STATE OF MINNESOTA

Memorandum

MNDNR

DEPARTMENT: Natural Resources – Ecological and Water Resources

DATE: February 19, 2016

This document was created in response to public comment on the Draft EIS. There is no Draft EIS version of this Report.

TO: Jill Townley, EIS Project Manager

FROM: Jim Solstad, PE

SUBJECT: **Final EIS Appendix N:** Fargo-Moorhead EIS Hydrologic Methodology Review

Introduction

The Draft EIS public comment period elicited many comments questioning the credibility of the hydrology used for Project design and for this EIS, in particular the wet-dry cycle assumption recommended by the Expert Opinion Elicitation Panel (EOEP). Based on these comments received the MNDNR determined that it would revisit the question of what is the most appropriate hydrologic method to determine the flood discharge frequency data for the Red River at Fargo-Moorhead. I reviewed the associated documents in Appendix A of the FFREIS, and offer the following comments for inclusion in the record.

While the greatest attention is generally focused on the 100-year flood, the other flood discharge values, such as the 10-year and 500-year floods are also important. Key elements of project design and regulatory considerations and topics within this EIS that utilize flood discharge data for the evaluation of potential impacts are listed below; the 100-year flood is not necessarily the key value for all of these elements.

- Project design – engineering and operation
- Socio-economic analyses
- Fish passage and biological connectivity
- Regulatory – floodplain management
- Stream stability - geomorphology
- Project alternatives evaluation

In this memo I will identify four different sets of flood frequency data developed using different methods and assumptions. The challenge is to identify the methodology that is most appropriate for the entire range of discharge values as it would not be appropriate to select the 10-year flood discharge value from method A, and the 100-year value from method B.

“Wet – Dry” cycle

The available Red River @ Fargo gage data show a noticeable difference between peak flows pre- and post-1940s (Figure 1). The highest recorded flow from 1902 through 1942 was 7,740 cubic feet per second (cfs); since 1943, that flow has been exceeded on average once every 2.4 years. The EOEP did not determine a cause of this trend in peak flows. Rather, they focused on how to account for that change in the statistical analysis of the stream flow record. The EOEP used the term “wet – dry cycle” without providing any climate data. Dan Reinartz, a former hydrologic engineer with the USACE who was involved in the EOEP discussions, indicated that the term “wet cycle” was not in reference to wet climatic conditions. Rather the term refers to a period of higher flows.

