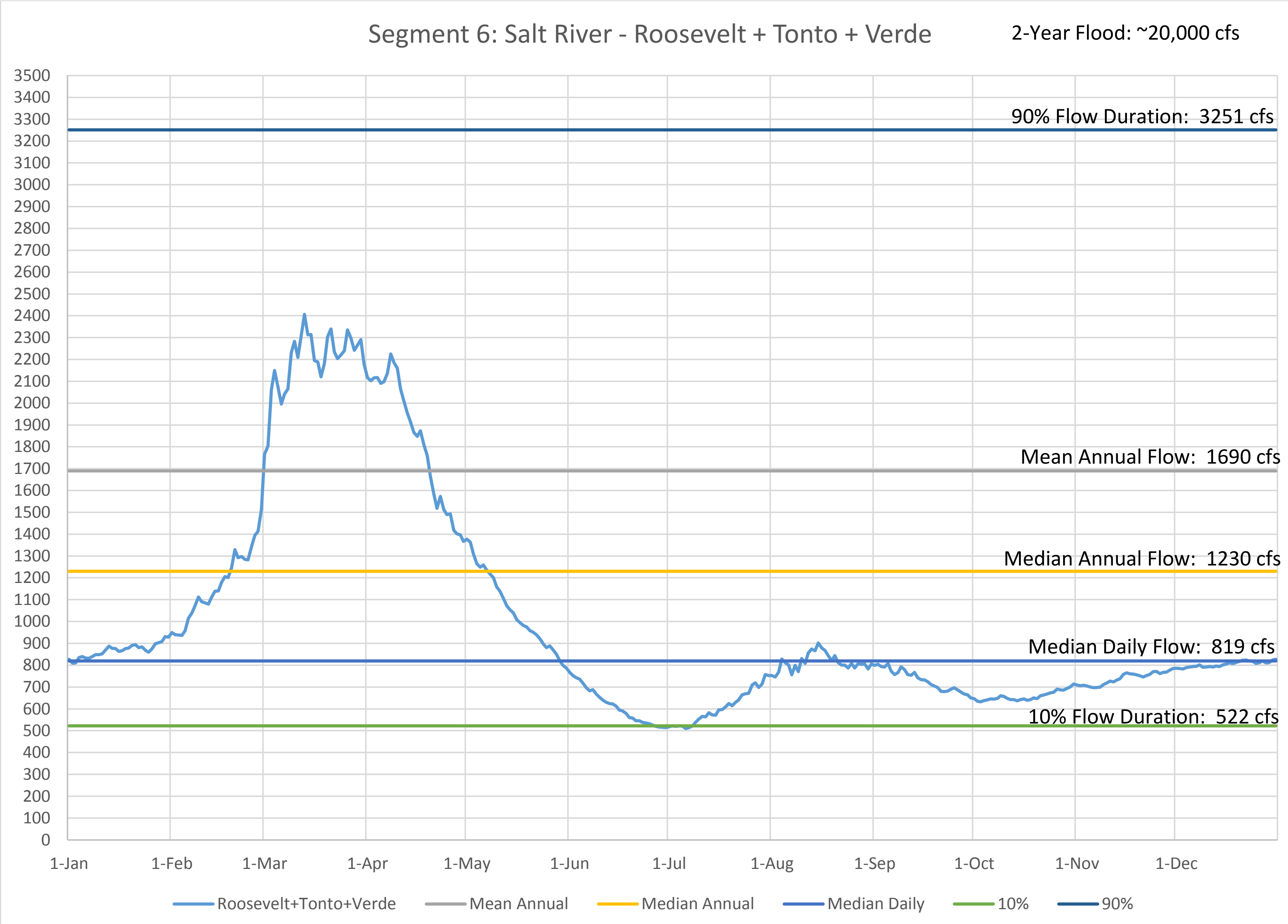

Figure 6. Flow rates for Segment 6.

Part 2:
Specific Rebuttal Responses

What's Wrong with the Flow Data Presented in the ASLD Reports?

