3.0 Results and Discussion

3.1 Basin Hydrology

This section presents the results of statistical analyses done on the historical rainfall and runoff volumes to develop frequency curves and runoff maps that represent low, average and high flow conditions within each basin. The variability of basin hydrology is important since the phosphorus load estimates for each flow condition are based on the annual runoff volumes that have been determined from recent water year flow data. A more detailed discussion about the results of the assessment for the basin hydrology is included in Appendix A.

3.1.1 Frequency Curves

The runoff and precipitation frequency curves for each of the watersheds are shown in Appendix A. The curves show that for gages in the south and west portions of the state, the period of 1979-2002 flows were consistently above the long-term period of record. The frequency curves for much of Northeast Minnesota, particularly the Rainy River, the North Shore of Lake Superior, and St. Croix River basins did not show this trend. The curves indicate that there is a general trend of decreasing runoff from east to west. The Lake Superior basin has the highest runoff rate in the state, with the Baptism River watershed having the highest values within that basin (average annual runoff of 15.3 inches). The Red River of the North basin had the least runoff, with the Buffalo River watershed experiencing 2.8 inches of runoff in an average year, which is the lowest of the Minnesota gages used in this analysis. Decreasing runoff from east to west also occurs in southern Minnesota, but the trend is less dramatic than in the north. The Root River watershed in extreme southeast Minnesota has nearly 11 inches of runoff for the period of 1979-2002, while the Rock River in southwest Minnesota and northwest Iowa has average annual runoff of 5.6 inches. Increases in runoff are more dramatic moving south in the state, as flows approach high flow conditions.

3.1.2 Runoff Maps

As discussed in Section 2.1.2.5, the runoff frequency curves were used to develop maps showing the statewide runoff values. The maps showing the estimated runoff volumes during low (dry), average and high flow (wet) conditions are shown in Figures 3-1, 3-2, and 3-3, respectively. The runoff mapping confirms what the frequency curves indicated: there is a general trend of decreasing runoff from east to west, but the trend is less dramatic in the south, compared to the northern part of the state for each flow condition. Also, comparing the runoff volume gradients in the east and west