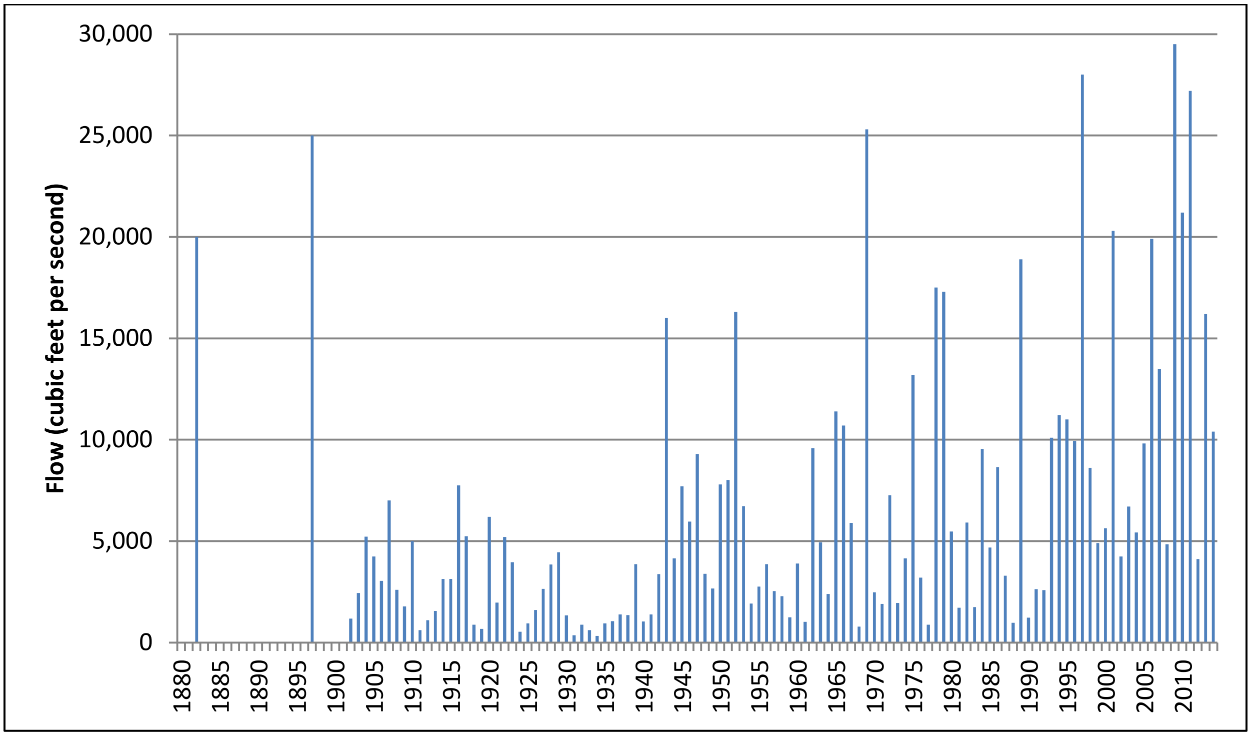


Figure 1: Figure 1: Annual peak flow at the USGS gage station on the Red River @ Fargo (1902 – 2014 with estimated flows for 1882 and 1897)

A strong argument can be made that widespread landscape changes including drainage have also contributed to the higher flows since the early 1940s. Many of the large public drainage systems in the Red River basin were constructed during the early part of the 20th century. Since the subsequent decades were relatively dry, there would have been little incentive for individual land owners to take additional action on their land to fully utilize the new drainage system. This lack of foresight became readily apparent during the wetter climate conditions of the 1940s.

Mr. Lorne Wilde, agricultural editor for the Fargo Forum, wrote a series of seven articles in 1945 titled “Agricultural Drainage in the Red River Valley.” These articles provide a vivid picture via anecdotal observations regarding the state of drainage pre-1940s within the basin. Quoting from the first two paragraphs:

> In the late summer season of 1941, following the driest 12 year period in the 83 year history of weather recording in the Red River Valley, mothernature suddenly changed her mood and sent drenching rains flooding down over the fields in the northern and southern ends of the valley. … It seemed to mark a turning point in the weather conditions for the whole valley.

Mr. Wilde documented production losses during that period, and the inevitable finger pointing that began as many began looking for someone to blame. He describes many instances of the lack of maintenance of drainage ditches, including obstructions caused by field roads. One memorable comment was that "Many young men who grew to manhood here in the last 25 years were convinced that the old-timers must have been a little daffy when they permitted all those drainage ditches to be dug…"

Mr. Wilde suggested that two things were needed: 1) adequate drainage systems to "carry the water rapidly to the river outlets"; and 2) "some way to get water from the farm land to these main ditches." He then noted that not all land owners saw the need for the second point.

> The soil conservation men are finding it difficult to understand the attitude of some farmers and land owners who make no effort to construct laterals on their own fields to get the water out of pockets or low lying sections.
>
> Many of course, do recognize the need to ditch their own lands, and all through the valley, instances are to be found where this work is being done….[emphasis added to suggest that that work was largely done post-1940].

I found the Mr. Wilde's observations regarding road ditches very interesting - contrasting the condition at that time to today:

> It is almost unbelievable that our road system, township, county and state highways, have been constructed without attention being paid to their effect on drainage.
>
> The ditches one sees alongside a road were not put there to carry water, except in rare instances. They were excavated to provide the earth fill for the highway.
>
> As in illustration, a road ditch might carry water for eight or 10 miles to a slight elevation in the natural slope of the land. At this point, no thought was given to drainage and the ditches were not sufficient deep to insure the continued flow of the water into the river or other outlet. The result was a natural dam which inundated many sections of land and created a regular lake.

Modern agriculture would not be possible in many areas of the Red River basin without drainage. So the point of this discussion is not to place value judgements on drainage. Rather to point out that the state of the drainage systems, from field to river, is drastically different comparing the pre- and post- 1940 period. That change has influenced Red River flow, both annual flow volume and peak flows.

