Platte River Flow and Sediment Transport
Between North Platte
and
Grand Island, Nebraska
(1895 - 1999)

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Effdis.for	FORTRAN computer program to calculate sediment loads (using sediment-discharge equations) and compute effective discharge by equal discharge intervals, probability intervals, and the median sediment transporting discharge.	
Channel cross section surveys	Repeat river cross section survey data from 1989 and 2002	
	246-5S.xls	River Mile 246.5 South
	246-0.xls	River Mile 246.0 South
	244-0S.xls	River Mile 244.0 South
	239-9.xls	River Mile 239.9
	239-3.xls	River Mile 239.3
	239-0.xls	River Mile 239.0
	237-5.xls	River Mile 237.5
	233-8.xls	River Mile 233.8
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	228-7.xls	River Mile 228.7
	210-6S.xls	River Mile 210.6 South
	206-6N.xls	River Mile 206.6 North
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	2002 Survey.xls	2002 Survey: GPS and Nebraska State Plane Coordinates, NAD 1983 and NGVD 1988
Effdis 1 -20.xls	Effective discharge analysis for the North Platte River at North Platte, NE (20 equal discharge intervals and 19 probability intervals)	
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1.0 Introduction

The North and South Platte Rivers both originate on the eastern slopes of the Rocky Mountains in Colorado (see figures 1 and 2). The North Platte River flows north into Wyoming and then southeast across Wyoming and through the northwestern panhandle of Nebraska. The South Platte River flows generally northeast through Colorado and into Nebraska. The North and South Platte Rivers join to form the Platte River at the City of North Platte, Nebraska. From there the Platte River flows generally eastward through Nebraska before joining the Missouri River near Plattsmouth, Nebraska.

The quantity of flow and sediment transported along the Platte River has significantly changed during the 20th Century in response to water resource development, droughts, and floods. These changes in flow and sediment transport have an effect upon the river channel width, depth, and the amount of riparian vegetation (Lyons and Randle, 1988, Karlinger et al. 1983). The shape and width of a river channel is a function of flow, the quantity and size of the sediment load, and the character and composition of the materials, including vegetation, composing the bed and banks of the channel (Leopold, Wolman, and Miller, 1964). Soar and Thorne (2001) presented an empirical regime equations relating bankfull channel width (W_b) to bankfull discharge (Q_b) for stable sandbed channels. Equation 1 is for sandbed channels with more than 50% tree cover along the banks, while equation 2 is for sandbed channels with less than 50% tree cover along the banks.

$$W_b = 1.87 Q_b^{0.50} e^{\pm 0.085} \tag{1}$$

$$W_b = 2.94 Q_b^{0.50} e^{\pm 0.082} \tag{2}$$

where W_b is the bankfull width, in feet, and Q_b is the bankfull discharge in ft^3/s.

Equation 1 was based on 26 stable, sandbed channels in the United States and explained 85 percent of the variance in bankfull width. Equation 2 was based on 40 stable, sandbed channels in the United States and explained 87 percent of the variance in bankfull width. These equations indicate that the bankfull channel width can increase by a factor of 1.57 if the tree cover along both banks decreases to less than 50 percent.

Beginning in 1909, large storage reservoirs were first constructed on the North Platte River to capture spring floods and provide water for irrigation during the summer. During the period 1909 to 1958, six major dams were constructed across the North Platte River in Wyoming and Nebraska. Pathfinder (1909), Guernsey (1928), Alcova (1938), Seminoe (1939), Kingsley (1941), and Glendo (1958) reservoirs have a combined storage capacity of nearly 5 million acre-feet (Collier and others, 2000). Large reservoirs also were constructed on the South Platte River, but these were located much higher in the watershed and stored a smaller fraction of the runoff (1.3 million acre-feet of reservoir storage at present). Simons and Associates (2000) lists the combined reservoir storage capacity of the Platte River Basin (for all reservoirs greater than 5,000 acre-feet) at 7.6 million acre-feet. These reservoirs stored water during periods of high flow and later released the water during periods of low flow. This pattern of reservoir storage significantly reduced the annual peak flows (especially on the North Platte River) and the application of water to agricultural lands via the thousands of small diversions throughout the watershed reduced annual average flows within the river channel.

Based on estimates of irrigation, municipal and industrial use, and evaporative loss, the consumptive use of water in the Platte River basin has reduced flows in the river by at least 1.2 million acre-feet in the average year (Murphy and Randle, 2003a). Without these depletions, Platte River flow near Grand Island, Nebraska would have been 80 percent greater during the period 1970 to 1999, and would be more if depletions due to groundwater use were also considered.

The science of tree-ring analysis has considerably extended the traditional record of climate based on instrument measurements. Instrumented data is available back to approximately 1895; however, the paleo technique of dating tree rings provides information back to the 1600's or 1700's in the west, while other paleo techniques can extend the record back a thousand years or more. Tree-ring data has been used to extend the period of record for temperature measurements, the Palmer Drought Severity Indices (PDSI), and for some hydrological records of streamflow. The PDSI is a drought model derived by Palmer (1965) computed from temperature and precipitation data to provide a measure of climatic stress on crops and water supplies.

Temperature data from studies by Briffa et al., 1998, Jones et al., 1998, Mann et al, 1998, and Overpeck et al, 1997 display a temperature rise from the 1920s to the 1950s, that exceeds temperature increases occurring in the reconstructed record back to the 1400s. In contrast, both stream flow records and values for the Palmer Drought Severity Index (PDSI) do not support a theory for a general trend of streamflow changes resulting from climatic change for the Great Plains. Instead, tree-ring data for the past 400 years indicates short periods of wet and dry, with durations of 3 to 10 years, fluctuating around a central norm. No general long term trend of drying is apparent for watersheds on the eastern slope of the Rockies or the Great Plains region in the 20th Century (Murphy and Randle, 2003a).

This report presents water and sediment budgets for the various reaches along the Platte River that are bounded by gauging stations between the cities of North Platte and Grand Island, Nebraska. The inputs of water and sediment from the North and the South Platte Rivers are included in this analysis. This report has been prepared as a supporting document for the report entitled “Platte River Channel: History and Restoration,” by Murphy and Randle (2003a) which discusses the causes of channel narrowing and presents a proposal for river restoration. The study objectives for this report are to develop water and sediment budgets of the Platte River for four historic time periods and evaluate how those budgets have changed over time and distance along the river channel. The specific parameters to be evaluated include the median and mean river flow, 1.5-year flood peaks, mean annual sediment transport, and effective discharge. This technical report provides background information for a more general description of the affected environment for the Environmental Impact Statement (EIS) being prepared for the recovery of endangered species along the Platte River.

2.0 Stream Flow Analysis

The various gauging stations within the Platte River Basin from which flow or sediment data were analyzed are listed in table 1. Most of these stations are along the Platte River in Nebraska, but two additional stations are included to represent the upper North Platte River upstream from much of the water resource development.

Table 1 — Platte River Basin gauging stations and periods of record.

Gauging Station Number and Name		Contributing Drainage Area (mi^2)[1]	Measured Period of Record
06620000	North Platte River near Northgate, CO	1,431	May 1915 to present
06627000	North Platte River near Saratoga, WY	2,840	July 1903 to Sept. 1970
06693000	North Platte River at North Platte, NE	26,300	February 1895 to present[2]
06765500	South Platte River at North Platte, NE	24,300	June to November 1897, June to August 1914, May to September 1915, and May 1917 to present[2]
06766500	Platte River near Cozad, NE	51,700	July to September 1932, May 1937 to present[2]
06768000	Platte River near Overton, NE	51,620	October 1914 to present
06770500	Platte River near Grand Island, NE	52,940	October 1933 to present

The Platte River and its two main tributaries have long historical records of stream flow at several gauging stations. The stream flow record for the North Platte River at North Platte, Nebraska is the longest, extending back to 1895. The stream flow data for the other gauging stations listed in table 1 were extended back to 1895 by correlation with long-term records from the South Platte River at Denver, Colorado; South Platte River near Julesburg, Colorado; North Platte River at North Platte,

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[1] Drainage areas are from U.S. Geological Survey Water-Data Reports (Boohar, Hoy, and Steele, 1990 and Ugland, et al., 1990) and the U.S. Geological Survey website at http://waterdata.usgs.gov/nwis/discharge/.

[2] Monthly discharge only for some periods, published in WSP 1310.

Nebraska; and the Platte River near Overton and Duncan, Nebraska (see table 2) (Stroup, et al, 2002).

Table 2 — Gauging stations and periods of record used to extend records at other Platte River gauging stations

Gauging Station Number and Name		Contributing Drainage Area (mi^2)	Measured Period of Record
06693000	North Platte River at North Platte, NE	26,300	February 1895 to present[3]
06714000	South Platte River at Denver, CO	3,861	May to October 1889, June to October 1890, July 1895 to present[1]
06764000	South Platte River at Julesburg, CO	23,193	April 1902 to present
06768000	Platte River near Overton, NE	51,620	October 1914 to present
06774000	Platte River near Duncan, NE	54,630	June 1895 to Dec. 1909 July 1910 to Dec. 1911, April 1912 to Sep. 1915, June 1928 to present

The historic period covered in this study ranges from water years 1895 to 1999. This 105-year historic period was divided into four periods of analysis based on trends in annual flow volume and annual peak flow for the North Platte River gauge at North Platte, Nebraska (see figure 3):

- 1895 to 1909
- 1910 to 1935
- 1936 to 1969
- 1970 to 1999

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[3] Monthly discharge only for some periods, published in WSP 1310.

Stream flows, from the North Platte River gauging station at North Platte, Nebraska, were used to determine the four time periods because the entire period from 1895 to 1999 was measured at this gauge. Also, stream flow data from this gauging station were used because the North Platte River was historically the primary source of water to the Platte River (see table 3). The first and second time periods were separated at the end of water year 1909 because there was a significant reduction in both the annual mean and peak flows for the North Platte River in 1910 and 1911. This reduction was primarily caused by the initial filling of Pathfinder Reservoir. The second and third time periods were separated at the end of water year 1935 because there was a reduction in both the annual mean and peak flows in 1936. With the exception of three water years, 1938, 1939, and 1952, mean flows for the third time period were less than any mean flows in the second time period. The third and fourth time periods were separated at the end of water year 1969. This separation is somewhat arbitrary, but makes the number of years in each period roughly equal.

The mean-annual flow, the median flow, and the 1.5-year flood peak flow were computed for the five gauging stations listed in table 1 and for each of the four selected time periods. The results from these analyses are presented in the following sections.

2.1 Mean Platte River Flows

The mean flows for the four historic time periods for the North and South Platte Rivers at North Platte, Nebraska and the Platte River near Cozad, Overton, and Grand Island, Nebraska are presented in table 3 and shown in figure 4. This figure shows the variation of mean flows for the time periods. All of the gauges have the lowest mean flow for the period 1936-1969, and the highest mean flow for the 1895-1909 period, except for the South Platte River at North Platte which has the highest mean flow during the 1970-1999 period. The high mean flows for the first period 1895 to 1909 corresponds with a period of pre-reservoir development, and may also coincide with the occurrence of a wet period for areas of the Great Plains and South Platte headwaters. In the Front Range region of Colorado, McKee et al. (1999), describes a 26 year wet period from 1905-1931. In contrast, a dendritic study by Cleaveland and Duvick (1992) of Iowa climate, directly to the west of the Platte study area, makes no mention of a wet period in the early century. Instead they identify an extreme wet period from 1876 to 1885, and two dry periods from 1886 to 1895 and 1931 to 1940.

