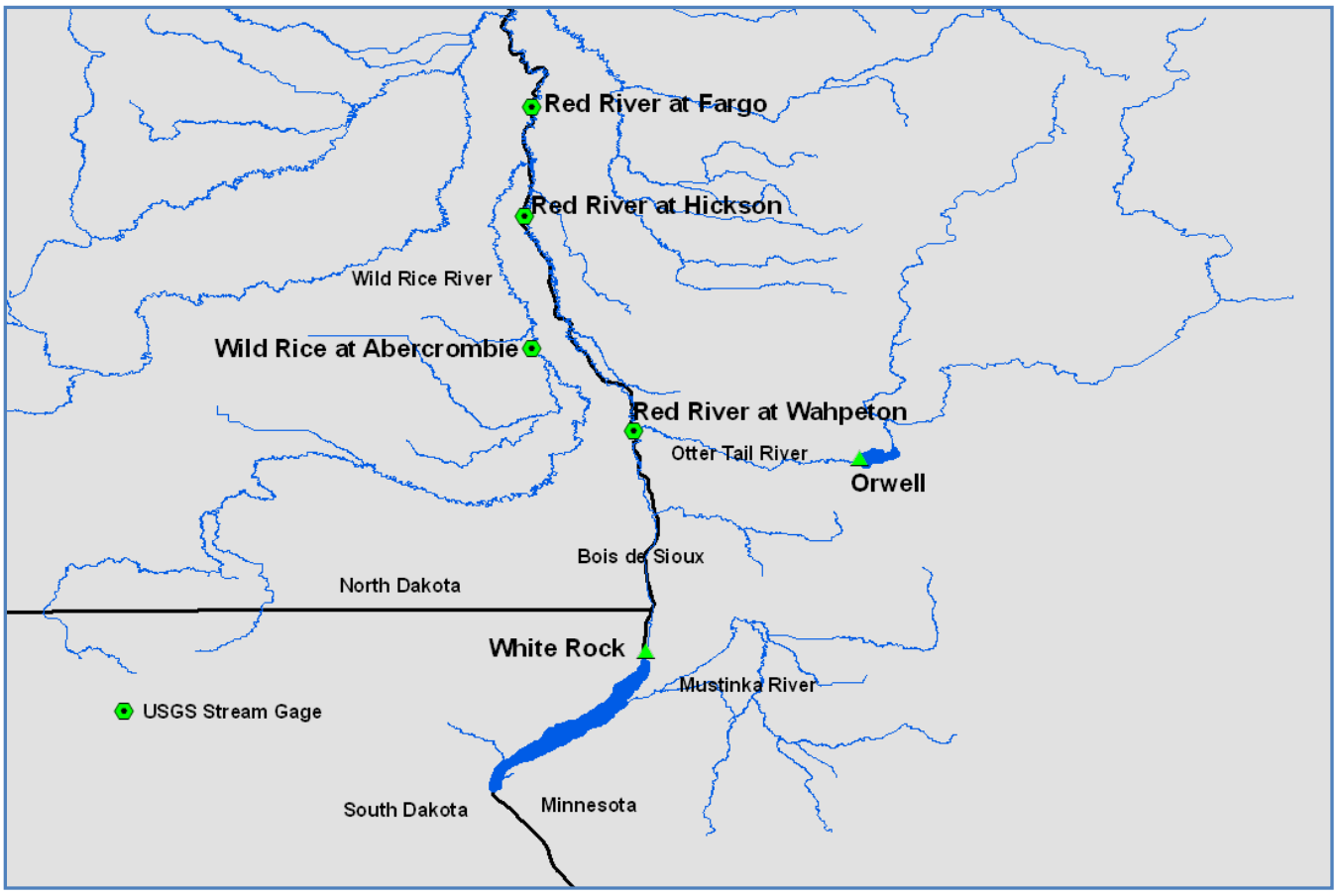
The Use of Synthetic Floods for Defining the Regulated Volume Duration Frequency Curves for the Red River at Fargo, ND



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1. Background

The Fargo-Moorhead Metropolitan Area Flood Risk Management Project requires balanced hydrograph inputs representative of the 0.2%, 0.5%, 1%, 2% and 10% regulated flows on the Red River of the North at Fargo, ND. Work done subsequent to the 2010 submittal of the Fargo-Moorhead Metropolitan Area Flood Risk Management Final Feasibility Report and Environmental Impact Statement (FEIS) has indicated that the regulated volumes estimated by the balanced hydrographs presented within the FEIS's Hydrology Appendix are too low.