Figure 3-1 Annual Runoff, Low Flow Conditions

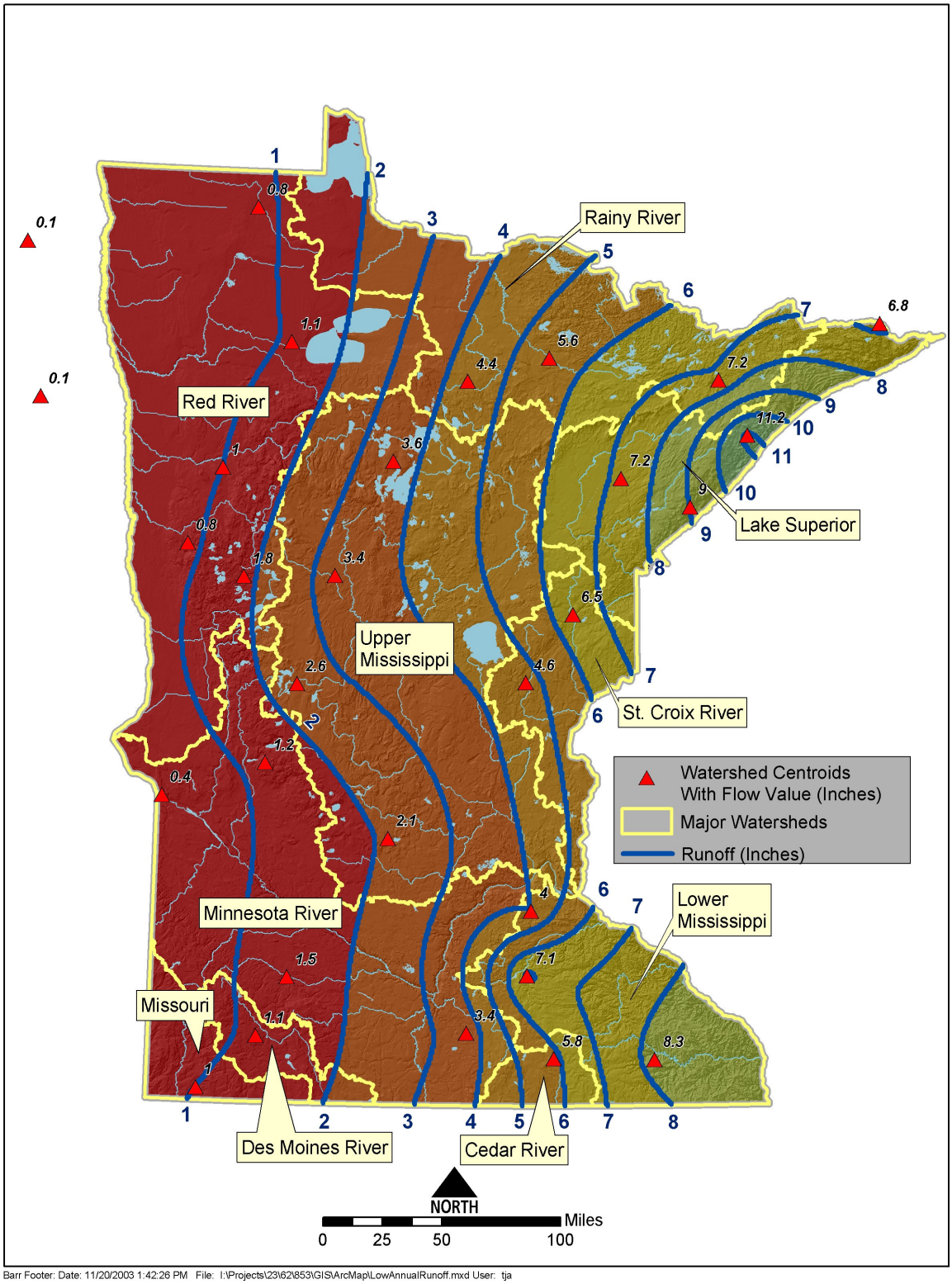


Figure 3-2 Annual