This line of argument cannot be used to argue that the major recent floods, including 1997 and 2009, were caused by drainage and land use changes. Excess snowfall and spring rains along with conducive weather conditions resulting in rapid snowmelt are the overwhelming cause of large floods along the Red River. The flood of record at Grand Forks occurred in 1826, an event that obviously cannot be attributed to drainage. But drainage can partially explain the more prevalent occurrence of moderate levels of flooding, up to say, the 10-year event. Pre-drainage, excess water collected in depressions throughout the basin had two possible avenues: evaporation or seepage into the soil column. That water did not become part of downstream flooding. With drainage, ponded water now has a third path, rapid movement along a swale and/or channel potentially contributing to a flood event along the Red River.

Considering both climate trends and land use changes suggests that splitting the gage record may provide a more accurate representation of conditions, especially at the low end of the discharge – frequency curve, i.e., the more frequent flood events.

USACE's Hydrologic Analysis

Nationwide, the USACE has decades of experience conducting basin-wide hydrologic studies. In watersheds that are regulated (having reservoirs that are manually operated for water supply, flood control, etc.), a strict analytical analysis of the gage data is generally not done. Instead, the USACE develops a "graphical" curve that typically uses gage data for the low end of the curve, with some other method to help define the high end, i.e., large floods. This is done because the effect (percent reduction in peak flows) of the reservoirs on large floods will not be same as it will be for more frequent flood events.

Any statistical analysis of the Fargo gage data is further complicated because the flood control reservoirs have been in operation for only part of the period of record. Modeling has shown that these reservoirs, in particular Orwell and Lake Traverse can lower flood levels at Fargo-Moorhead. Irrespective of the wet-dry cycle, that portion of the gage record prior to construction of the reservoirs represents a different watershed condition than the record since their construction in the early 1940s. The USACE employed a multi-step method to develop a homogeneous data step for their hydrologic analysis. Pre-1942 data were adjusted so that that data reflect what the yearly peak flows would have been had the reservoirs been operational during that time frame. Those adjusted values were used for the full period of record analysis.

The effectiveness of the reservoirs at reducing downstream flood flows is diminished during major flood events. The USACE based the high end of the flood frequency curve on hydrologic modeling. The final USACE results are a combination of statistical analysis for the low end of the curve (small floods), with hydrologic model results defining the high end (large floods).

A key element of the USACE's hydrologic models was based on statistical analysis of the available gage data within the Red River basin, including the Fargo gage. These analyses were completed using the EOEP wet-dry cycle assumption; an identical analysis was also performed using the entire period of record. The following table compares the two sets of USACE number with the "FEMA" flood discharge values used in the current effective flood insurance studies.

Comparison of FEMA vs. USACE Flood Data (adapted from Table 3.1, EIS)

	10-yr flood		50-yr flood		100-yr flood		500-yr flood	
	Discharge	Stage	Discharge	Stage	Discharge	Stage	Discharge	Stage
FEMA	10,300	29.5	22,300	36.6	29,300	39.3	50,000	43.5
EOEP "Wet" Cycle	17,000	35.0	29,300	40.4	34,700	42.1	61,700	46.3
USACE Updated Period of Record	13,865	32.5	26,000	39.5	33,000	41.3	66,000	46.5

Discharge: Cubic feet per second at the U.S. Geological Survey gage at Fargo, ND

Stage: Feet at the USGS Fargo gage

Updated Period of Record: 1902 through 2009, plus 1882 and 1897

Comparison of the USACE "wet" cycle and updated POR at selected locations.

The previous table contains discharge and stage data for the Red River at the USGS gage station. Flood elevation data at three additional locations are shown in the following table. These data compare the difference in flood levels due to the two USACE hydrologic methods. The computed water surface elevations based on the EOEP "wet" cycle hydrology were obtained from tabular data provided by the USACE for their F-M Metro Phase 7.0 EA Model runs, dated March 28, 2013. The corresponding elevation data for the updated POR hydrology were based on a linear interpolation of that same tabular data using the POR discharge values.

The approximate maximum levee height elevations are also shown for each location. These elevations were taken from the *Distributed Storage Alternative Final Report*, prepared by Wenck Associates, Inc., July 2014.