During feasibility hydraulic engineers addressed the issue by utilizing Unsteady HEC-RAS to carry out a series of sensitivity tests to ensure that the proposed diversion project can successfully reduce the flood potential along the Red River of the North in the Fargo-Moorhead metropolitan area. It was found that the functionality of the proposed diversion project is not sensitive to increases in flood volume. The duration of holding water in the upstream staging area and the duration of flow in the diversion were increased slightly, but the maximum flow allowed into the risk management area and the maximum water surface elevation in the staging area were unchanged with the higher volume.

As the Fargo project team transitions into the design phase of project development, the St. Paul District Hydrology, Water Management and Hydraulics Branch feels that it is imperative that a consistent and a more accurate set of hydrographs with respect to volume representative of 0.2%, 0.5%, 1%, 2% and 10% regulated flows at Fargo, ND is developed.

The updated hydrographs are developed to be representative of the WET portion of the period of record adopted as part of the FEIS (1942-2009).

2. Feasibility Phase Methodology

Regulated volume duration frequency curves were developed to be representative of Red River flows at Fargo, ND. Regulated volume duration frequency curves were developed from the regulated annual instantaneous peak flow frequency curve by applying the same percent reductions in volume as were observed between the unregulated instantaneous peak flow frequency and the 3-day, 7-day, 15-day and 30-day unregulated volume duration frequency curves.

The regulated balanced hydrographs for key frequencies (10%, 2%, 1%, 0.5%, 0.2%) come from these regulated volume duration frequency curves. HEC-1 was used to generate the corresponding balanced hydrographs. The balanced hydrographs were then graphically smoothed using HEC-DSSVue. While this is a reasonable initial approximation of the balanced hydrographs for the project, this method can underestimate volumes for the longer durations. This is likely due to the fact that regulation attenuates a hydrograph (volume is spread out, but not lost).

3. Revised Methodology

3.1 Volume Duration Frequency Analysis

Regulated volume duration frequency curves are developed utilizing observed, regulated mean daily flows as reported by USGS gage 0505400 located on the Red River of the North at Fargo, ND for the portion of the period of record from 1953 to 2009. Simulated, regulated mean daily flows as developed as part of the FEIS utilizing an HEC-5 model were adopted for the portion of the period of record from 1942 to 1952. Simulated flows were utilized to account for the effects of Orwell Dam, which went into operation in 1953.

Because the flow record observed on the Red River at Fargo, ND is affected by upstream reservoirs and breakout flows, a graphical volume duration frequency analysis must be applied. An analytical Log Pearson Type III distribution does not fit the observed flows. Similarly as what was done to define the upper end of the regulated flow frequency curve for the Red River at Fargo, synthetic floods are applied to define the upper end of the regulated volume duration frequency curves.

The regulated synthetic flood hydrographs prepared by the Hydrologic Engineering Center to define the 10%, 2%, 1%, 0.5% and 0.2% peak annual flows at Fargo, ND were also utilized to define the 10%, 2%, 1%, 0.5% and 0.2% 3-day, 7-day, 15-day and 30-day flows as displayed in **Table 1**.

Table 1. Synthetic Events at Fargo, ND

	Synthetic Events in CFS				
Percent Chance of Exceedance	Annual Instantaneous Peak Flow	Mean Maximum 3-day	Mean Maximum 7-Day	Mean Maximum 15-day	Mean Maximum 30-day
0.2	61,693	57,835	51,962	42,592	30,050
0.5	46,117	42,811	39,789	33,525	23,843
1	34,662	33,578	31,637	27,271	19,457
2	29,314	28,062	26,045	21,672	15,467
10	16,676	16,107	14,671	11,979	8,615

An explanation of how these hydrographs were developed is included in Appendix A of the FEIS. The suite of volume duration frequency curves representative of flows at Fargo, ND were developed graphically by fitting a curve to observed/simulated annual maximum peaks plotted against empirical frequency estimates defined using the Weibull plotting position, and the synthetic floods plotted against their specified frequencies. The resulting volume duration frequency curves are displayed in **Plate I**. A comparison between the volumes developed as part of the Feasibility Study versus the volumes generated utilizing the graphical curves is displayed in **Table 2**.