Runoff, Average Flow Conditions

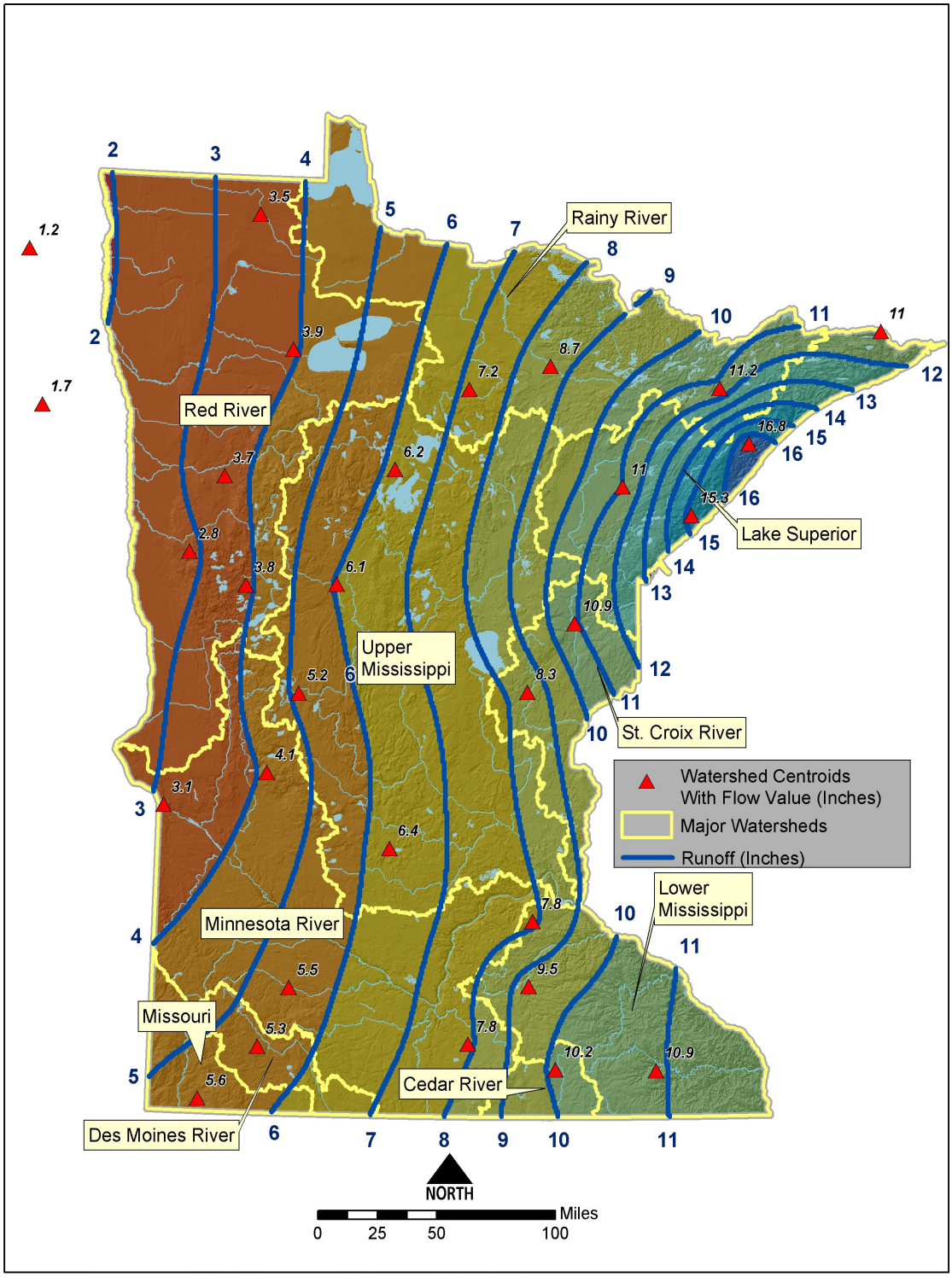
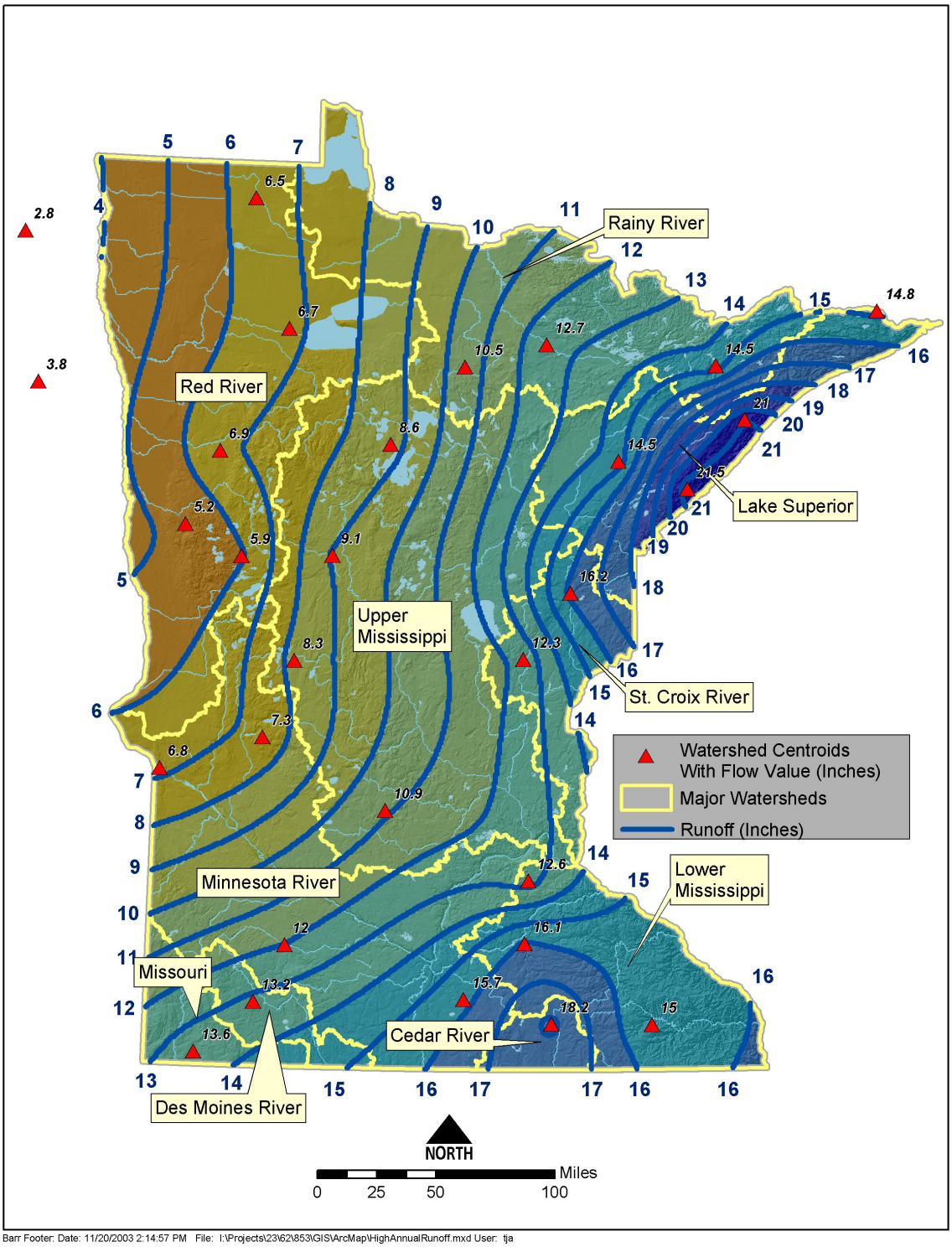