Computed flood elevations (feet above mean sea level, NAVD88) at three locations

Flood Return	**Cass Co. Hwy 20**			**VA Hospital**			**52nd Ave S.**		
Period (ft)	EOEP "wet"	POR	Diff (ft)	EOEP "wet"	POR	Diff (ft)	EOEP "wet"	POR	Diff
25-year	894.3	893.1	-1.2	897.1	895.7	-1.4	905.9	904.4	-1.5
50-year	895.4	894.9	-0.5	898.5	897.7	-0.8	907.8	906.9	-0.9
100-year	896.4	896.3	-0.1	899.9	899.4	-0.5	909.3	908.9	-0.4
500-year	897.3	897.4	0.1	902.0	902.3	0.3	913.9	914.6	0.7
Approx. Max Levee Height (ft)		898.3			902.7			915.7	

Upstream flood storage as the results of emergency flood fight efforts

The existing permanent and emergency levees constrict larger flood flows through the metropolitan area. That constriction causes higher upstream flood levels during a given flood event than would occur if no emergency actions were employed (emergency actions for the purposes of this discussion include permanent levees). The higher flood levels, essentially additional flood water storage, will attenuate peak flows through the metropolitan area. The measured peak flow during recent large flood events, including 1997, 2009, and 2011, would have been somewhat higher had no emergency measures been employed.

The amount of additional storage will increase with the severity of the flood event – of course assuming that the emergency and permanent levees remain effective. The USACE model results for existing conditions with and without emergency protection measures was compared:

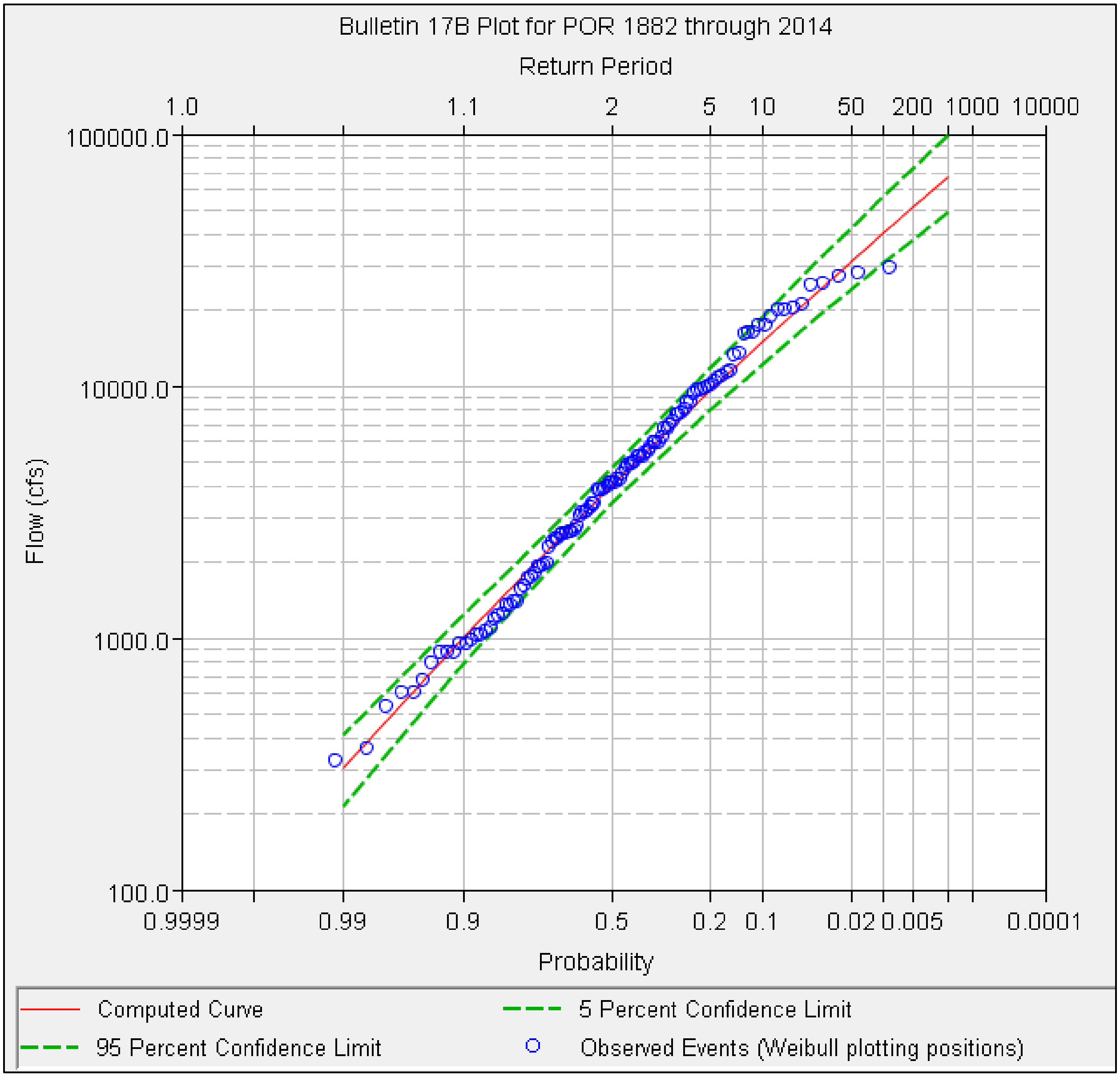
Flood Return Period	Increase in flood levels @ 52nd Ave S bridge Due to emergency and permanent levees (feet)
10-year	0.1
25-year	0.4
50-year	1.1
100-year	2.2
500-year	6.0