Nothing. The data used by ASLD and presented to ANSAC was taken directly from peer-reviewed, unbiased, agency publications, and include the types of data that are routinely used for describing flow conditions on western rivers like the Salt. The non-navigability experts have raised several objections about the use of the US Geological Survey's predevelopment median flow rate of 1230 cfs to characterize the flow rates in Segment 6, indirectly implying that Mr. Fuller somehow doctored or made up the number, or that median flow is an "average of medians." The only adjustment to the number published by the US Geological Survey was to convert the units of acre-feet/year to cubic feet/second, which is a simple unit conversion that Dr. Mussetter demonstrated that Mr. Fuller had done correctly. The median flow rate Mr. Fuller presented is a number computed by the US Geological Survey. While it is true that median annual discharge not equal to the median daily discharge, both are fully legitimate ways to describe flow rates on the Salt River, if you wish to use a single number to describe the full range of ordinary, expected flows that occurred in its ordinary and natural condition. And because the Salt River varies seasonally, Mr. Fuller also provided data that describes that seasonal monthly fluctuation and flow duration. The bottom line is that regardless of whose median flow rate and what type of median flow rate you choose to use, the resulting flow depths are shown to be adequate for small boats typical of the type available for use at the time of Statehood, particularly when you consider the higher depths that occur during the annual high flow season in late winter and spring.

Some Fact-Checking Discussions

Claim: All of the runoff on the Salt River is derived from the Upper Watershed. The lower watersheds contribute little additional runoff during ordinary and natural conditions. Dr. Mussetter and Mr. Gookin have advanced the theory that the watersheds downstream of the USGS gages (Salt River near Roosevelt, Tonto Creek above Gun Creek, and Verde River below Tangle Creek) do not contribute significant amounts of runoff. Therefore, they hypothesize, flow estimates based solely on data from the upstream gages do not underestimate flow rates in Segments 4, 5 and 6.

Truth: All of the available data indicate that regardless of what flow descriptor is considered (mean, median, monthly, etc.), the flow rates increase in the downstream direction as the watershed size increases. To suggest otherwise is unfounded. While it is true that the upper watersheds contribute a higher percentage of runoff on a per-square-mile basis, it does not mean that the lower elevations contribute *no* runoff. Some facts to be considered regarding use of the upstream gages relative to Segments 4, 5 and 6 include the following:

- Watershed Area. As shown in **Table 3**, the upstream gages (Roosevelt, Tonto, Tangle Ck) miss about 1,000-3,000 square miles of drainage area, which is 14-22 percent of the total drainage area in the downstream river segments.[11]

[11] Based on the Renard Equation (1982), an estimate of the mean annual runoff for this drainage area if it were completely ephemeral would be an additional 10 to 30 cfs. This estimate would be higher if the perennial and intermittent streams, seeps and springs were accounted for.

- Tributary Inflows. The following perennial or near perennial major tributaries join the Salt River or its tributaries downstream of the USGS gages: Deadman Creek, Lime Creek, Sheep Creek, Sycamore Creek, Pinto Creek, Fish Creek, LaBarge Canyon Creek/Boulder Creek, and Gun Creek.
- Springs and Seeps. Because of the shallow bedrock and canyon geology in Segment 4, there are many springs and seeps that discharge directly into the river.

Table 3. Comparison of Gaged Drainage Area to Segment Drainage Area

Location	Drainage Area (mi2)	Drainage Area Not Captured by Upstream Gages (mi2) (%)	Upstream Gages
Segment 4			
Upstream End	5,824	843 (14%)	Salt River nr. Roosevelt (4306 mi2) +
Downstream End	6,211	1,320 (21%)	Tonto Creek ab. Gun Ck. (675 mi2)
Segment 5			
Upstream End	6,211	1,320 (21%)	Salt River nr. Roosevelt (4306 mi2) +
Downstream End	6,270	1,379 (22%)	Tonto Creek ab. Gun Ck. (675 mi2)
Segment 6			Salt River nr. Roosevelt (4306 mi2)+
Upstream End	12,430	1,681 (14%)	Tonto Creek ab. Gun Ck. (675 mi2) +
Downstream End	13,700	2,951 (22%)	Verde River bl. Tangle Ck (5858 mi2)

Claim: The Salt River flow is erratic & unpredictable. In its past, the navigability opponents have repeatedly argued that the Salt River "was erratic and unpredictable, characterized by periodic floods…and interspersed with periods of drought."[12]