The occurrence of the lowest mean flow for all the gauges during the period 1936-1969 appears to be due to the combined effects of the filling of new reservoirs and two periods of drought in the 1930s and 1950s. The two gauging stations that represent the North Platte River upstream of reservoir development also show some decline in mean flow over the three periods from 1903 to 1969 and then an increase in mean flow for the period 1970 to 1999. However, the decline in mean flow from the second to the third time periods (1910 to 1969) is much less for the two upper North Platte River stations (24 percent) than the decline in mean flow for the North Platte River station at North Platte, Nebraska (77 percent). Of the 77 percent decrease in mean North Platte River flow during the period 1936 to 1969 (relative to the period 1910 to 1935), this indicates a maximum 31 percent was due to climate fluctuations, assuming no reductions due to irrigation, and a minimum 69 percent was resulting from reservoir development.

Table 3 — Mean Platte River flows

	Mean River Flows (ft^3/s) for each time period			
Gauging Station	1895 to 1909	1910 to 1935	1936 to 1969	1970 to 1999
North Platte River at Northgate, CO		502	383	432
North Platte River at Saratoga, WY	1,670	1,310	1,000	
North Platte River at North Platte, NE	3,190	2,750	646	862
South Platte River at North Platte, NE	582	492	322	619
Platte River at North Platte, NE	3,780	3,240	968	1,480
Platte River near Cozad, NE	3,550	3,040	461	990
Platte River near Overton, NE	3,660	3,160	1,140	2,100
Platte River near Grand Island, NE	3,580	2,950	1,080	2,110

2.2 Median Platte River Flows

The median river flows were determined for the same gauging stations on the Platte River System for which the annual mean flows were determined. The median river flow was computed as the flow that is equaled or exceeded 50 percent of time, in days. The median flows were analyzed for trends and compared with mean flows and 1.5-year flood peak flows. The results are presented in Table 4, and in Figure 5. The median flows at the five gauges were always less than the mean flows. Typically for most streams, the mean annual river flow is only exceeded 25 to 40 percent of the days in a year (Leopold, 1994).

The median flows were lowest for the same period (1936-1969) as the mean flows. However, the median flows were the highest for the period 1910-1935. In contrast, 1895 to 1909 was the highest period of mean flow. Depending on the reference, the first or second period could include wetter climatic periods. The increase in median flows in the second period is most likely caused by reservoir regulation of river flows where the magnitude of high flows tend to decrease and low flows tend to increase. Both the median and mean flows were lower in 1936-1969 than during the period 1970-1999.

Table 4 — Median Platte River flows

	Median River Flows (ft^3/s) for each time period			
Gauging Station	1895 to 1909	1910 to 1935	1936 to 1969	1970 to 1999
North Platte River at North Platte, NE	1,820	2,390	419	410
South Platte River at North Platte, NE	296	239	156	218
Platte River near Cozad, NE	2,020	2,530	236	274
Platte River near Overton, NE	2,110	2,600	1,000	1,470
Platte River near Grand Island, NE	1,970	2,430	850	1,510

2.3 1.5-Year Flood Peak Flows

Geomorphologists have defined the channel forming discharge in many different ways. One example is the effective discharge, which is the discharge that transports the most sediment over many years (Biedenharn, et al., 2000). Dunne and Leopold (1978) noted that the bank-full discharge of the stream is a key indicator of the channel forming discharge. Leopold (1994) stated that most investigations have concluded that the bankfull discharge recurrence intervals range from 1.0 to 2.5 years and is often assumed to have a recurrence interval of 1.5 years. For 58 sandbed rivers in the United States that were thought to have stable channels, 83 percent had a bankfull discharge with a recurrence interval of between 1 and 2 years (Soar and Thorne, 2001). Although, the bankfull discharge of the Platte River may not have a recurrence interval of 1.5 years, this recurrence interval is a useful indicator of the temporal and spatial trends in annual peak flow. The effective discharge for the Platte River has been computed by different methods and compared with the 1.5-year flood peak values (see section 4.0).

The 1.5-year flood values for each gauging station and time period were determined by sorting the data and performing simple frequency analysis based on the number of annual peak values. The 1.5-year flood peaks were determined for the same gauging stations on the Platte River System for which the mean and median river flows were determined. The analysis was based on annual peak discharge for a given gauging station. However, instantaneous peak-discharge values were not available for certain years and certain gauging stations during the earliest two time periods (1895 to 1909 and 1910 to 1935). In these cases, the annual maximum mean-daily discharge values were used. These mean-daily discharge values were obtained from Stroup et al. (2002). During the early two time periods, the annual peak discharge was typically dominated by snow melt runoff with a broad multi-day peak. Therefore, the peak mean-daily discharge is somewhat less than the instantaneous peak discharge, especially for the period 1915 to 1923 (see table 5). During the period 1915 to 1923 (excluding 1918), the annual maximum, mean-daily discharge was 92.7 to 100 percent of the annual peak flow, with an average of 97.8 percent.

The 1.5-year flood peaks are presented in Figure 6 and in Table 6. The 1.5-year peak flows are highest during the first time period (1895 to 1909), decrease through the second time period (1910 to 1935), and were lowest during the third time period (1936 to 1969). The 1.5-year peak discharge values increase somewhat during the most recent time period (1970-1999). The trends in the 1.5-year peak discharge are similar to the trends in mean discharge. A discussion of how the 1.5-year floods compare with effective discharge is presented in section 4.0.

The two gauging stations that represent the upper North Platte River also show some decline in the 1.5-year peak flows over the three periods from 1903 to 1969 and then an increase in the 1.5-year peak flow during the period 1970 to 1999. However, the decline in the 1.5-year peak flow from the second to the third time periods (1910 to 1969) is much less for the two North Platte River stations (14 to 26 percent) upstream of reservoir development, than the decline in the 1.5-year peak flow for the North Platte River station at North Platte, Nebraska (73 percent).

Table 5 — Comparison of flood peak and mean-daily discharge for the Platte River near Overton, Nebraska.

Date	Flood Peak Discharge (ft^3/s)	Mean-Daily Discharge (ft^3/s)	Ratio of Mean-Daily Discharge to Peak Discharge
May 29, 1915	19,600	19,300	98.5%
May 24, 1916	5,200	4,820	92.7%
June 2, 1917	29,300	29,300	100.0%
May 13, 1918		9,271	
October 10, 1918	9,000	9,000	100.0%
May 18, 1920	21,500	21,500	100.0%
June 14, 1921	37,000	36,700	99.2%
May 23, 1922	9,400	9,300	98.9%
June 17, 1923	22,000	20,500	93.2%
June 23, 1924		18,800	
October 9, 1924		6,000	
June 20, 1926	15,500	13,500	87.1%
April 19, 1927	12,800	12,000	93.8%
June 12, 1928	23,000	21,000	91.3%
June 7, 1929	19,000	18,800	98.9%
May 13, 1930	9,940	9,800	98.6%
April 4, 1931	10,600	8,500	80.2%
March 18, 1932	6,120	5,750	94.0%
April 23, 1933	8,440	7,840	92.9%
February 1, 1934	5,210	3,700	71.0%
June 5, 1935	37,600	29,400	78.2%

The months during which the annual peak flows occurred for the North Platte River has changed substantially over time (see table 7). During the first time period, the annual peak flows were dominated by snowmelt which typically occurred during May and June. By the fourth time period, the annual peak flows typically occurred during the summer and fall (July through October) when thunderstorms normally occur. Reservoir regulation has reduced the snowmelt peak during the later time periods so that the summer thunderstorms, which occur downstream of dams and within the study area, now produce the annual peak river flow during most years. The duration of the annual peak discharge has also decreased with the shift from snowmelt peaks to thunderstorm peaks, but the magnitude of this decrease has not been quantified.

Table 6 — Platte River 1.5-year flood peak flows

	1.5-year flood peak flows (ft^3/s) for each time period			
Gauging Station	1895 to 1909	1910 to 1935	1936 to 1969	1970 to 1999
North Platte River at Northgate, CO		2,600	2,220	2,430
North Platte River at Saratoga, WY	9,200	7,720	5,710	
North Platte River at North Platte, NE	16,300	8,150	2,160	2,380
South Platte River at North Platte, NE	2,330	1,430	712	1,420
Platte River near Cozad, NE	17,600	9,140	1,980	2,590
Platte River near Overton, NE	19,400	9,000	3,490	4,750
Platte River near Grand Island, NE	17,300	10,100	4,500	6,010

Table 7 — Occurrence of Annual Peak Flows for the North Platte River at North Platte, Nebraska

	Occurrence of Annual Peak Flow			
Time Period	Nov-Feb	Mar-Apr	May-June	July-Oct
1895 to 1909	0.0%	6.7%	93.3%	0.0%
1910 to 1935	3.8%	11.5%	65.4%	19.2%
1936 to 1969	2.9%	8.8%	23.5%	64.7%
1970 to 1999	0.0%	10.7%	17.9%	71.4%

2.4 Streamflow Trends

Stream flow through the North Platte and Platte Rivers has significantly decreased over the 20th Century because of reservoir regulation and river flow diversion. Stream flow has also exhibited lesser increases and decreases due to climatic fluctuations. The cumulative reservoir storage in the Platte River Basin is now 7.6 million acre-feet. This volume of reservoir storage is 2.9 to 9.2 times the mean annual flow rate of the Platte River near Overton, Nebraska (based on the mean flows of the four time periods presented in table 3). This large reservoir storage volume is capable of significantly altering the natural flows of the Platte River. While North Platte River flows, upstream from the major storage reservoirs, have declined 14 to 26 percent from the second to third time periods (1910 to 1935 versus 1936 to 1969), presumably due to climatic fluctuations, the North Platte River flows at North Platte, Nebraska, downstream from major storage reservoirs, have declined 73 to 76 percent.

The mean and median flows and the 1.5-year flood peaks in Nebraska have declined significantly from the two earlier time periods (1895-1909 and 1910-1935) to the two more recent time periods (1936-1969 and 1970-1999). Annual flood peaks of the North Platte River in Nebraska have also changed typically from being large events occurring during the snowmelt season (May and June) to being smaller events occurring during the summer and fall (July through October). Also, there is now a significant reduction in river flow along the 70-mile reach of the Platte River from the Tri-County Diversion Dam downstream to the Johnson-2 return channel. The general decrease in river flow over the 20th century and the decrease in flow over the 70-mile reach, since 1941, would be expected to affect sediment transport rates and the width of the active river channel over time (Williams and Wolman, 1984).

The mean flows and the 1.5-year flood peaks were highest during the period 1895 to 1909, decreased over the period 1910 to 1935, and decreased again to their lowest values during the period 1936-1969. The mean flows and the 1.5-year flood peaks increased somewhat during the period 1970 to 1999.

During the period 1895 to 1935, the mean and median flows and the 1.5-year flood peaks were high and of similar magnitude along the Platte River from North Platte to Grand Island, Nebraska. During the period 1936 to 1969, a new pattern began where the Platte River flows at the gauge near Cozad, Nebraska were significantly lower than the flows at the gauges near Overton and Grand Island, Nebraska. The Tri-County Diversion Dam and Canal began diversion of flows around this 70-mile reach of the Platte River in 1941 (see figure 2). A significant portion of the Platte River flow was and is diverted at the confluence of the North and South Platte Rivers for delivery through the Tri-County Canal. Much of this diverted water is then returned to the Platte River through the Johnson-2 return channel, a few miles upstream from the stream gauge near Overton, Nebraska. During the period 1970 to 1999, Platte River flows increased over the previous time period (1936 to 1969), with the pattern of lower flows at the stream gauge near Cozad, Nebraska continuing. The increase in the mean flow and the 1.5-year flood peaks for the fourth time period was primarily due to the high flows that occurred during water years 1971, 1973, 1983, and 1984.