The hydrologic model used by the USACE described in the previous section is based on the assumption of no emergency protection measures, i.e., no additional upstream storage. That conservative assumption results in higher discharge values being adopted.

"Traditional" statistical analysis of the Fargo Gage data

The long standing guidance for conducting statistical analyses of gage data is contained in the *Guidelines for Determining Flood Flow Frequency*, Bulletin 17b, by the Interagency Advisory Committee on Water Data for the U.S. Department of the Interior 1981. I used a program developed by the USACE (HEC-SSP 2.0) to generate flood frequency discharge data for the Red River at Fargo gage following the guidelines of Bulletin 17b. The entire period of record was used (1902 through 2014) as well as the estimated flows for 1882 and 1897. No adjustments were made for the reservoirs. The station skew was weighted with a regional skew adopted from the Grand Forks gage station (from Appendix A-2, FFREIS). Results are tabulated below, and shown in Figure 2.

10-year flood	15,000 cfs
50-year flood	31,500
100-year flood	40,800
500-year flood	67,800



System Statistics	
Log Transform: Flow	
Statistic	Value
Mean	3.597
Standard Dev	0.457
Station Skew	-0.115
Regional Skew	-0.260
Weighted Skew	-0.147
Adopted Skew	-0.147

Number of Events	
Event	Number
Historic Events	0
High Outliers	0
Low Outliers	0
Zero Or Missing	0
Systematic Events	115
Historic Period	

Figure 2: "traditional" statistical analysis of all gage data records for the USGS Red River at Fargo gage (1902 – 2014 plus 1882 and 1897)

Discussion

The current FEMA flood discharge values are based on a report completed in 1971. The three highest flood years have occurred since then - 1997, 2009, and 2011. Of the 22 years with a peak flow greater than the FEMA 10-year flood discharge, 15 have occurred since 1971. Updated hydrology was completed for all other locations along the Red River in 2001. Due in large part to a technicality, the Fargo-Moorhead values were not revised as part of that study. It is therefore long overdue that the discharge values at F-M be updated.

What is termed a "traditional" analysis in this memo comes closes to a simple hydrologic analysis in which available gage data are entered into a computer program that in turn calculates the discharge values. In this case the results are not reasonable.

Another option would be to hand draw a curve that best fits the plotted data points. This method would result in a 100-year discharge of about 30,000 cfs – essentially the same as the 2009 flood (Figure 3). The problem with this approach is that the curve would be very flat at the high end. Extrapolating the line to estimate the 500-year would result in an unrealistic low value of no greater than 35,000 cfs. As indicated at the very top of this memo, whatever method is chosen must work for all return period floods, i.e., the 10-year through the 500-year floods.