Truth: Erratic means "deviating from what is ordinary or standard."[13] Unpredictable means "not able to be foretold on the basis of observation, experience or scientific reason."[13] First, it is unclear on what hydrologic evidence opponents based their opinion since every hydrology expert has submitted evidence that indicates that the Salt River flows between a relatively narrow range of flows 80 to 90 percent of the time, and that floods and droughts are not within the "ordinary" flow conditions the Arizona courts have directed ANSAC to consider. Second, neither term has any scientific hydrologic meaning when applied to the hydrology of the Salt River. If the Salt River was truly "unpredictable" then there would be no observable or regular seasonal fluctuation of high flow indicated by median monthly discharges, i.e., the monthly average flow rates would be nearly identical. Even if ANSAC had ignored the totality of the river's record of stream gauging, repeated statements by both SRP[14] and ANSAC[15] demonstrate that they implicitly recognized the regular seasonal fluctuation of flows on the Salt River. Third, the only hydrologic data which were available to ANSAC clearly indicate there were regular seasonal fluctuations in flow that corresponded to expected periods of storms and snowmelt,[16] flow rates varied within predictable ranges,[17] and that floods were unusual, short-duration events, much as they are today. These fluctuations are summarized in Figure 1 to Figure 6, which illustrates the data

[12] ANSAC RBOD p. 22.
[13] Webster's Seventh New Collegiate Dictionary.
[14] Tr @ 47:25-48:2 "[Q] Again, this is another February trip which I think we already talked about was – it's normally a high runoff period? [A] Normally, yes."
[15] ANSAC RBOD p. 14 "they all occurred during periods of high water during the late fall or winter…"
[16] ASLD p. 7-17, Table 7-14.
[17] ASLD p. 7-17, Table 7-13; p. 7-18, Table 7-15

presented in the ASLD Report. Fourth, Dr. August's and Dr. Littlefield's use of the terms reflects a historian's perspective derived from their study of irrigators trying to divert the over-appropriated river for farming. The irrigators were no doubt frustrated when the river flowed too much when no diversions were needed or too little when irrigation water was in demand. The use of these terms applied to a navigability study (i.e., when can boats be used?) is incorrect and does not reflect the actual hydrologic data for the river. Finally, even if the Salt River were subject to "erratic and unpredictable" flow, the question ANSAC should consider is whether boatable conditions existed within the range of this "erratic" fluctuation, i.e., could the river be boated at the low and high end of this "erratic" range. None of the opposing experts opined on what they considered the natural, ordinary range of flow in the Salt River. The flow data summarized in Figure 1 to Figure 6 indicate that, in fact, the river's natural flow rates were normally within a well-defined range, and that the only time flows occurred that might not be boatable was during the short durations of the largest floods, or perhaps during unusual droughts.

Rebuttal of Dr. August's Opinion on Salt River Flow Rates

Dr. August is not a hydrologist and did no analysis of the ordinary and natural flow of the Salt River. However, his opinion is that Segment 6 of the Salt River ordinarily dried up completely (0 cfs flow). Specifically, he stated that in 1897 "water scarcely trickled in the Salt River." This opinion is based on an undisclosed document he reports having seen in the archived writings of Carl Hayden in which Hayden recollects walking across the dry riverbed of the Salt River as a child. Dr. August preferentially relies on this later-life recollection of Hayden's childhood from the period after the river had been diverted, over all of the scientific and historical evidence that the Salt River was ordinarily flowing prior to these diversions. The scientific and historical evidence includes the following:

- The USGS reports that the minimum inflow to the Salt River (Segment 6) in any month from 1888 to 1896 was 331 cfs, and the minimum average annual inflow during that period was 2656 cfs. Clearly, if the river had scarcely a trickle in 1897, it was because of overuse, unregulated diversions, and/or drought, not the ordinary and natural condition of the river.
- Thousands of years of Hohokam irrigation in Segment 6. It is hard to imagine that the Hohokam's irrigation-based civilization could have been sustained for so long if the river ordinarily dried up and disappeared. Even a cursory review of maps of Hohokam era irrigation canals should have led him to conclude that the number of canal heads downstream of Tempe Butte indicated that the river was normally flowing throughout Segment 6. There would have been no reason for the Hohokam to expend the effort to build canal heads in a normally or frequently dry stream bed.
- Historical descriptions by early Arizona explorers, pioneers, irrigators, and the military. None of these accounts describe a normally (or even seasonally) dry riverbed on any segment of the Salt River, prior to the period of man-made diversions of the river's natural flow.
- USGS and USRS gage records. As reported in the ASLD Lower Salt Report (c.f., Chapter 7, Table 7-3,) none of the early measurements records zero flow, except where irrigators had completely diverted the river (i.e., not natural conditions). These observations included:
    - Powell: Minimum annual flow of 800-900 cfs (p. 7-7), later revised to 500 cfs.
    - Davis: Minimum instantaneous flow of 300 cfs (p. 7-7) from Aug 1888 to Feb 1891.
    - USRS, Salt River nr. McDowell, Minimum Average Monthly Flow 64 cfs (June, 1904).
    - USRS, Verde River nr. McDowell, Minimum Average Monthly Flow 52 cfs (June, 1892).

- USRS, Salt River at Arizona Dam, Minimum Average Monthly Flow 331 cfs (Oct, 1889).
- The Kent and Kibbee Decrees indicate that the minimum flow rate of the Salt River was 300 cfs at Granite Reef Dam.

Summary: Dr. August's opinion that the Salt River was sometimes dry in its ordinary condition is contrary to the scientific record.

Rebuttal of Mr. Gookin's Flow Estimates

It is not possible to fully review Mr. Gookin's flow estimates because his source data and methodologies are not fully disclosed or adequately documented. His estimate of the median daily flow at the Salt/Verde confluence (791 cfs) is within 28 cfs (3%) of the value recommended (819 cfs) in **Table 2** above. His estimates of seasonal lows and lack of consideration of ordinary seasonal fluctuations in flow rates is more problematic. The problems with Mr. Gookin's estimates include the following:

- Channel Infiltration. Mr. Gookin correctly cites the USGS' estimate of losses of 52.5 cfs (or 27.2 cfs) in Segment 6(a), as well as their estimate that 34.5 cfs (or 13.5 cfs) of this loss returns to the channel upstream of Tempe Butte. The net loss is less than 10% of the minimum flow rate assumed in the Kent and Kibbee Decrees, and insignificant to a navigability determination since even Mr. Gookin's own rating curve indicates that a loss or addition of 10 to 50 cfs makes no significant difference in the predicted flow depths.
- Pre-Development Conditions. Much of Mr. Gookin's discussion in his report and PowerPoint presentation revolve around irrigation return flows, overwatering by irrigators, excess diversions, etc., none of which are relevant to the determination of the ordinary and natural, i.e., pre-development, condition of the river.
- Mr. Gookin's definition of "base flow" includes only the flow welling up from the subsurface into the stream channel. While that is a technically correct definition, Mr. Gookin's application of it includes only the flow welling up in a short reach of the river segment. He incorrectly ignores the base flow contributions from other river segments upstream that flow as surface flow into his segment of interest. Consequently, his estimate of "base flow" at the GRIC boundary of 86 cfs would only be correct if the Salt River upstream of the GRIC boundary were ordinarily dry, a condition which all of the scientific evidence indicates did not exist prior to manmade diversion of the river in ordinary conditions.
- Underground Diversion. Although not discussed in his report, in his PowerPoint presentation to ANSAC (Slide #22), Mr. Gookin advances an unpublished, undocumented, and frankly implausible assertion that most of the natural low flow of the Salt River escapes the river corridor through an underground channel that bypasses Tempe Butte to the south and joins the Gila River. While the existence of a former (in geologic time) flow path of the Salt River south of Tempe Butte has long been hypothesized, the possibility that this abandoned corridor of river sediments that has since been long filled in and buried under the desert floor would have higher permeability and greater discharges than the open channel of the pre-statehood Salt River is not credible. The consequence of relying on this unproven theory is that Mr. Gookin's estimate of the minimum discharge in Segment 6 is low, as is his estimate of flow depth.
- Season Flow Variation. Mr. Gookin's report does not include any estimates of ordinary seasonal fluctuations in runoff, and relies solely on his (incorrect) estimate of base flow, the median daily flow, and mean annual flow. Several of the slides in Mr. Gookin's PowerPoint show the regular

seasonal fluctuation, but the effect of these seasonal discharges were not discussed in the context of navigability.