The comparison of flow duration curves over time helps to characterize how the hydrology has changed at each gauging station. Flow duration curves for each gauging station and time period are presented in figures 7 through 11. For the North Platte River at North Platte, Nebraska, the flows were generally much less during the last two time periods compared with the first two time periods (see figure 7). From the first to the second time periods, the higher flows that were exceeded up to 34 percent of the time (in days) generally decreased while the lower flows that were exceeded between 34 and 98 percent of the time increased. This shift in occurrences accounts for the decrease in mean flow and the increase in median flow. From the third to the fourth time periods, the flows generally increased, but were still much less than the earliest two time periods. Moderate flows that were exceeded between 36 and 74 percent of the time remained about the same between the third and fourth time periods, accounting for the small decrease in the median flow. However, high flows (exceeded 34 percent of the time) and low flows (exceeded between 74 and 100 percent of the time) both increased, accounting for the increase in mean flow.

For the South Platte River at North Platte, Nebraska, the higher flows that were exceeded up to 60 percent of the time were generally about the same for the first, second, and fourth time periods (see figure 8). However, the flows that were exceeded up to 60 percent of the time were significantly less during the third time period. For the lower flows that were exceeded between 60 and 100 percent of the time, there was an initial decrease from the first to second time periods and then a significant and steady increase from the second to fourth time periods. In fact, the flows that are exceeded between 75 and 100 percent of the time were highest during the fourth time period. This substantial increase in the South Platte River low flows is most likely due to the trans-mountain diversions from the Colorado River Basin and irrigation return flows.

During the first two time periods, flows from the North Platte River were much more than flows from the South Platte River. Therefore, the Platte River flows during the first two time periods tend to follow a trend that is similar to the trend for the North Platte River flows.

For the Platte River gauge near Cozad, Nebraska, the flows were very much less during the last two time periods compared with the first two time periods (see figure 9). From the first to the second time periods, the higher flows that were exceeded up to 34 percent of the time generally decreased while the moderate flows that were exceeded between 34 and 84 percent of the time increased. Low flows that were exceeded between 84 and 100 percent of the time decreased from the first to second time periods. Therefore, the mean flow decreased while the median flow increased. From the third to the fourth time periods, the mean and median flows both increased, but were still much less than the earliest two time periods.

For the Platte River gauges near Overton and Grand Island, Nebraska, the flows were generally much less during the last two time periods compared with the first two time periods (see figures 9 and 10). From the first to the second time periods, the higher flows that were exceeded up to 34 percent of the time generally decreased while the moderate flows that were exceeded between 34 and 82 percent of the time increased. Low flows that were exceeded between 82 and 100 percent of the time decreased from the first to second time periods. Therefore, the mean flow decreased while the median flow increased. From the third to the fourth time periods, the mean and median flows both increased, but were still less than the earliest two time periods. For the low flows that were exceeded between 82 and 100 percent of the time at the Overton gauge, there was an initial decrease from the first to second time periods and then a steady and significant increase from the second to fourth time periods. The flows that are exceeded between 90 and 100 percent of the time are highest during the fourth time period. This increase in Platte River low flows appears to be caused by the reservoir regulation on the North Platte River, the trans-mountain diversions from the Colorado River Basin through the South Platte River, and the irrigation and canal return flows.

3.0 Sediment Transport Analysis

In addition to stream flow, sediment transported by stream flow is an important consideration in understanding changes in the riverine environment. Therefore, sediment budgets were computed for the central Platte River between the cities of North Platte and Grand Island, Nebraska for the same four time periods described in section 2.0. Mean-daily sediment loads were computed as a function of mean-daily river flows (see sections 3.1.1 through 3.1.3 and 3.2). The sediment loads for the North and South Platte Rivers at North Platte, Nebraska were computed separately and then combined to obtain the sediment load for the Platte River at North Platte, Nebraska. The sediment loads for the Platte River at North Platte, Nebraska were then compared with Platte River sediment loads for the gauges near Cozad, Overton, and Grand Island, Nebraska. Much of the sediment load from the North Platte River is trapped in upstream reservoirs such as Seminoe, Pathfinder, Glendo, Guernsey, and McConaughy. Immediately downstream from Lake McConaughy, sediment is eroded from the North Platte River channel. Some sediment is also supplied to the North Platte River from local drainage areas along the 58-mile reach between the Keystone Diversion Dam and the City of North Platte, Nebraska. North Platte River flow and sediment transport capacity at the City of North Platte, Nebraska has reduced from historic conditions to the extent that sediment may be aggrading the riverbed. Flood stage reported by the National Weather Service at this location is now reached by river flows less than 2,000 ft^3/s.

The sediment budgets were computed using sediment-discharge equations by

- Simons and Associates, Inc. (2000),
- Kircher (1983), and
- Lyons and Randle (1988), and
- from a sediment transport model developed by Murphy and Randle (2001).

The three sets of sediment-discharge equations and the sediment transport model were used to compute sediment loads for the period 1895 to 1999 at each of the stream gauges listed in table 1. A FORTRAN computer program was written to compute the mean-daily sediment loads, mean annual loads, and the frequency distribution of the daily sediment loads for each method. The source code of this computer program is provided in the Appendix (see compact disk, CD).

Different types of sediment load were computed for the various methods. Suspended sediment load is the transport of particles suspended in the turbulent flow of the river water. Bed load is the transport of coarse particles that roll or bounce along the river bed. Total sediment load transport includes both suspended load and bed load and consists of clay, silt, sand, and gravel-sized particles. Bed-material load consists of particles present in the bed, typically sand and gravel, and includes the transport of these particles as either suspended load or bed load. Although the computation of total sediment load should always be greater than bed-material load, the trends in either type of sediment load should be comparable. The sediment-discharge equations presented by Simons and Associates, Inc. (2000) were empirically derived and separately predict suspended load and bed load as a function of river flow (see section 3.1.1). The sediment-discharge equations presented by Kircher (1983) were also empirically derived and predict total sediment load as a function of discharge (see section 3.1.2). A set of sediment-discharge equations by Lyons and Randle (1988) predict suspended load, unmeasured load (roughly equivalent to bed load), and bed-material load. The sediment transport model (Murphy and Randle, 2003b) computes bed-material load, at 17 river cross sections from North Platte to Grand Island, Nebraska, by using the equations presented by Yang (1973 and 1984), see section 3.2.

3.1 Sediment-discharge Equations

Sediment load measurements along the Platte River began in about 1950 and continued at various times and frequencies and at various locations until 1984. The sediment load data that were used to produce the three sets of sediment-discharge equations are listed in table 8.
Each of the three sets of sediment-discharge equations were applied without modification to the four time periods of analysis. The rate of sediment supply to the wide, braided channel of the historic Platte River was assumed to be large and, therefore, the sediment transport rate was limited by the hydraulic transport capacity of the channel. As the river channel became narrower and deeper and the sediment size became coarser over time, the sediment-discharge relations may have changed. The narrower and deeper channel would likely have a higher velocity and a higher transport capacity; however, the coarser grain size would tend to decrease the transport capacity. Although the sediment-discharge relations may have changed, the application of a constant set of equations over the four time periods assists in evaluating the effect of river flow changes on sediment transport.

The sediment-discharge equations are constant with time, but the sediment transport model accounts for changes in Platte River channel hydraulics including width, depth, velocity, and the bed-material grain size. Therefore, the model cross sections are allowed to evolve over time, except for the two upstream boundary cross sections that represent the North and South Platte River channels. These two boundary cross sections are not allowed to change with time.

Table 8 — Use of sediment load measurements along the Platte River.

Stream gauge location	Simons and Associates, Inc. (2000)	Kircher (1983)	Lyons and Randle (1988)
North Platte River at North Platte, NE	1979 and 1980	1979 and 1980	not used
South Platte River near Kersey, Weldona, and Balzac, CO, and at North Platte, NE	1952-1953, 1962-1967, 1977-1984		
South Platte River at North Platte, NE		1979 and 1980	not used
Platte River near Overton, NE	1950-1953, 1964-1969, 1971, 1973	1979 and 1980	1950-1956, 1964-1969, 1971, 1980
Platte River near Grand Island, NE	1979 and 1980	1979 and 1980	1979 and 1980

3.1.1 Sediment-Discharge Equations by Simons and Associates, Inc. (August 2000)

The report by Simons and Associates, Inc. (2000) is entitled: "Physical History of Platte River in Nebraska: Focusing upon Flow, Sediment Transport, Geomorphology, and Vegetation." This report was prepared for the Platte River EIS office, U.S. Bureau of Reclamation. The sediment-discharge equations for the prediction of suspended load and bed load at five different gauging stations are presented in table 3-6 of the Simons and Associates, Inc. report. These equations are presented below in table 9. Additional background information, about the data these regression equations are based on, can be found in Simons and Associates, Inc. (2000).

Table 9 — Sediment-discharge equations reported by Simons and Associates, Inc. (2000) for suspended load and bed load.

Stream gauge location	Equation	Number of data pairs	R^2
Suspended Load Equations			
North Platte River at Sutherland and North Platte, NE	$Q_{ss} = 3.30\ Q^{0.812}$	8	0.23
South Platte River at Kersey, Weldona, and Balzak, CO and North Platte, NE	$Q_{SS} = 0.0947\ Q^{1.32}$	21	0.82
Platte River near Overton, NE[4]	$Q_{SS} = 0.00274\ Q^{1.61}$	199	0.78
Platte River near Overton and Grand Island, NE[5]	$Q_{SS} = 0.0472\ Q^{1.28}$	14	0.93
Bed Load Equations			
North Platte River at Sutherland and North Platte, NE	$Q_{Sb} = 1.20\ Q^{0.849}$	8	0.61
South Platte River at Kersey, Weldona and Julesburg, CO and North Platte, NE	$Q_{Sb} = 0.0484\ Q^{1.35}$	15	0.95
Platte River near Overton and Grand Island, NE[6]	$Q_{Sb} = 0.146\ Q^{1.18}$	17	0.94

Where:

Q = Mean daily water discharges in cubic feet per second (ft^3/s)

Q_{SS} = Suspended sediment load in tons per day

Q_{Sb} = Bed load in tons per day

The mean annual sediment loads for each time period and stream gauge are presented in table 10 and figure 12. The sediment-discharge equation for the North Platte River is based on only 8 data pairs that

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[4] This equation was also applied to stream flows at the gauge near Cozad, NE.

[5] This equation was only applied to the stream flows at the gauge near Grand Island, NE.

[6] This equation was also applied to stream flows at the gauge near Cozad, NE.

explain 23 percent of the variance, however, the combined mean annual sediment loads for the North and South Platte Rivers, at North Platte, Nebraska, are in good agreement with the other Platte River stations during the first two time periods.