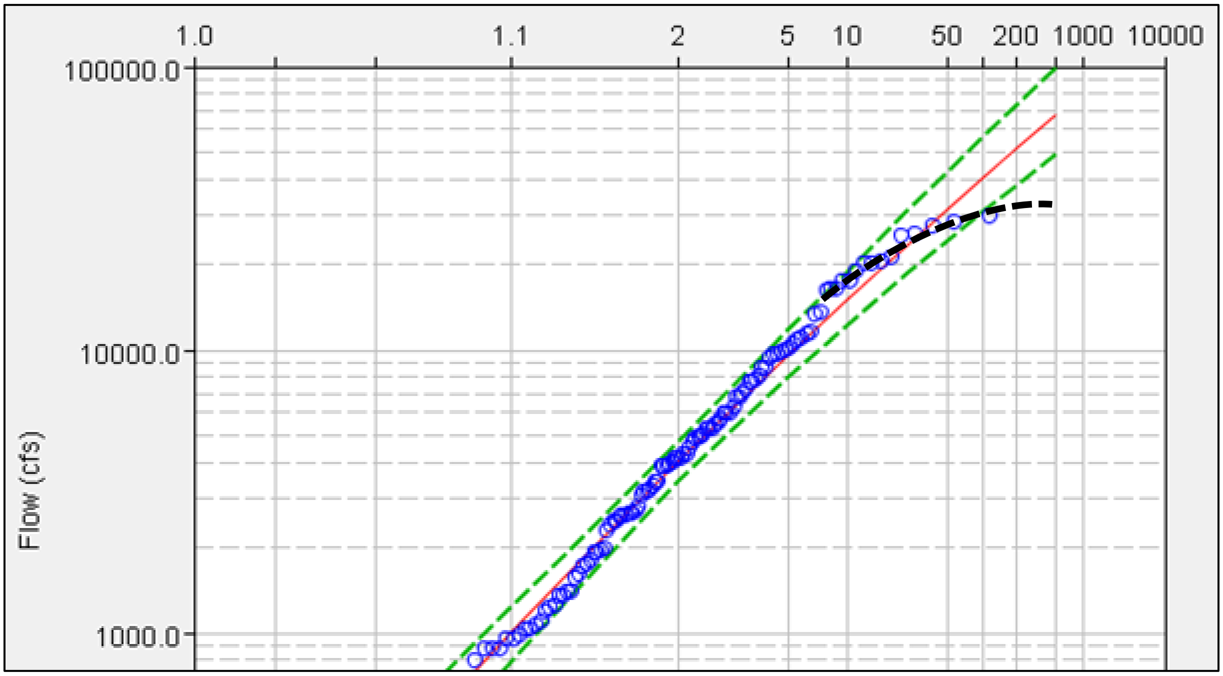


Figure 3: Example graphical curve fitting the upper end of the data points from Figure 2

As I'm not aware of another viable hydrologic method, the question then becomes whether the USACE full period of record or the "wet-dry" cycle assumption is more appropriate. If in fact the 1930s drought was an extreme event, and if land use changes have changed the watershed response in particular for the more frequent events and that change will likely persist into the future, then the EOEP wet-period hydrology better represents current conditions for the more frequent flood events.

As previously mentioned, the USACE analysis (both EOEP “wet” cycle and updated POR) is based on a conservative assumption regarding the existing permanent and emergency flood protection measures. The actual peak flows through F-M during recent floods would have been higher without the emergency measures, and therefore closer to the updated 100-year flood discharge values. The decision to not account for that flood attenuation is conservative, and appropriate.

Whether to use the so-called wet-dry cycle numbers or the full period of record results remains a judgement call. The differences between the two sets of numbers are small enough that it is difficult to imagine that either the Project design or the results of the EIS would have been substantially different had the full period of record numbers been adopted.

(Note: The original work plan called for a side-by-side comparison of the USACE analysis with an updated analysis by including data through 2014. A full appreciation was gained of the complexities of the analyses undertaken by the USACE and their consultants during review of the FFREIS Appendix A documents. In particular the use of the “graphical approach” that is based on both statistical analyses and hydrologic modeling. Adding years to the period of record is a relatively straightforward task using what’s been termed the “traditional” statistical analysis. Redoing the hydrologic modeling would involve a major study that was not feasible as part of this effort.)

Distributed Storage Alternative Implications

A key question remains as to whether the DSA would meet the project purpose if the POR hydrology were adopted instead of the hydrology based on the EOEP wet-dry cycle. Based on the data for four sites included in this report, the amount of freeboard for the 100-year flood would increase by 0.1 to 0.8 feet. Especially considering the minimal change along the downstream reaches, there is essentially no change in regard to FEMA accreditation as articulated in our report title *Distributed Storage Alternative Screening Analysis – Draft EIS Version* February 17, 2015:

> Freeboard – FEMA requires levees to have 3-4 feet of freeboard above 100-year flood elevation and that the levees are certified by an engineer. The levees by themselves do not have the required 3-4 feet of freeboard. The levees combined with flood reductions from the 96 distributed storage sites could provide 3 feet of freeboard. Because the Project is a joint local-federal project the USACE would likely be tasked with levee certification. Preliminary review by the USACE has indicated that the DSA would not provide 100-year flood protection with a 90-percent confidence that is required for USACE levee certification.