- Segment 6 Only. Mr. Gookin's opinions and flow estimates are limited to Segment 6. He did not perform any specific analyses of any of the other river segments.

Summary: Mr. Gookin's estimates of flow depletion are too high and his base flow estimate for Segment 6b is too low.

Rebuttal of Dr. Mussetter's Flow Estimates

The following are noted with respect to Dr. Mussetter's opinions on the hydrology of the Salt River:

- Modern Flow Only. Dr. Mussetter relied entirely on modern gage records and made no attempt to consider the impacts of flow diversions on the ordinary and natural runoff in the river, and therefore underestimates the flow rates he uses in the subsequent parts of his analysis. This is particularly apparent when comparing his estimates of the median daily discharges for Segment 5 (348 cfs) and Segment 6 (554 cfs). His estimates indicate a flow increase of only 206 cfs due to the Verde River. However, the pre-development median daily flow estimates for the Verde River alone range from 437 cfs (Burtell) to 550 cfs (Hjalmarson). His estimates are substantially lower than Mr. Gookin's estimate of 791 cfs for the median daily discharge.
- Boating Season Flows. Dr. Mussetter, unlike Mr. Gookin and Mr. Burtell, explicitly acknowledges the existence of a "rafting season" on Segments 2 and 3 of the Salt River, and computes a separate flow duration curve for that time of year (Slide 28). The ordinary flow rates during his "rafting season" are two to eight times the flow rates during the rest of the year, a significant increase. However, he inexplicably does not consider these boating season flow rate increases when computing rating curves used to determine if the river is susceptible to boating.
- Data Set. Dr. Mussetter claimed that the period from 1996 to 2015 (the additional data set he included when criticizing the data published by the USGS and used by Mr. Fuller) was representative of the long-term median. In fact, 13 of the 19 years between 1996 and 2015 were below the long-term median, and overall that period averaged 10% below the median. Therefore, it is no surprise that Dr. Mussetter's estimates of the median decreased by inclusion of this portion of the modern record.

Rebuttal of Mr. Burtell's Flow Estimates

- Note that Mr. Burtell provides no flow estimates for Segments 4-6.
- Mr. Burtell claims his reconstruction is based on USGS data from the late 1880's to 1940. Actually:
    - The Chrysotile record is: Sept 1924-December 1939 (15 yrs).
    - The Salt River nr Roosevelt record is: Oct 1913-Dec 1939 (26 yrs).
    - The Salt River at Roosevelt record is: Jan 1889 – Oct 1908, with many data gaps (19 yrs).[18]
    - There is no overlap between the two Salt River Roosevelt gages.

[18] Also note that no mean daily flow data were used for the "at Roosevelt" gage. Mean monthly data and data from the "at McDowell" gage were used.

- The period from 1880-1889 has no data at any gage. Data for Near Roosevelt & Chrysotile doesn't begin until 1913 and 1924, respectively.
- The period from 1908-1913 has no data at any gage. Therefore, Mr. Burtell is missing data for ~15% of his reconstruction period.
- While the period from 1880 – 1940 may balance out close to the median as he states, the periods of data for which there is actual data (1889-1908, 1913-1940) are decidedly below median, according to the tree-ring data on which he relies, as shown in Figure 7 below. Therefore, his calculations based on these data will be low.