Table 2. Feasibility Phase Volume Duration Frequency Analysis versus Graphical Volume Duration Frequency Analysis

	0.2 % Event			0.5 % Event			1 % Event			2 % Event			10 % Event		
	FLOWS in CFS														
	Revised	Feasibility	% difference	Revised	Feasibility	% difference	Revised	Feasibility	% difference	Revised	Feasibility	% difference	Revised	Feasibility	% difference
Peaks	61,700	61,700	0%	46,200	46,200	0%	34,700	34,700	0%	29,300	29,300	0%	17,000	17,000	0%
3-day	58,100	56,469	3%	43,400	42,372	2%	33,000	31,883	4%	28,150	26,976	4%	16,500	15,751	5%
7-day	52,000	46,118	13%	39,800	34,801	14%	31,500	26,314	20%	26,000	22,388	16%	15,200	13,297	14%
15-day	42,600	31,549	35%	33,500	24,060	39%	27,350	18,359	49%	22,500	15,783	43%	12,000	9,675	24%
30-day	31,500	21,161	49%	25,000	16,322	53%	20,500	12,576	63%	16,500	10,932	51%	8,000	6,931	15%

3.2 Balanced Hydrographs

HEC-1 is utilized to generate balanced hydrographs based upon the volume duration frequency curves displayed in **Plate I**. The 2006 regulated flow hydrograph observed at Fargo, ND is utilized as the pattern event for this analysis in order to be consistent with how balanced hydrographs were generated during the FEIS. The graphical editor in HEC-DSSVUE is utilized to smooth out the receding limb of the hydrographs. The peak of the balanced hydrograph is defined by the regulated annual instantaneous peak flow frequency curve for the WET portion of the period of record. Volumes were checked after smoothing to ensure that they were reasonably (within 2%) close to the volumes prescribed by the volume duration frequency analysis. The resulting balanced hydrographs are plotted in comparison to the originally adopted Fargo, ND balanced hydrographs in **Figure 1** through **Figure 5**.