Figure 3-3 Annual Runoff, High Flow Conditions



extremes of the state, shows that the gradient increases significantly from low to average flow, and from average to high flow, conditions.

Table 3-1 shows the 10 basinwide average values developed from these maps for the wet (high flow), average and dry (low flow) conditions. Table 3-1 also provides a summary of basin wide average precipitation for the wet, average and dry years based on the frequency determinations. Also shown in Table 3-1 is the runoff percentage calculated using the ratio of runoff to rainfall. This runoff percentage is significantly lower (less than 9 percent) for the Des Moines, Minnesota, Missouri, and Red River basins, compared to the remaining basins under low flow conditions. With the exception of the Upper Mississippi River (approximately 16 percent), the runoff percentage in the remaining basins exceeds 20 percent under low flow conditions. Comparing the runoff percentages from low flow to average and high flow conditions, the percentages increase more significantly (to between 21 and 37 percent) for the Des Moines, Minnesota, Missouri, and Red River basins, than they do for the remaining basins (between 30 and 48 percent). The runoff percentages under high flow conditions, with the possible exception of the Red River basin (21 percent), indicate that a large percentage of the rainfall volumes (between 30 and 48 percent) would be measured as runoff at a downstream gaging location. However, it should be noted that some portion of the runoff volumes shown in Table 3-1 does not represent runoff from land surfaces, and are actually entering surface waters from groundwater or other subsurface flow paths.

Table 3-1 Basinwide Runoff and Precipitation

	Dry Conditions			Average Conditions			Wet Conditions		
Basin	Rainfall (inches)	Runoff (inches)	Percent Runoff	Rainfall (inches)	Runoff (inches)	Percent Runoff	Rainfall (inches)	Runoff (inches)	Percent Runoff
Cedar River	27.5	5.6	20.4%	32.1	9.8	30.6%	41.3	17.5	42.4%
DesMoines River	22.0	1.4	6.4%	28.0	5.7	20.3%	36.8	13.4	36.4%
Lake Superior	25.5	7.9	30.8%	29.1	12.4	42.7%	35.1	16.7	47.7%
Lower Mississippi	27.0	7.1	26.5%	33.3	10.3	30.9%	39.8	15.6	39.1%
Minnesota River	22.1	1.9	8.7%	28.1	5.6	19.9%	34.8	11.2	32.2%
Missouri River	21.1	1.0	4.6%	27.2	5.3	19.3%	35.6	12.8	36.0%
Rainy River	22.4	4.8	21.4%	26.2	8.0	30.6%	32.1	11.4	35.6%
Red River	18.6	1.1	5.7%	23.3	3.4	14.7%	28.9	6.1	21.1%
St. Croix River	23.7	5.6	23.7%	30.6	9.7	31.7%	37.6	14.3	38.1%
Upper Mississippi River	22.6	3.6	15.8%	28.1	6.9	24.5%	34.3	10.4	30.5%