Table 10 — Platte River mean annual sediment loads based on sediment discharge equations by Simons and Associates, Inc. (2000)

	Mean annual sediment load (tons/year) for each time period			
Platte River stream gauge location	1895 to 1909	1910 to 1935	1936 to 1969	1970 to 1999
North Platte River at North Platte, NE	1,180,000	1,070,000	324,000	400,000
South Platte River at North Platte, NE	355,000	313,000	176,000	411,000
Platte River at North Platte, NE	1,530,000	1,380,000	500,000	812,000
Platte River near Cozad, NE	1,730,000	1,300,000	132,000	396,000
Platte River near Overton, NE	1,810,000	1,380,000	347,000	817,000
Platte River near Grand Island, NE	1,670,000	1,270,005	381,000	845,000

3.1.2 Sediment-Discharge Equations by Kircher (1983)

James E. Kircher presented results of his study on “Interpretation of Sediment Data for the South Platte River in Colorado and Nebraska, and the North Platte and Platte Rivers in Nebraska” in Geological Survey Professional Paper 1277, which was published in 1983. His study was based on data collected on the South Platte, North Platte, and Platte Rivers during 1979 and 1980. He presented total sediment load equations for four selected gauging stations. These regression equations were converted to English units and are presented below in table 11.

The mean annual sediment loads for each time period and stream gauge are presented in table 12 and figure 13. The results are very similar to results obtained using Simons and Associates, Inc. (2000) sediment discharge relations, shown in figure 12.

Table 11 — Sediment-discharge equations reported by Kircher (1983) for total sediment

load.

Stream gauge location	**Equation**	**Number of data pairs**	**R^2**
North Platte River at North Platte, NE	$Q_s = 0.129\ Q^{1.29}$	5	not reported
South Platte River at North Platte, NE	$Q_S = 0.128\ Q^{1.32}$	7	not reported
Platte River near Overton, NE[7]	$Q_S = 0.0925\ Q^{1.29}$	7	not reported
Platte River near Grand Island, NE	$Q_S = 0.128\ Q^{1.26}$	8	not reported

Where:

Q = Mean daily water discharges in cubic feet per second (ft^3/s)

Q_S = Total sediment load in tons per day

Table 12 — Platte River mean annual sediment loads based on sediment discharge equations by Kircher (1983)

	Mean annual sediment load (tons/year) for each time period			
Platte River stream gauge location	1895 to 1909	1910 to 1935	1936 to 1969	1970 to 1999
North Platte River at North Platte, NE	1,840,000	1,410,000	220,000	343,000
South Platte River at North Platte, NE	292,000	256,000	145,000	337,000
Platte River at North Platte, NE	2,130,000	1,670,000	365,000	680,000
Platte River near Cozad, NE	1,540,000	1,190,000	126,000	361,000
Platte River near Overton, NE	1,600,000	1,260,000	335,000	760,000
Platte River near Grand Island, NE	1,680,000	1,250,000	365,000	826,000

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[7] This equation was also applied to stream flows at the gauge near Cozad, NE for the purposes of this study.

3.1.3 Sediment-Discharge Equations by Lyons and Randle (1988)

A study was conducted by Lyons and Randle (1988) on the Platte River channel characteristics in the Big Bend reach. Sediment-discharge equations were developed for predicting suspended sediment load, unmeasured load, and bed-material load for Platte River near Overton, Nebraska (see table 13). The equations for suspended load were based on measurements that were obtained from 1950 to 1956, from 1964 to 1969, and during 1971 and 1980. A total of 215 suspended load measurements were used to develop the equations. These data were divided by discharge into two sets: less than and greater than 2,000 ft^3/s. The modified Einstein procedure was used to predict the sediment load that was transported as bed load and not measured by the suspended-sediment load sampler (unmeasured load). This procedure was applied to 25 samples where both the suspended sediment concentration and the bed-material grain size distribution were measured. The modified Einstein procedure also produced the bed-material load (sand and gravel load) for the 25 samples.

Table 13 — Sediment-discharge equations reported by Lyons and Randle (1988) for suspended load, unmeasured load, and bed-material load at the USGS stream gauge near Overton, Nebraska

Sediment discharge equation type	Equation	Number of data pairs	R^2
Suspended sediment load for $Q < 2{,}000\ ft^3/s$	$Q_{SS} = 0.00663\ Q^{1.51}$	155	0.81
Suspended sediment load for $Q > 2{,}000\ ft^3/s$	$Q_{SS} = 5.60\times10^{-5}\ Q^{2.30}$	60	0.54
Unmeasured sediment load	$Q_{um} = 0.000993\ Q^{1.76}$	25	
Bed-material load	$Q_{BM} = 0.000325\ Q_W^{1.96}$	25	

Where:

Q = Mean daily water discharges in cubic feet per second (ft^3/s)
Q_{SS} = Suspended sediment load in tons per day
Q_{um} = Unmeasured load in tons per day
Q_{BM} = Bed-material load in tons per day

The bed-material load equation for the stream gauge near Overton, Nebraska was also applied to the

Platte River gauge near Grand Island, Nebraska. Lyons and Randle (1988) computed mean annual sediment loads for the period 1958 to 1986 (see table 14). The total sediment load was computed to be 3.7 times more than the bed material load. The computed total sediment load for this period is large relative to the mean annual sediment loads computed using the sediment-discharge equations presented by Simons (2000) and Kircher (1983). Both the suspended sediment and bed-material load equations were influenced by the large sediment concentrations measured during the floods in 1965 and 1971. The 1965 flood was caused by a short-duration rain storm where the suspended sediment concentrations reached 16,000 mg/l. The 1971 flood was of similar magnitude, but was caused by snow melt and the suspended sediment concentrations were much less (700 to 800 mg/l).

Table 14 — Platte River mean annual sediment loads based on sediment discharge equations by Lyons and Randle (1988) for the period 1958 to 1986

	Mean annual sediment load (tons per year)	
Type of Sediment load	Platte River near Overton, Nebraska	Platte River near Grand Island, Nebraska
Total sediment load (clay, silt, sand, and gravel)	2,700,000	not available
Bed-material load (sand and gravel)	698,000	706,000

The bed-material load equation was applied to the stream gauges near Cozad, Overton, and Grand Island for the same four time periods listed in table 3. The mean-annual bed-material loads for these locations and time periods are presented in table 15 and figure 14. Although the bed-material load estimates in figure 14 are larger, they show the same temporal and spatial trends as the total sediment load estimates that were computed using the equations by Simons and Associates, Inc. (2000) and Kircher (1983).

Table 15 — Platte River mean annual bed-material loads based on sediment discharge equations by Lyons and Randle (1988)

	Mean annual bed-material load (tons/year) for each time period			
Platte River stream gauge location	1895 to 1909	1910 to 1935	1936 to 1969	1970 to 1999
Platte River near Cozad, NE	2,440,000	1,530,000	88,400	454,000
Platte River near Overton, NE	2,860,000	1,620,000	223,000	840,000
Platte River near Grand Island, NE	2,380,000	1,300,000	247,000	823,000

3.2 Sediment Transport Model

A sediment transport model was developed specifically for the Platte River reach between North Platte and Grand Island, Nebraska by Murphy and Randle (2001) in conjunction with Simons and Associates, Inc. The model has been used to study the causes of channel narrowing and the future channel characteristics under different management scenarios. The model simulates the process linkages between hydrology, river hydraulics, sediment transport, erosion, deposition, grain size armoring, and the growth and removal of vegetation. The initial conditions for the model include the cross section geometry (station and elevation coordinates) and the bed-material grain size distribution and vegetation characteristics for each coordinate point. The boundary conditions include the mean-daily stream flow at a cross section over time.

For each daily time step, the model computes channel hydraulics at each river cross section based on the assumption of normal depth. The model then computes the bed-material load, based on the local channel hydraulics and bed material grain size, using Yang's sediment transport equations for sand and gravel (Yang, 1973 and 1984). Deposition or erosion is determined based on the difference in the daily sediment transport rate between any two cross sections. The bed material tends to become finer with deposition and coarser with erosion. Vegetation is allowed to establish on bare sand and grow during the proper seasons. The model removes vegetation that dies of desiccation, drowning, river flow scour, or ice scour.

The model was used to compute daily bed-material loads at each of 17 cross sections from North Platte to Grand Island, Nebraska for water years 1895 to 1999. The daily sediment loads, corresponding to the stream gauges listed in table 1, were used in this analysis. The mean annual bed-material loads computed by the model are presented in table 16 and figure 15.

Table 16 — Platte River mean annual sediment loads based on the sediment transport model by Murphy and Randle (2001)

	Mean annual sediment load (tons/year) for each time period			
Platte River stream gauge location	1895 to 1909	1910 to 1935	1936 to 1969	1970 to 1999
North Platte River at North Platte, NE	896,000	545,000	31,000	71,900
South Platte River at North Platte, NE	212,000	203,000	99,600	245,000
Platte River at North Platte, NE	1,110,000	748,000	131,000	317,000
Platte River near Cozad, NE	1,030,000	662,000	40,900	191,000
Platte River near Overton, NE	1,060,000	739,000	106,000	562,000
Platte River near Grand Island, NE	1,040,000	645,000	121,000	374,000

3.3 Comparison of Sediment Transport Functions

The sediment-discharge equations that were used in this analysis are summarized in table 17. This table shows the equations (listed in tables 9 and 11) applied to each stream gauge location. The equations for the Platte River near Overton, Nebraska were also applied to the station near Cozad, Nebraska; therefore the differences in sediment load between these two stations are only due to the differences in river flow. Separate equations were used for the Platte River near Grand Island, Nebraska, but the computed mean annual sediment loads for this station are similar to the loads computed for the station near Overton, Nebraska for all four time periods.

Table 17 — Application of sediment-discharge equations by Kircher (1983) and Simons and Associates, Inc. (2000) to Platte River stream gauge locations.

	Sediment-discharge Equations	
Platte River Gauging Station	**Total Sediment Load (Kircher, 1983)**	**Total Sediment Load (Simons, 2000)**
North Platte River at North Platte, NE	$Q_s = 0.1287\ Q^{1.29}$	$Q_s = 3.3\ Q^{0.812} + 1.20\ Q^{0.849}$
South Platte River at North Platte, NE	$Q_s = 0.1278\ Q^{1.32}$	$Q_s = 0.0947\ Q^{1.32} + 0.0484\ Q^{1.35}$
Platte River near Cozad, NE	$Q_s = 0.0925\ Q^{1.29}$	$Q_s = 0.00274\ Q^{1.61} + 0.146\ Q^{1.18}$
Platte River near Overton, NE	$Q_s = 0.0925\ Q^{1.29}$	$Q_s = 0.00274\ Q^{1.61} + 0.146\ Q^{1.18}$
Platte River near Grand Island, NE	$Q_s = 0.1283\ Q^{1.26}$	$Q_s = 0.0472\ Q^{1.28} + 0.146\ Q^{1.18}$

Note: Q_s is the sediment load in tons per day and Q is the mean-daily discharge in ft^3/s.

The three methods for computing sediment loads produce similar temporal and spatial trends. The same trends were noted from the values for the mean river flow and the 1.5-year flood peaks. Although the sediment-discharge equations are assumed to remain constant over time, the trends in mean annual sediment load computed from these equations are essentially the same as the sediment load trends produced using the SEDVEG model where the Platte River sediment-discharge relationships are allowed to change over time.

For a given stream gauge location and time period, the computed mean annual sediment loads are about the same using either the sediment-discharge equations presented by Simons and Associates, Inc. (2000) or by Kircher (1983). However, when North Platte River flows exceed 9,000 ft^3/s, the total sediment loads predicted using the equation by Simons and Associates (2000) are at least 50 percent less than the sediment loads computed using the equation by Kircher (1983). When North Platte River flows are less than 450 ft^3/s, the sediment loads computed using the equation by Simons and Associates (2000) are more than double the sediment loads computed using the equation by Kircher (1983). When North Platte River flows are 2,000 ft^3/s, the computed sediment loads are the same using either equation.