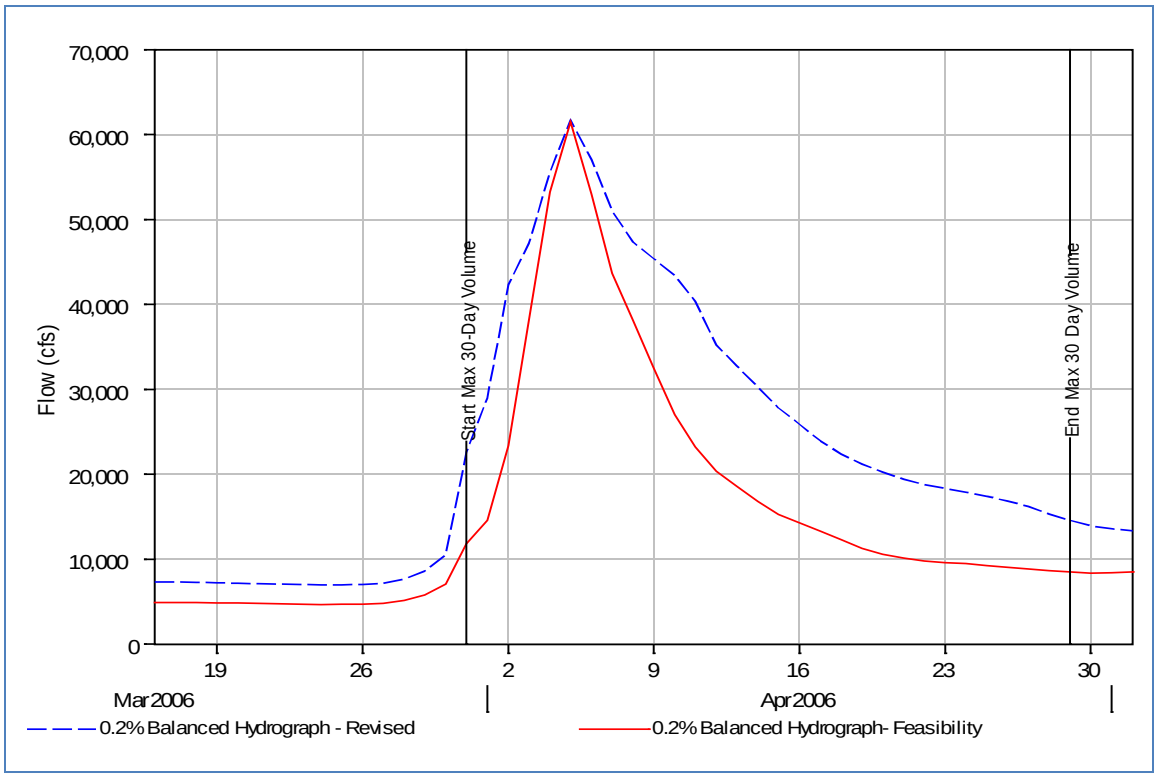

Figure 1. Balanced Hydrographs at Fargo, ND 0.2% Event

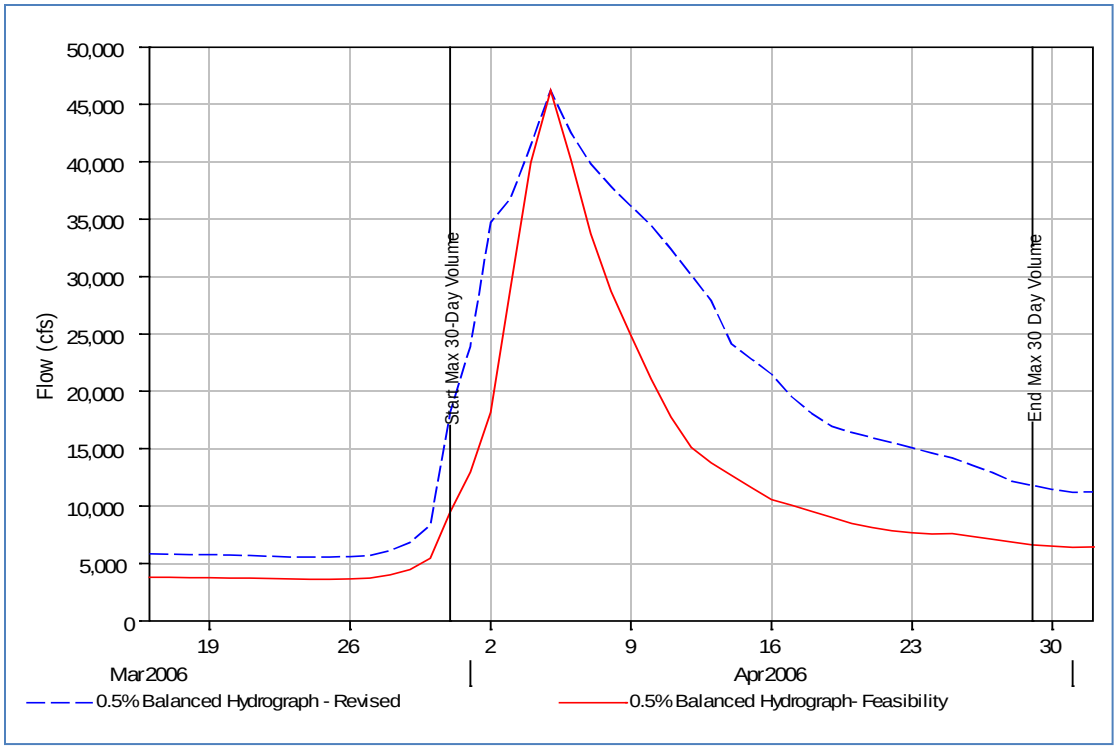