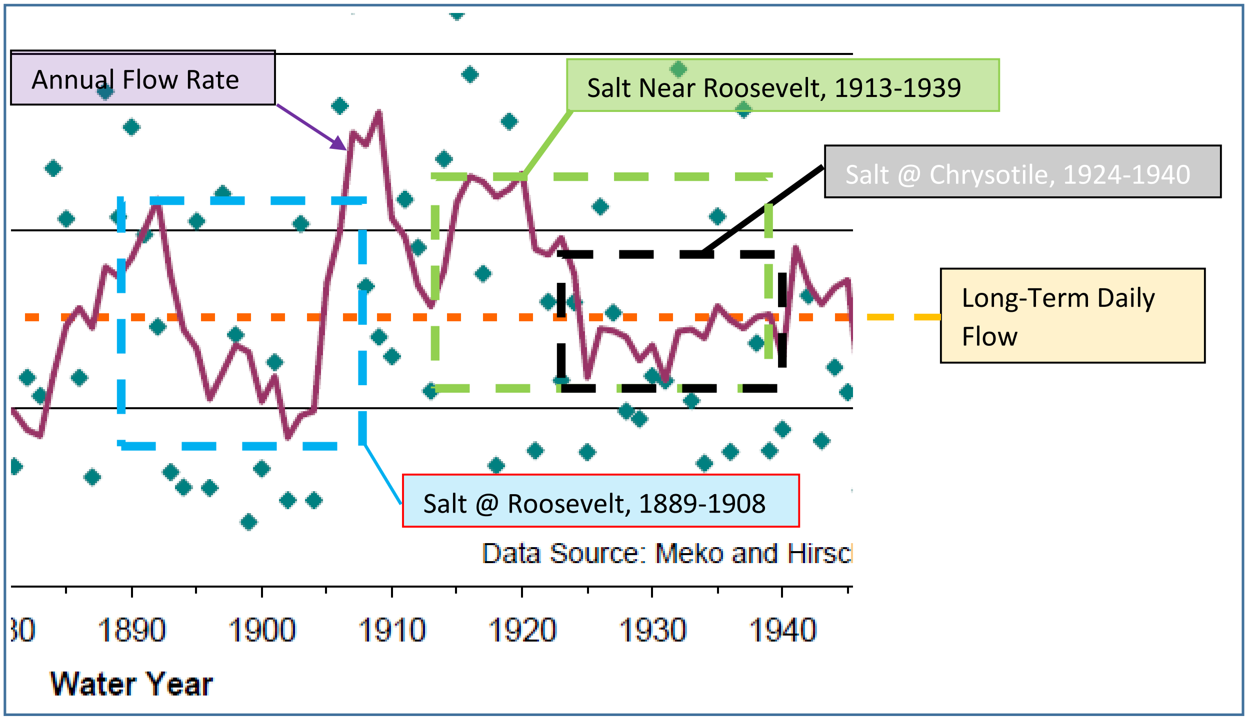

Figure 7. Period of records for Burtell's flow reconstructions, clipped from Burtell Figure 8 and annotated to show the actual periods of record for the gage data used compared to the stated reconstruction period of 1880's to 1940. The data used by Burtell are generally from below median years, and not thus representative of the long-term flow of the Salt River.

- Mr. Burtell makes no recognition of seasonal fluctuations in flow, and no consideration of the differences between the winter/spring high flow season and the low flow periods of the year.
- Mr. Burtell repeatedly stated that he believed his flow reconstruction was conservative and resulted in reconstructed flow rate estimates that were probably higher than reality. Some aspects of his analysis indicate that his reconstruction may in fact be less conservative than he claimed.
    - As shown in Figure 7 above, the period of record he chose was dominated by below-average flow years.
    - Mr. Burtell attempted to verify his estimates by making a comparison to a long-term flow estimate made by the US Bureau of Reclamation (1952). According to his testimony, his verification was based on the relative values of his estimate of the 25% flow (918 cfs) to the USBR's (1952) estimate of the average flow (710 cfs).

Unfortunately, he misread the units on the USBR table. The USBR estimate was actually 710 thousand AF/yr (not cfs), or 980 cfs, indicating that his estimate was not conservative after all, according to his own testing criteria.

- Mr. Burtell further attempted to verify his estimate by comparing it to long-term flow records based on tree-rings studies by Meko & Hirshboeck. Regarding Figure 6 in Mr. Burtell's report, he stated during his cross-examination that that the long-term median flow estimated from tree data was "about 220,000" (3022:11) acre-feet/year (304 cfs) or 330,000 AF/yr (456 cfs). Note that the actual tree ring data in the figure are average annual discharges, not annual median flows. The median of the average annual values is considerably higher than 220,000 or 330,000 AF/yr, since the definition of a median is that half the values are higher and half are lower. This can be readily seen when plotting 330,000 AF/yr on his Figure 6, as is done on Figure 8 below (green dashed line). Either he is using a data set not shown in his Figure 6 to derive the median flow estimates from the tree-ring data set, or he has used some other technique to derive some other kind of median. The actual median of the data points shown is close to the orange dashed line he plotted on his original figure. Regardless, the point is that Meko & Hirshboeck were using average annual flow as their measure, so one needs to compare averages to averages, not average to medians to determine if a period was above or below the long-term trend. And the time periods chosen by Mr. Burtell to do his reconstruction occurred during below average periods of runoff. In other words, his results will be low compared to the long-term record for the Salt River.