Average annual sediment loads computed using the sediment-discharge equations presented by Simons (2000) or the SEDVEG model show close agreement at all stations for the first two time periods. In contrast, the sediment-discharge equations presented by Kircher (1983) produce average annual sediment loads for the North Platte River at North Platte, Nebraska that are at least 10 percent higher than the average annual loads for the downstream stations. The combined average annual sediment loads for the North and South Platte Rivers are at least 27 percent higher than the downstream stations.

For the South Platte River, the sediment loads computed using the equations by Simons and Associates are about 20 percent greater than the sediment loads computed using the equations by Kircher (1983). For the Platte River gauges near Cozad, Overton, and Grand Island, Nebraska, the total sediment loads computed using the equations by Simons and Associates (2000) are typically greater than, but very close to (within 10 to 20 percent) the sediment loads computed using the equations by Kircher (1983).

The average annual bed-material loads, computed by the sediment transport model, are 21 to 90 percent less (averaging 50 percent less) than the average annual loads computed by either set of sediment-discharge equations. This is expected because the bed-material load does not include the silt and clay-sized sediments that are carried in suspension, whereas the total sediment loads include all particle sizes (clay, silt, sand, and gravel). Of the 12 sediment load samples from the Platte River gauges near Overton and Grand Island, Nebraska (Kircher, 1983), the silt and clay portions of those sediment loads ranged from 2 to 89 percent with an mean of 59 percent. These data suggest that the sediment loads computed by the SED-VEG Model agree reasonably well with the sediment loads computed using the sediment-discharge equations.

3.4 Sediment Load Trends

Regardless of the computational methods used, sediment loads for the North Platte and Platte Rivers have generally decreased over the 20th century. The general decrease in sediment loads for the North Platte and Platte Rivers follows the reduction in mean river flow and the 1.5-year peak flood. The general decrease in river flow and sediment load would be expected to result in a narrower river channel (Leopold and Maddock, 1953).

The North Platte River was the dominant source of sediment to the Platte River during the first two time periods (1895 to 1935). During these time periods, the average annual sediment loads from the North

Platte River were roughly 3 to 6 times greater than the average annual sediment loads from the South Platte River. Average annual sediment loads from the North Platte River decreased to their lowest levels during the third period (1936 to 1969) and then increased again during the fourth period (1970 to 1999). However, average annual sediment loads for this most recent period (1970 to 1999) were only 13 to 37 percent of the average annual sediment loads for the second period (1910 to 1935).

Average annual sediment loads from the South Platte River decreased to their lowest level over the third time period, but then increased to their highest level over the fourth time period. During the first two time periods, sediment loads from the South Platte River were only a fraction of the sediment loads supplied from the North Platte River. As the sediment loads from the North Platte River decreased over the third and fourth time periods, the sediment loads from the South Platte River became a much more significant contribution to the total sediment load supplied to the Platte River.

The mean annual sediment loads for the North Platte and Platte Rivers were highest for the period 1895 to 1909 and of similar magnitude for all gauging locations. During the period 1910 to 1935, the mean annual sediment loads decreased, but were still of similar magnitude for all North Platte and Platte River gauging stations. The mean annual sediment loads decreased to their lowest values during the period 1936 to 1969. During this period, a new spatial trend began where the average annual sediment load for the Platte River gauge near Cozad, Nebraska was much less than the sediment loads at either the upstream or downstream gauging stations.

Because of flow diversions into the Tri-County Canal, Platte River flows and sediment loads have especially reduced in the 70-mile reach between North Platte, Nebraska and the Johnson-2 Return Channel. This is indicated by the significant reductions in the Platte River sediment load passing the gauge near Cozad, Nebraska during the last two time periods (see figures 12 through 15). During the period 1936 to 1969, the average annual sediment load passing near Cozad, Nebraska was 26 to 35 percent of the combined average annual sediment load from the North and South Platte Rivers and 38 to 39 percent of the average annual sediment load passing Overton, Nebraska. During the period 1970 to 1999, the average annual sediment loads increased at all stations and the amount passing near Cozad, Nebraska was 49 to 60 percent of the combined average annual sediment load from the North and South Platte Rivers and 34 to 48 percent of the average annual sediment load passing Overton, Nebraska. The decrease in sediment transport for the reach represented by the stream gauge near Cozad, Nebraska, relative to the combined contributions from the North and South Platte Rivers, would be expected to result in sediment deposition or aggradation along a portion of this 70-mile reach.

The decrease in sediment loads for the gauge near Cozad, Nebraska (during the period 1936 to 1999) results from the decreased stream flow. A significant volume of the Platte River is diverted at the Tri-County Diversion Dam into the Tri-County Canal (see figure 1) and then returned to the Platte River through the Johnson-2 return channel a few miles upstream from the stream gauge near Overton, Nebraska. Any sediment in the flows diverted into the Tri-County Canal would likely deposit in the reservoirs along the alignment of the canal. The canal flow that is returned back to the Platte River at the Johnson-2 return, upstream from Overton, Nebraska, contains little if any sediment and has the capacity to erode the downstream river channel.

Sediment loads then increase downstream of the Johnson-2 return, in the reach between Overton and Grand Island, Nebraska. The main source of sediment between the Johnson-2 return channel and the stream gauge near Overton, Nebraska is the channel bed and banks. Erosion of the channel bed has been measured over the 13-year period from 1989 to 2002 in the 18-mile reach downstream from the Johnson-2 canal return-flow channel (see cross section survey data in the CD appendix). Immediately downstream from the Johnson-2 return channel, the channel thalweg in 2002 was nearly 20 feet lower than the top of the right bank. Between 1989 and 2002, the channel at this location eroded 6 feet vertically. The amount of vertical erosion over this same time period decreased in the downstream direction and was 1 foot at a distance of nearly 18 miles downstream from the clear water return flow.

4.0 Effective Discharge Analysis

An alluvial river continually adjusts its channel geometry, including width and depth, to the wide range of flows that mobilize its bed and banks (Biedenharn, et al., 2000). However, in many rivers a single representative discharge can be used to determine a stable geometry assuming that the river channel is in equilibrium. In this case, equilibrium means that the channel is neither aggrading nor degrading. Even though the channel may migrate laterally across the flood plain, the active channel width remains fairly constant over time. This representative discharge has been given several names including *dominant* discharge, *channel-forming* discharge, *bankfull* discharge, and *effective* discharge. The bankfull discharge is the flow rate that fills the channel to the top of its banks or the threshold discharge that just begins to inundate the flood plain. However, the bankfull discharge is very difficult to determine when channels are either aggrading or degrading (incising). Leopold (1994) stated that most investigations have concluded that the bankfull discharge recurrence intervals range from 1.0 to 2.5 years and is often assumed to have a recurrence interval of 1.5 years.

Biedenharn, et al. (2000) defines the effective discharge as the flow “that transports the largest fraction of the bed material load.” Hey (1997) has indicated that the dominant channel forming discharge is best represented by the effective discharge. In theory, the effective discharge maintains the channel geometry because of its frequency of occurrence and sediment transport capacity, by transporting more sediment during a given period than any other discharge (Karlinger, et. al. 1983). For the Platte River, the effective discharge has been calculated using three different methods and the results are compared to the 1.5-year peak flood magnitudes (see section 2.3).

In the first method, the discharge that transports the most sediment over time is determined from the greatest cumulative sediment load transported among 20 equal discharge intervals or classes. The use of arithmetically based discharge increments is the method most commonly used to compute effective discharge and is described by Biedenharn, et al. (2000) and Soar and Thorne (2001). Other investigators have also used logarithmically based discharge increments (Karlinger et al. 1983 and Lyons and Randle, 1988).

In the second method, the discharge that transports the most sediment over time is determined from the greatest sediment load transported among many discharge intervals that correspond to an interval of cumulative sediment transport probability. This method has been used by Reclamation (Strand and Pemberton, 1982) to determine the mean annual sediment transport rate of a river over a given time period. In the third method, the median sediment transporting discharge separates the stream flows so that half the sediment load is transported by discharges that are greater while the remaining half is transported by discharges that are lower. The median sediment transporting discharge is determined from a cumulative frequency analysis of discharge and sediment load.

Each of these three methods requires a continuous record of discharge, on a mean-daily or hourly basis, and a sediment transport function. Because there is considerable flow variability within each month and because sediment load increases with the power of discharge, mean-monthly flow values are not applicable for the effective discharge computation. For most of the Platte River, hourly variability within the mean-daily discharge is small. Therefore, mean-daily discharge values were used in the effective discharge computations. The discharge record for each gauging station and time period was sorted by flow magnitude along with the corresponding sediment load. The cumulative exceedance probability was then computed for each discharge along with the cumulative exceedance probability for flow volume and sediment load.

Three different sediment transport functions were used to compute the sediment load for each of the three effective discharge methods described above. Two of these functions are sediment-discharge equations based on statistical regression analysis of measured discharge and sediment load (see sections 3.1.1 and 3.1.2). The other sediment transport function is in the form of deterministic hydraulic and sediment transport model developed specifically for the Platte River (see section 3.2) and based on the sediment transport equations by Yang (1973 and 1984). While the sediment-discharge equations assume a constant relationship between discharge and sediment load, the sediment transport model allows the cross section geometry, roughness, and the bed-material grain size to change over time.

Both channel width and vegetation can affect the sediment transport rate. The effective discharge computation and two of the sediment transport functions do not directly consider riparian vegetation or channel width, however, the sediment transport model does account for channel width and vegetation.

4.1 Effective Discharge by Equal Discharge Interval Method

For this method, the range of flows for a given station and time period are grouped into equal discharge class intervals and the cumulative sediment load transported in each class interval is calculated. The arithmetic mean of the class which transports the greatest amount of sediment is defined as the Effective Discharge.

The mean-daily flows were divided into 20 equal discharge intervals for each gauging station and each time period. An example of the equal discharge interval method is presented in table 18 for the Platte River near Overton, Nebraska during the period 1895 to 1909. For this example, the discharge values range from 1 to 30,000 ft^3/s. When 20 class intervals are used, the equal discharge increment is 1,500 ft^3/s. The class interval is shown in column 1. The number of discharge values and the midrange discharge of the class interval are shown in columns 2 and 3. The water flow volume for each class interval and fraction of the flow volume is presented in columns 4 and 5. The cumulative sediment load for each class interval and the fraction of the sediment load is presented in columns 6 and 7. The effective discharge of 2,250 ft^3/s, in class interval 19, corresponds to the interval with the greatest sediment load.

Figure 16 shows how the effective discharge curves have changed over time for the Platte River near Overton, Nebraska. For the equal discharge increment method, the effective discharge is skewed toward low flows. The detailed results from the application of the equal-discharge-increment method to all stream gauge locations and time periods are presented in the CD Appendix. Equal discharge increments with 30 and 40 intervals were also tried, but the results were somewhat erratic (see CD appendix). A comparative summary of these results are presented in tables 19 through 23 and figures 17 through 21. These figures show the variation of effective discharge with both time and location along the Platte River and its tributaries.

Soar and Thorne (2001) found that the effective discharge computed using equal discharge increments is less than the bankfull discharge at 86 percent of their 58 sites. This suggests that the effective discharge procedure using equal discharge intervals frequently underestimates the bankfull discharge. In order to remedy this problem, Soar and Thorne (2001) developed an equation to compute the ratio of bankfull discharge to effective discharge as a function of the long-term sediment load fraction that is transported by discharges that are less than the effective discharge.

$$\frac{Q_b}{Q_e} = 121.75\, Y_e^{-1.19} \qquad (3)$$

Where Q_b is the bankfull discharge,

Q_e is the effective discharge, and Ye is the percentage of the long-term sediment load transported by discharges not exceeding the effective discharge.