Figure 2. Balanced Hydrographs at Fargo, ND 0.5% Event

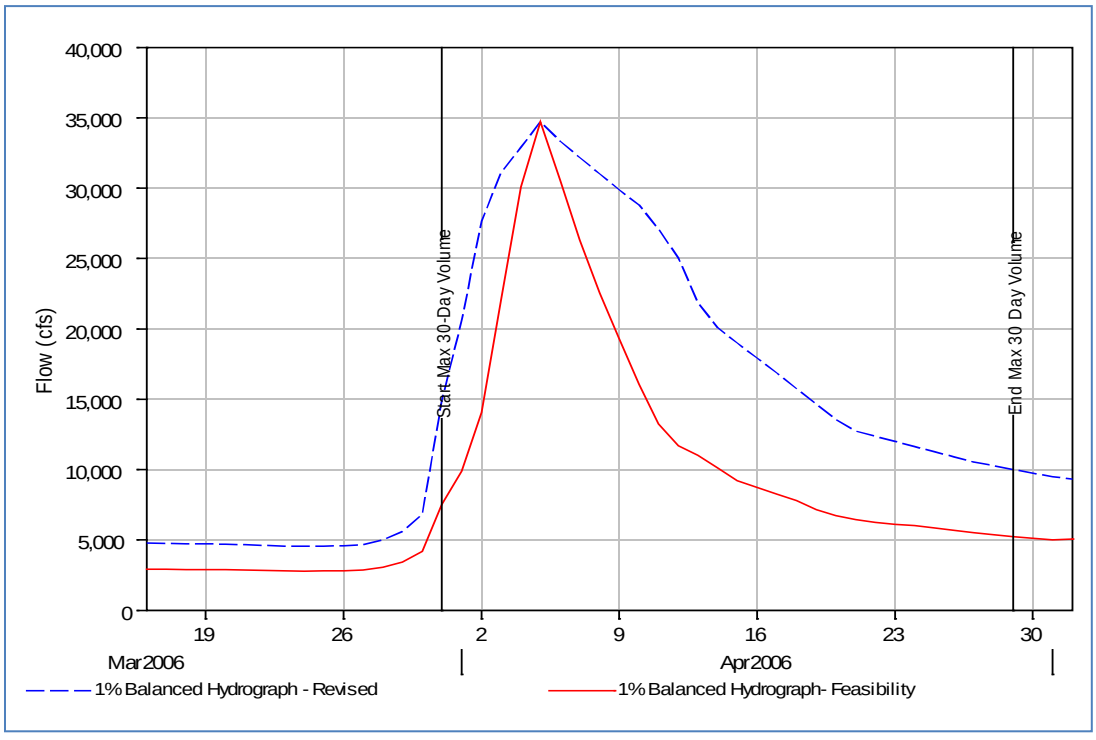

Figure 3. Balanced Hydrographs at Fargo, ND 1% Event

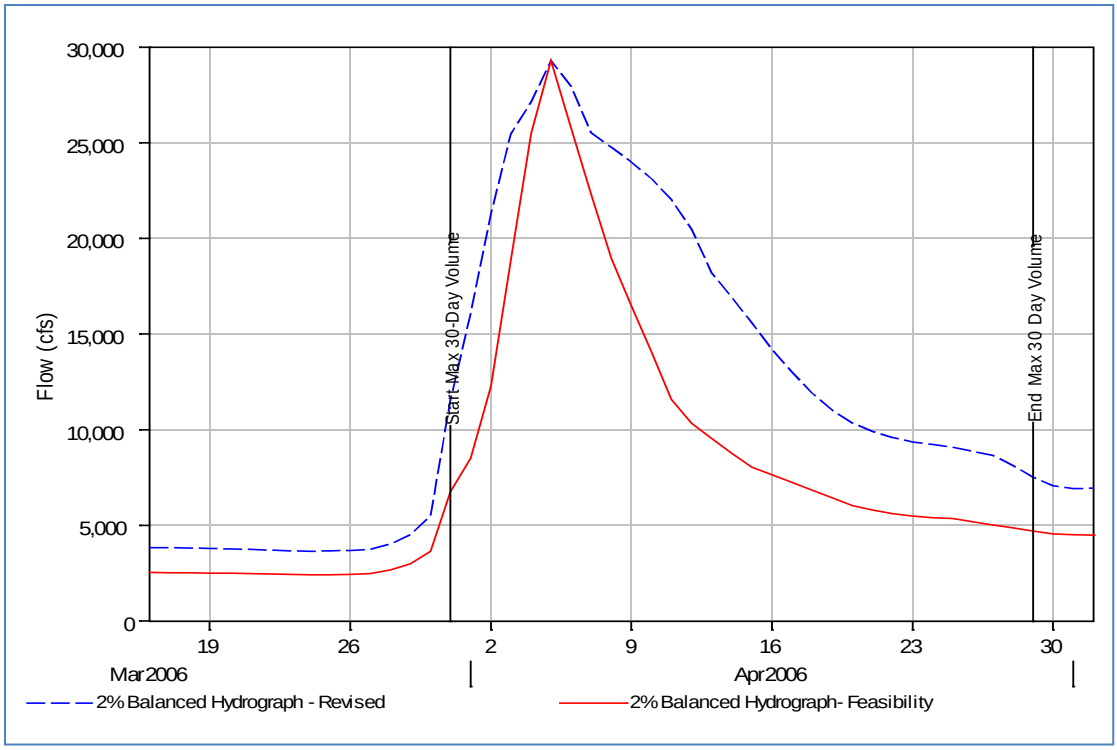