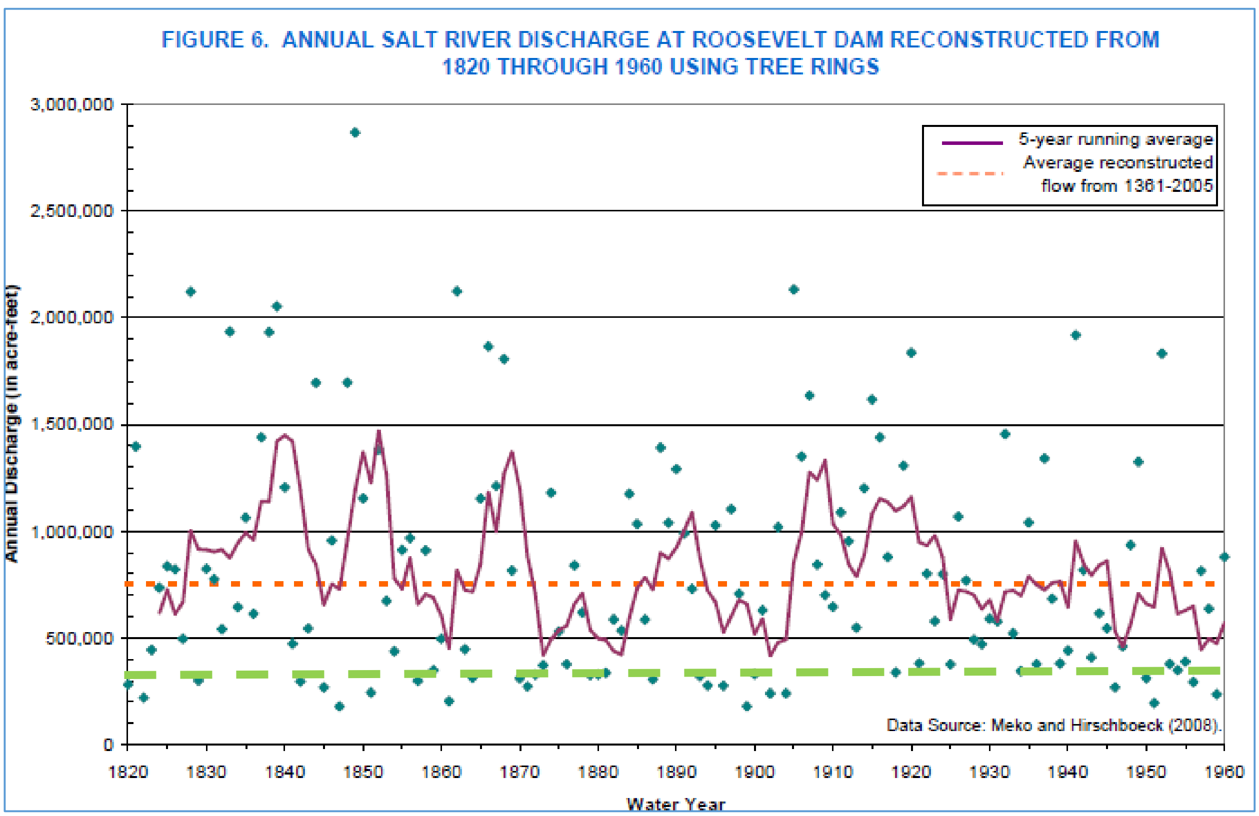

Figure 8. Reproduction of Mr. Burtell's Figure 6 with his estimate of the long-term median flow of 330,000 AF/yr shown by the green dashed line. The long-term average annual estimate by Meko & Hirshboeck is shown by the orange dashed line.