Table 18 — Effective discharge analysis by equal discharge increments for the Platte River near Overton, Nebraska

The analysis period is from 10/1/1894 to 9/30/1909

Maximum Discharge (ft^3/s)	Minimum Discharge (ft^3/s)	Number of Intervals	Discharge Increment (ft^3/s)
30,000	1.0	20	1,500

(1)	(2)	(3)	(4)	(5)	(6)	(7)
					Sediment Load Computed using Simons (2000)	
Class Interval	**Number of discharge values**	**Midrange Discharge of Class Interval (ft^3/s)**	**Flow Volume (ft^3/s-days)**	**Flow Volume Fraction**	**Load (tons/yr)**	**Sediment Fraction**
1	4	29,250	7,805	0.00584	18,597	0.01027
2	5	27,750	9,271	0.00694	21,599	0.01193
3	6	26,250	10,525	0.00788	23,931	0.01322
4	10	24,750	16,630	0.01244	36,942	0.02040
5	12	23,250	18,438	0.01380	39,579	0.02186
6	15	21,750	21,734	0.01626	45,490	0.02513
7	27	20,250	36,634	0.02741	74,557	0.04118
8	28	18,750	35,204	0.02634	69,371	0.03832
9	41	17,250	47,071	0.03522	89,282	0.04931
10	57	15,750	59,962	0.04487	109,670	0.06057
11	62	14,251	59,169	0.04427	103,963	0.05742
12	76	12,751	64,098	0.04796	107,109	0.05916
13	111	11,251	83,054	0.06215	132,277	0.07306
14	112	9,751	72,528	0.05427	109,136	0.06028
15	170	8,251	91,715	0.06863	128,573	0.07102
16	230	6,751	102,953	0.07704	134,518	0.07430
17	278	5,251	95,882	0.07174	113,882	0.06290
18	656	3,751	156,884	0.11739	163,823	0.09048
19	1775	**2,251**	250,822	0.18768	**220,451**	0.12176
20	1628	751	96,054	0.07187	67,758	0.03742
TOTAL			1,336,444		1,810,506	

Table 19 — Comparison of effective discharge results for the North Platte River at North Platte, Nebraska

	Analysis time period			
Analysis Method	1895-1909	1910-1935	1936-1969	1970-1999
1.5-year flood peak (ft^3/s)	16,300	8,150	2,160	2,380
Effective discharge by equal discharge interval method (ft^3/s):				
Simons and Associates, Inc (2000)	2,050	3,010	471	321
Kircher (1983)	2,050	3,010	471	321
Sediment Transport Model (Murphy and Randle, 2003b)	11,500	3,010	1,660	6,620
Adjusted to bankfull discharge using equation 3				
Simons and Associates, Inc (2000)	3,870	2,540	612	571
Kircher (1983)	7,650	3,280	966	1,210
Sediment Transport Model (Murphy and Randle, 2003b)	9,960	5,170	1,660	3,830
Effective discharge by probability method (ft^3/s):				
Simons and Associates, Inc (2000)	7,950	4,660	1,480	1,920
Kircher (1983)	7,950	4,660	1,480	1,920
Sediment Transport Model (Murphy and Randle, 2003b)	7,950	4,660	1,480	3,440
Median sediment transporting discharge (ft^3/s):				
Simons and Associates, Inc (2000)	4,750	3,000	730	1,240
Kircher (1983)	7,440	3,500	1,180	1,980
Sediment Transport Model (Murphy and Randle, 2003b)	10,200	5,200	1,700	4,130

Table 20 — Comparison of effective discharge results for the South Platte River at North Platte, Nebraska

Analysis Method	Analysis time period			
	1895-1909	1910-1935	1936-1969	1970-1999
1.5-year flood peak (ft^3/s)	2,330	1,430	712	1,420
Effective discharge by equal discharge interval method (ft^3/s):				
Simons and Associates, Inc (2000)	343	551	493	464
Kircher (1983)	343	551	493	464
Sediment Transport Model (Murphy and Randle, 2003b)	1,030	551	493	1,290
Adjusted to bankfull discharge using equation 3				
Simons and Associates, Inc (2000)	1,160	1,140	846	1,730
Kircher (1983)	1,130	1,110	825	1,680
Sediment Transport Model (Murphy and Randle, 2003b)	3,680	2,710	2,570	6,150
Effective discharge by probability method (ft^3/s):				
Simons and Associates, Inc (2000)	3,080	2,250	8,610	3,410
Kircher (1983)	3,080	2,250	8,610	3,410
Sediment Transport Model (Murphy and Randle, 2003b)	3,080	5,750	8,610	8,540
Median sediment transporting discharge (ft^3/s):				
Simons and Associates, Inc (2000)	2,370	3,050	2,200	4,200
Kircher (1983)	2,330	3,000	2,120	4,100
Sediment Transport Model (Murphy and Randle, 2003b)	4,290	5,800	5,720	6,970

Table 21 — Comparison of effective discharge results for the Platte River near Cozad, Nebraska

Analysis Method	**Analysis time period** 1895-1909	1910-1935	1936-1969	1970-1999
1.5-year flood peak (ft^3/s)	17,600	9,140	1,980	2,590
Effective discharge by equal discharge interval method (ft^3/s):				
Simons and Associates, Inc (2000)	2,300	3,000	381	531
Kircher (1983)	2,300	3,000	381	531
Sediment Transport Model (Murphy and Randle, 2003b)	11,500	3,000	1,900	10,100
Adjusted to bankfull discharge using equation 3				
Simons and Associates, Inc (2000)	10,300	4,130	921	3,610
Kircher (1983)	9,140	3,870	899	3,330
Sediment Transport Model (Murphy and Randle, 2003b)	13,500	6,940	5,360	8,730
Effective discharge by probability method (ft^3/s):				
Simons and Associates, Inc (2000)	8,830	5,590	1,030	6,400
Kircher (1983)	8,830	5,590	1,030	6,400
Sediment Transport Model (Murphy and Randle, 2003b)	8,830	5,590	7,630	6,400
Median sediment transporting discharge (ft^3/s):				
Simons and Associates, Inc (2000)	9,630	4,750	2,040	6,340
Kircher (1983)	8,860	4,420	1,970	6,060
Sediment Transport Model (Murphy and Randle, 2003b)	12,400	7,220	4,700	9,260

Table 22 — Comparison of effective discharge results for the Platte River near Overton, Nebraska

	Analysis time period			
Analysis Method	1895-1909	1910-1935	1936-1969	1970-1999
1.5-year flood peak (ft^3/s)	19,400	9,000	3,490	4,750
Effective discharge by equal discharge interval method (ft^3/s):				
Simons and Associates, Inc (2000)	2,250	2,750	1,100	1,750
Kircher (1983)	2,250	2,750	1,100	1,750
Sediment Transport Model (Murphy and Randle, 2003b)	11,300	2,750	1,840	1,750
Adjusted to bankfull discharge using equation 3				
Simons and Associates, Inc (2000)	10,200	5,020	1,800	3,880
Kircher (1983)	9,020	4,680	1,760	3,630
Sediment Transport Model (Murphy and Randle, 2003b)	14,500	8,850	2,620	3,670
Effective discharge by probability method (ft^3/s):				
Simons and Associates, Inc (2000)	9,100	6,000	2,140	4,070
Kircher (1983)	9,100	6,000	2,140	4,070
Sediment Transport Model (Murphy and Randle, 2003b)	9,100	6,000	2,140	4,070
Median sediment transporting discharge (ft^3/s):				
Simons and Associates, Inc (2000)	10,200	5,150	1,770	4,020
Kircher (1983)	9,210	4,970	1,740	3,760
Sediment Transport Model (Murphy and Randle, 2003b)	12,900	7,310	2,600	3,500

Table 23 — Comparison of effective discharge results for the Platte River near Grand Island, Nebraska

	Analysis time period			
Analysis Method	1895-1909	1910-1935	1936-1969	1970-1999
1.5-year flood peak (ft^3/s)	17,300	10,100	4,500	6,010
Effective discharge by equal discharge interval method (ft^3/s):				
Simons and Associates, Inc (2000)	2,880	2,520	1,340	1,760
Kircher (1983)	2,880	2,520	1,340	1,760
Sediment Transport Model (Murphy and Randle, 2003b)	10,600	2,520	2,240	2,940
Adjusted to bankfull discharge using equation 3				
Simons and Associates, Inc (2000)	8,400	4,770	1,790	3,570
Kircher (1983)	8,890	4,940	1,850	3,730
Sediment Transport Model (Murphy and Randle, 2003b)	14,900	9,930	3,340	7,450
Effective discharge by probability method (ft^3/s):				
Simons and Associates, Inc (2000)	9,220	5,770	2,290	7,610
Kircher (1983)	9,220	5,770	2,290	4,400
Sediment Transport Model (Murphy and Randle, 2003b)	9,220	5,770	2,290	4,400
Median sediment transporting discharge (ft^3/s):				
Simons and Associates, Inc (2000)	8,000	4,250	1,990	3,580
Kircher (1983)	9,960	4,920	2,280	4,500
Sediment Transport Model (Murphy and Randle, 2003b)	12,800	7,300	3,450	6,640

Equation 3 suggests that effective discharge will equal the bankfull discharge when 56.55 percent of the sediment load is transported by discharges up to the effective discharge. The equation was used to compute bankfull discharge, as an indicator of the channel forming discharge, for each of the effective discharges that were computed using the equal discharge method (see tables 19 through 23).

The effective discharge of Platte River near Overton was also determined by Lyons and Randle (1988) for three different periods: 1926-39, 1940-57 and 1958-86 (see table 24). The range of discharge values were equally divided into 33 equally spaced logarithmic intervals with the highest interval incorporating the highest discharge value in the record. The sand-load rating curves presented in this report were used to compute the sand load carried by each discharge interval. For the later time period (1958 to 1986) there were multiple peaks in the effective discharge curve so a range of effective discharge values were described rather than a single discharge. The effective discharge plots in Lyons and Randle (1988) show that the sediment load has decreased dramatically over time.

Table 24 — Effective discharge results for the Platte River near Overton, Nebraska based on the equations by Lyons and Randle (1988).