Figure 4. Balanced Hydrographs at Fargo, ND 2% Event

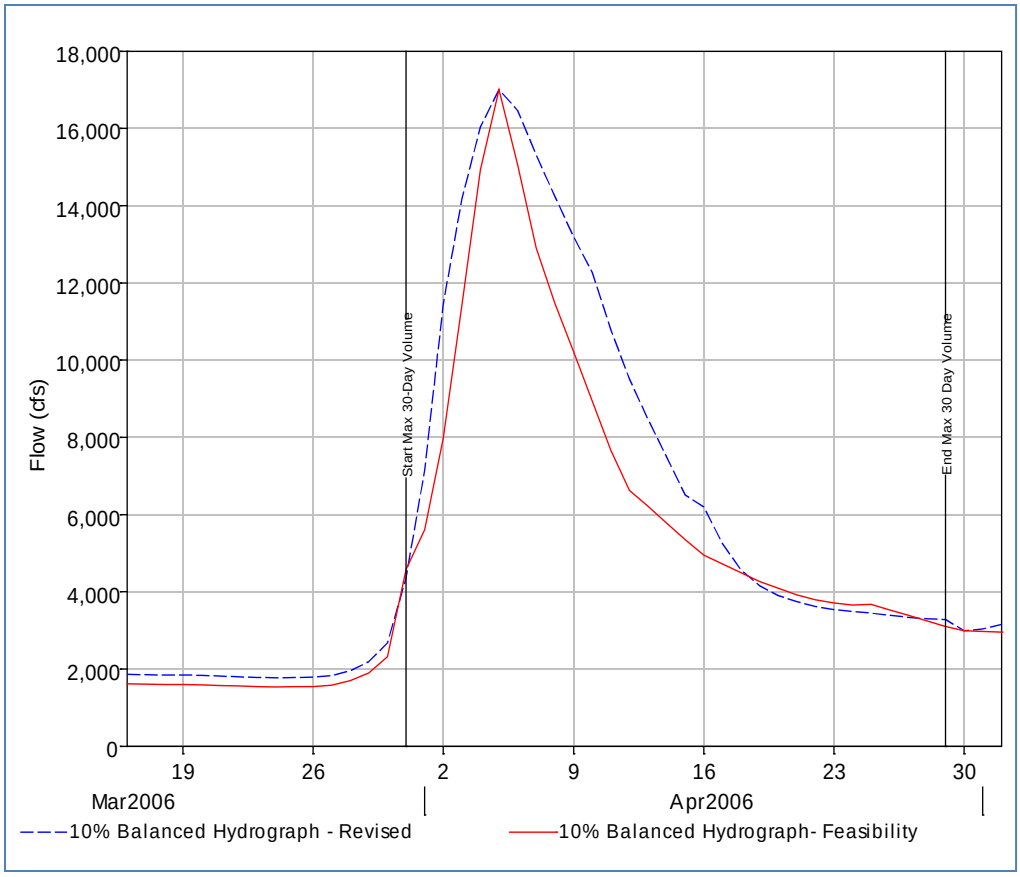

Figure 5. Balanced Hydrographs at Fargo, ND 10% event