	Analysis time period		
Analysis Method	1926-1939	1940-1957	1958-1986
Effective discharge by 33 logarithmic discharge intervals (ft^3/s):Lyons and Randle, 2001	3,900	1,650	1,000 to 10,000

4.2 Effective Discharge by Probability Method

For this method, the cumulative discharge exceedance probability is computed for each of the ranked discharges. The ranked discharge values are then divided into probability intervals, assuming a normal probability distribution. An example of the probability method is presented in table 25 for the Platte River near Overton, Nebraska for the period 1895 to 1909. A total of 19 class intervals were used. The class interval is shown in column 1. The number of discharge values and their cumulative exceedance probability are shown in columns 2 and 3. The class intervals are determined so that there are an equal number of discharge values (548 in this

Table 25 — Effective discharge analysis by probability increments for the Platte River near Overton, Nebraska

The analysis period is from 10/1/1894 to 9/30/1909

Maximum Discharge (ft^3/s)	Minimum Discharge (ft^3/s)	Number of Intervals
30,000	1.0	19

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Class Interval	**Number of discharge values**	**Cumulative Exceedance Probability**	**Midrange Discharge (ft^3/s)**	**Flow Volume (ft^3/s-days)**	**Flow Volume Fraction**	**Sediment Load**	
						Load (tons/yr)	**Sediment Fraction**
1	1	0.0001	30,000	2,000	0.00150	4,818	0.00266
2	4	0.0006	28,882	7,683	0.00575	18,179	0.01004
3	22	0.0030	25,315	37,728	0.02823	85,001	0.04695
4	55	0.0100	20,914	77,507	0.05799	160,439	0.08862
5	191	0.0325	15,800	202,904	0.15182	373,756	0.20644
6	548	0.1000	**9,100**	346,722	0.25944	**522,381**	**0.28853**
7	548	0.2000	5,140	193,567	0.14484	233,066	0.12873
8	548	0.3000	3,399	124,837	0.09341	127,975	0.07068
9	548	0.4000	2,520	93,311	0.06982	86,697	0.04789
10	547	0.5000	2,111	77,018	0.05763	67,144	0.03709
11	548	0.6000	1,805	65,312	0.04887	54,005	0.02983
12	548	0.7000	1,417	51,648	0.03865	39,681	0.02192
13	548	0.8000	1,078	38,739	0.02899	27,339	0.01510
14	547	0.9000	508	17,066	0.01277	9,891	0.00546
15	192	0.9675	7	398	0.00030	140	0.00008
16	55	0.9900	1	4	0.00000	1	0.00000
17	22	0.9970	1	1	0.00000	0	0.00000
18	4	0.9994	1	0	0.00000	0	0.00000
19	1	0.9999	0	0	0.00000	0	0.00000
TOTAL				1,336,445		1,810,513	

example) in the middle 9 class intervals (intervals 6 through 14). The number of discharge values reduces toward the lowest and highest class intervals (intervals 1 and 19). The midrange discharge of each class interval is shown in column 4. The water flow volume for each class interval and its fraction of the total volume are presented in columns 5 and 6. The sediment load for each class interval and its fraction of the total are presented in columns 7 and 8. The effective discharge of 9,100 ft^3/s (class interval 6) corresponds to the class interval with the greatest sediment load.

Figure 22 shows how the effective discharge curves have changed over time for the Platte River near Overton, Nebraska. For the probability method, the effective discharge is relatively close to the centroid of the area under the curve. The detailed results from the application of the probability-increment method to all stream gauge locations and time periods are presented in the Appendix (see compact disk). A comparative summary of these results are presented in tables 19 through 23 and figures 17 through 21. These figures show the variation of effective discharge with both time and location along the Platte River and its tributaries.

4.3 Median Sediment Transporting Discharge Method

For this method, the discharge values are ranked along with the corresponding sediment loads. The cumulative exceedance probability of the total sediment load is then computed for each discharge-sediment load pair (see table 26). The effective discharge corresponds to the discharge for which half of the total sediment load is transported by discharges that are greater while the remaining half is transported by discharges that are lower. The discharge corresponding to any cumulative exceedance probability for sediment load (e.g., 25, 50, and 75 percent) can also be determined (see figure 23).

An example this method is presented in table 26 for the Platte River near Overton, Nebraska for the period 1895 to 1909. All discharge values are used in the analysis without combining them into class intervals. The discharge ranking (highest to lowest) is shown in column 1. The date (year/month/day) on which the discharge occurred is shown in column 2. The cumulative exceedance probability and the corresponding discharge are shown in columns 3 and 4. The cumulative exceedance probability for water flow volume is shown in column 5. The sediment load and its cumulative exceedance probability are shown in columns 6 and 7.

This method of analysis uses the cumulative exceedance probability of each discharge-sediment load pair for the time period of analysis. The cumulative exceedance probability curves present a clear picture of flow and sediment transport for a given location and period of analysis. The summary results are presented in tables 19 through 23 and detailed results are presented in the CD Appendix. The cumulative sediment load probabilities are used to determine the discharge values corresponding to the quartiles of cumulative sediment load (i.e., 0 to25 percent, 25 to50 percent, 50 to 75 percent, and 75 to100 percent of the total sediment load). The range of flow required to transport one fourth of total sediment load is relatively narrow for the two middle quartiles (25 to 50 percent and 50 to 75 percent) and widest for the highest quartile (75 to 100). This is because the flows that transport sediment in the highest quartile occur with the least frequency and over a wide range. From these plots one can choose the range of flow, which transports 25 percent, 50 percent, or 75 percent of the sediment. The median sediment transporting discharge for each gauging station and time period are presented in tables 19 through 23 and figures 17 through 21.

Table 26 — Median sediment transporting discharge method applied to the Platte River near Overton, Nebraska

(1)	(2)	(3)	(4)	(5)	(6)	(7)
					Sediment Load Computed using Simons (2000)	
Discharge ranking	**Date**	**Discharge Cumulative Exceedance Probability**	**Discharge (cfs)**	**Flow Volume Cumulative Exceedance Probability**	**Sediment Load (tons/day)**	**Sediment Cumulative Exceedance Probability**
1	1905 / 6 / 17	0.00018	30,000	0.00150	72,263	0.00266
2	1897 / 6 / 10	0.00037	29,192	0.00295	69,472	0.00522
3	1905 / 6 / 18	0.00055	29,000	0.00440	68,814	0.00775
164	1909 / 6 / 10	0.02994	16,124	0.16514	29,749	0.24942
165	1905 / 5 / 11	0.03012	16,100	0.16594	29,686	0.25051
484	1906 / 5 / 31	0.08835	10,200	0.36686	15,634	0.49946
485	1895 / 3 / 1	0.08854	**10,160**	**0.36737**	**15,549**	**0.50003**
1242	1896 / 6 / 2	0.22673	4,517	0.62260	5,099	0.74995
1243	1900 / 3 / 12	0.22691	4,510	0.62283	5,088	0.75014
5477	1906 / 8 / 23	0.99982	1	1.00000	0	1.00000
5478	1900 / 9 / 20	1.00000	1	1.00000	0	1.00000

4.4 Comparison of Effective Discharge Methods

The effective discharge varies with the method of computation: equal discharge intervals, discharge intervals based on probability increments, or the median sediment transporting discharge. For the equal discharge interval method, Karlinger et al. (1983) found that the effective discharge varies with the number of discharge intervals and the type of interval used: arithmetic or logarithmic. A comparison of effective discharge computations, by Karlinger (1983), for the Platte River gauges near Overton and Grand Island, Nebraska shows how the results vary with both the number and type of intervals (see table 27).

Table 27 — Variation in effective discharge as a function of the number and type of water-discharge intervals (Karlinger et al. 1983)

	Platte River near Overton, Nebraska (1950 to 1979)			Platte River near Grand Island, Nebraska (1935 to 1979)		
Type of Interval	Number of Intervals	Sediment Load (tons/day)	Effective Discharge (cfs)	Number of Intervals	Sediment Load (tons/day)	Effective Discharge (cfs)
Arithmetic	35	1,229	1,624	35	1,211	1,624
Arithmetic	69	1,224	1,236	69	1,197	1,589
Arithmetic	103	1,220	1,201	103	1,210	1,430
Arithmetic	137	1,220	1,095	137	1,185	1,271
Arithmetic	171	1,214	1,148	171	1,186	1,148
Logarithmic	35	823	1,165	35	1,173	2,101
Logarithmic	69	1,207	1,448	69	1,175	1,942
Logarithmic	103	1,213	1,554			
Logarithmic	137	1,221	1,624	137	1,183	1,518

Arithmetic discharge intervals can include too many discharge values in the lowest discharge intervals and relatively few discharge values in the highest discharge intervals. This can bias the results so the number of intervals becomes important. Logarithmic discharge intervals are effective at dividing the low discharge values into many intervals, but they can include too many discharge values in the highest discharge intervals. The report by Biedenharn, et al. (2000) only recommends the use of arithmetic intervals. Biedenharn also states that "the computed effective discharge will be significantly underestimated" when a large portion of the discharge values fall within the lowest discharge intervals. Compared to the other methods presented in tables 19 through 23, the effective discharges that were computed using 20 equal discharge intervals consistently yielded the lowest values. This might suggest that more intervals are needed, but 30 and 40 intervals often produced erratic results with multiple peaks (see appendix).

One way to judge the validity of the effective discharge results is to determine the portion of the sediment load that is transported by discharges that are greater than the effective discharge. If a substantial portion of the sediment load is transported by discharges greater than the computed effective discharge, then the results likely are not representative of the channel forming discharge and equation 3 (Soar and Thorne, 2001) should be used to correct the results to the bankfull discharge. The correction to the bankfull discharge produces results that are much more consistent with the effective discharge computed using probability intervals and the median sediment transporting discharge. Equation 3 predicts that the effective discharge will equal the bankfull discharge when the effective discharge is close to the median sediment transporting discharge (i.e., 56 percent of the sediment is transported by discharges up to and including the effective discharge).

When probability intervals are used to compute the effective discharge, the discharge values are more uniformly distributed among the intervals and there is much less bias toward either high flows or low flows. In general, the effective discharge results, using probability intervals, more closely agree with the median sediment transporting discharge, than the results using the equal discharge interval method.

The median sediment transporting discharge is the one method that does not depend on the number or type of discharge intervals nor the number of modes that may be present in the effective discharge curve. The method will always provide the centroid of the effective discharge curve (i.e., half the total sediment load for the period will be transported by discharges that are higher and half by discharges that are lower). This method only varies by the choice of the time period and the sediment transport function.

For a given effective discharge method, gauging station, and time period, there is little or no variation in results when using either the sediment discharge rating curve equation by Kircher (1983) or Simons and Associates, Inc. (2000). The sediment loads computed using the sediment-discharge equations by Simons and Associates, Inc. (2000) or Kircher (1983) do not account for changes in cross section geometry, roughness, or bed-material grain size over time. However, the sediment loads computed using the transport model by Murphy and Randle (2003b) do account for these changes over time. The effective discharge results computed using the sediment transport model were nearly always the same or greater than the results using one of the sediment discharge rating curve equations. However, when effective discharge was computed using the probability increments, the results did not vary among the three sediment transport function 80 percent of the time.

The determination of effective discharge for the Platte River, by the use of equal discharge intervals (either arithmetic or logarithmic), was sensitive to the number and type of discharge intervals and the choice of the sediment transport function. The lowest effective discharge values were computed using the equal discharge interval method and the sediment-discharge equations by either Simons and Associates, Inc. (2000) or Kircher (1983). The fraction of sediment transported by flows up to these effective discharge values is typically less than one-third, so that two thirds of the sediment is transported by flows greater than the effective discharge. When a large portion of the total sediment load is transported by discharges that are greater than the computed effective discharge, the results should be adjusted by equation 3 (Soar and Thorne, 2002). This equation suggests that effective discharge will equal the bankfull discharge when the effective discharge is close to the median sediment transporting discharge.

The effective discharge values computed using the probability intervals agreed well with the median sediment transporting discharge and did not require adjustment. The trends in these values also agreed well with the trends in mean river flow and the 1.5-year peak flow. The median sediment transporting discharge is the most objective indicator of the channel forming flow method because it does not depend on either the number or type of discharge intervals. The median sediment transporting discharge only depends on the hydrology for the period time selected and the choice of the sediment transport function.

4.5 Effective Discharge Trends

As an indicator of the channel forming discharge, the trends in effective discharge have implications for the width and depth of the river channel. Regardless of the method used, effective discharge has declined over the 20th century along the North Platte and Platte Rivers. In general, the effective discharge values are greatest during the period 1895 to 1909 and lowest during the period 1936 to 1969. This trend is consistent with the trends for 1.5-year flood peaks, mean-annual discharge, and the mean-annual sediment load.

For the North Platte River and all Platte River stations, the computed effective discharge was typically less than the 1.5-year flood peak for the first three time periods (1895 to 1969). For the last time period (1970 to 1999), the computed effective discharge values were both higher and lower than the 1.5-year flood peak. For the South Platte River, the effective discharge computed using the equal discharge increments was always lower than the 1.5-year flood peak. However, the effective discharge computed using either the probability increments or the median sediment transporting discharge was always higher than the 1.5-year flood peak for the South Platte River station.

5.0 Conclusions

Mean flows, median flows, and the 1.5-year flood peaks of the North Platte and Platte Rivers in Nebraska have significantly decreased over the 20th century in response to reservoir storage, river flow diversions, and periods of drought (see figures 4, 5, and 6). The trend in the mean river flows and the 1.5-year flood peaks are both very similar with flows being the highest during the first time period (1895 to 1909), a wetter climatic period, declining somewhat during the second period (1910 to 1935) when reservoirs began to come on line, and declining to their lowest values of the 20th century during the third time period (1936 to 1969). During the third period, several reservoirs and irrigation diversions came on line as part of the Tri-County canal, and two periods of drought in the 1930s and the 1950s occurred. Mean flows and the 1.5-year flood peaks increased somewhat over the fourth time period (1970 to 1999), but were still significantly less than either of the first two time periods (1895 to 1935).

Mean flows of the South Platte River have also declined over the second and third periods, but increased during the fourth period to an amount 6 percent greater than the mean for the first time period. During the first two periods (1895 to 1935), flows from the North Platte River were the dominant water supply to the Platte River, with the mean flow being 5.5 times more than mean flow of the South Platte River. During the most recent time period (1970 to 1999), the mean flow of the North Platte River was only 1.4 times more than the mean flow of the South Platte River.

Upstream from the large storage reservoirs on the North Platte River, mean flows and the 1.5-year peak flows decreased by 14 to 26 percent from the second to third time periods. At the same time, downstream from these large storage reservoirs, mean flows and the 1.5-year peak flows for the North Platte River at North Platte, Nebraska decreased by 73 to 76 percent. Although a flow decrease of 14 to 26 percent in the river downstream of the reservoirs might be explained by natural drought and some agricultural use, most of the 73 to 76 percent decrease in North Platte River flow at North Platte, Nebraska is due to storage reservoirs and river flow diversions.

These reductions in river flow have caused a substantial reduction in the sediment transport rates over the 20th century. In addition, large storage reservoirs on the North and South Platte Rivers have also trapped sediment. Reductions in river flow and sediment load would be expected to result in a narrower Platte River channel.

Beginning in 1941, Platte River Flows decreased substantially through the 70-mile reach downstream from the Tri-County Diversion Dam at North Platte, Nebraska to the Johnson-2 return channel a few miles upstream from the stream gauge near Overton, Nebraska. Sediment is still transported past the Tri-County Diversion Dam (either by natural transport or hydraulic dredging), but the transport capacity of the downstream river flows to keep this sediment moving has reduced over time along the 70-mile reach. This causes sediment to deposit and aggrade portions of the downstream river channel.

Downstream from the Johnson-2 return channel, clear water flows have eroded and degraded the river channel and resulted in greater sediment loads past the stream gauges near Overton and Grand Island, Nebraska. The clear-water degradation is expected to continue for some time into the future and progressively erode the Platte River channel in the downstream direction. The amount of degradation at any location will likely be limited by the armoring of coarser particles and, to some extent, by the introduction of sediment from local drainages.

The indicators of channel forming discharge evaluated for this study include the 1.5-year peak flood, effective discharge (computed by two different methods), and the median sediment transporting discharge. All of these indicators of channel forming discharge have declined over the 20th century. The effective discharge and the median sediment transporting discharge values generally follow the same trend as for the 1.5-year peak flood.

6.0 References

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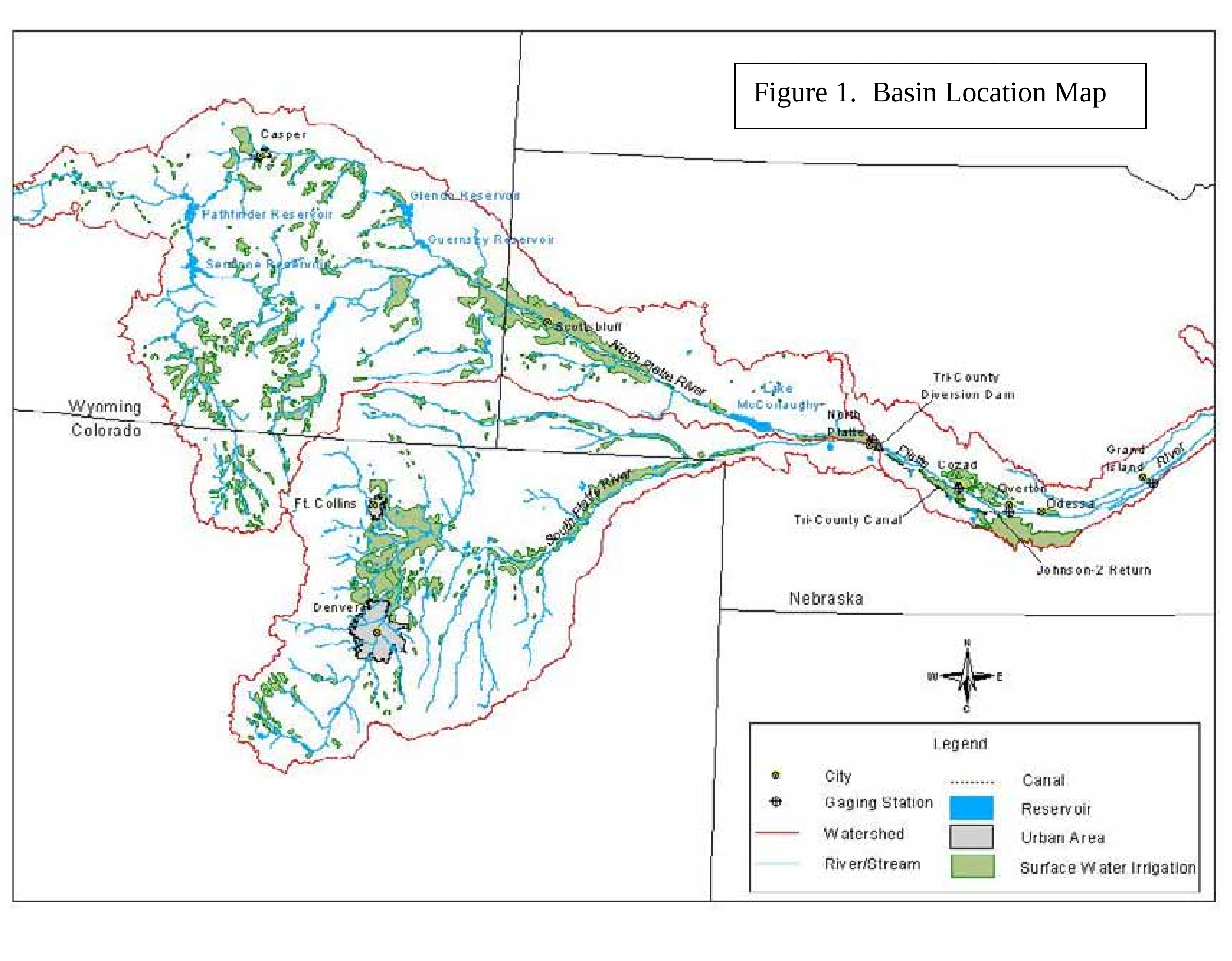

Figure 1. **Platte River basin location map.**

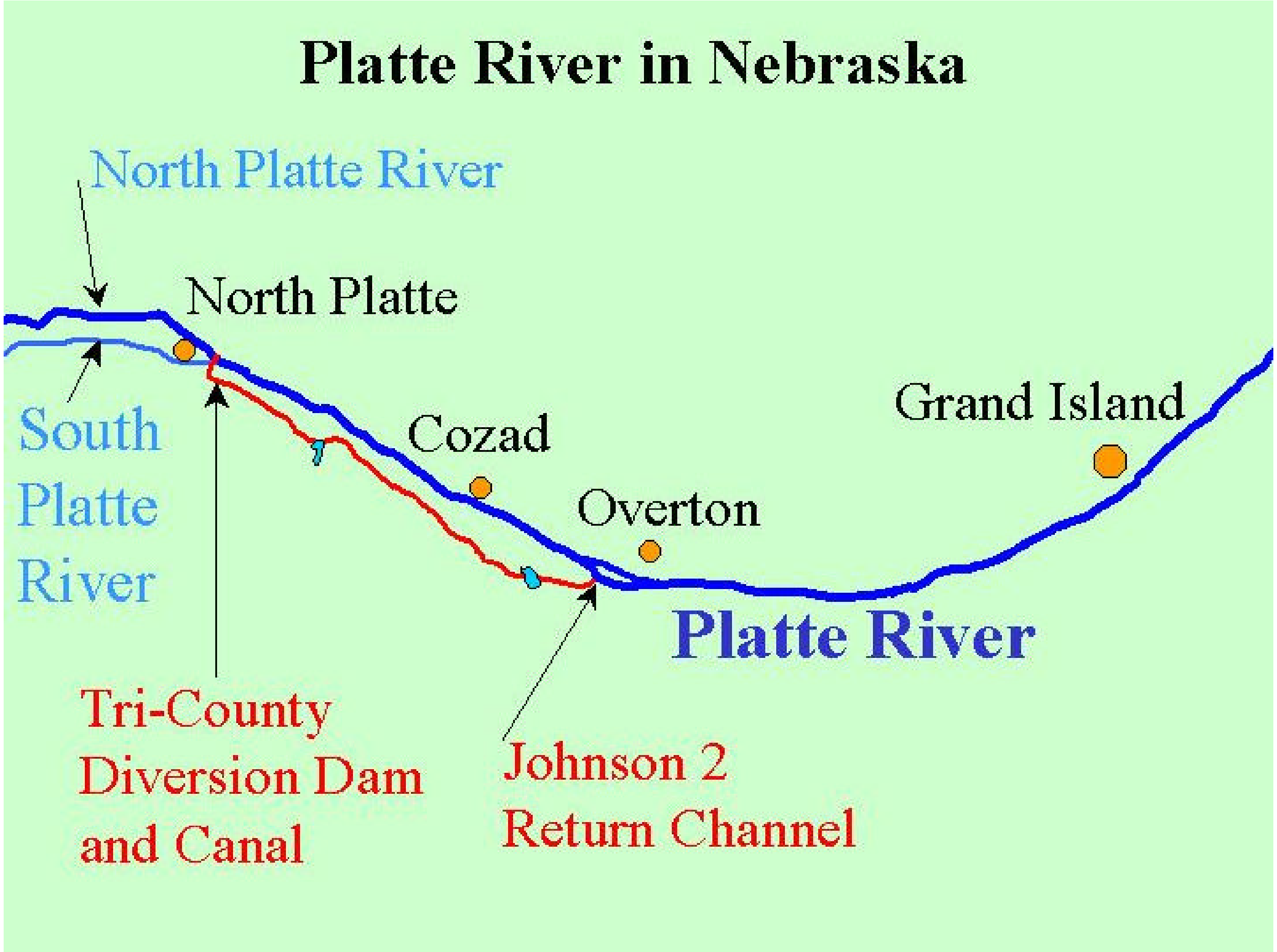

Figure 2. Platte River reach location map.

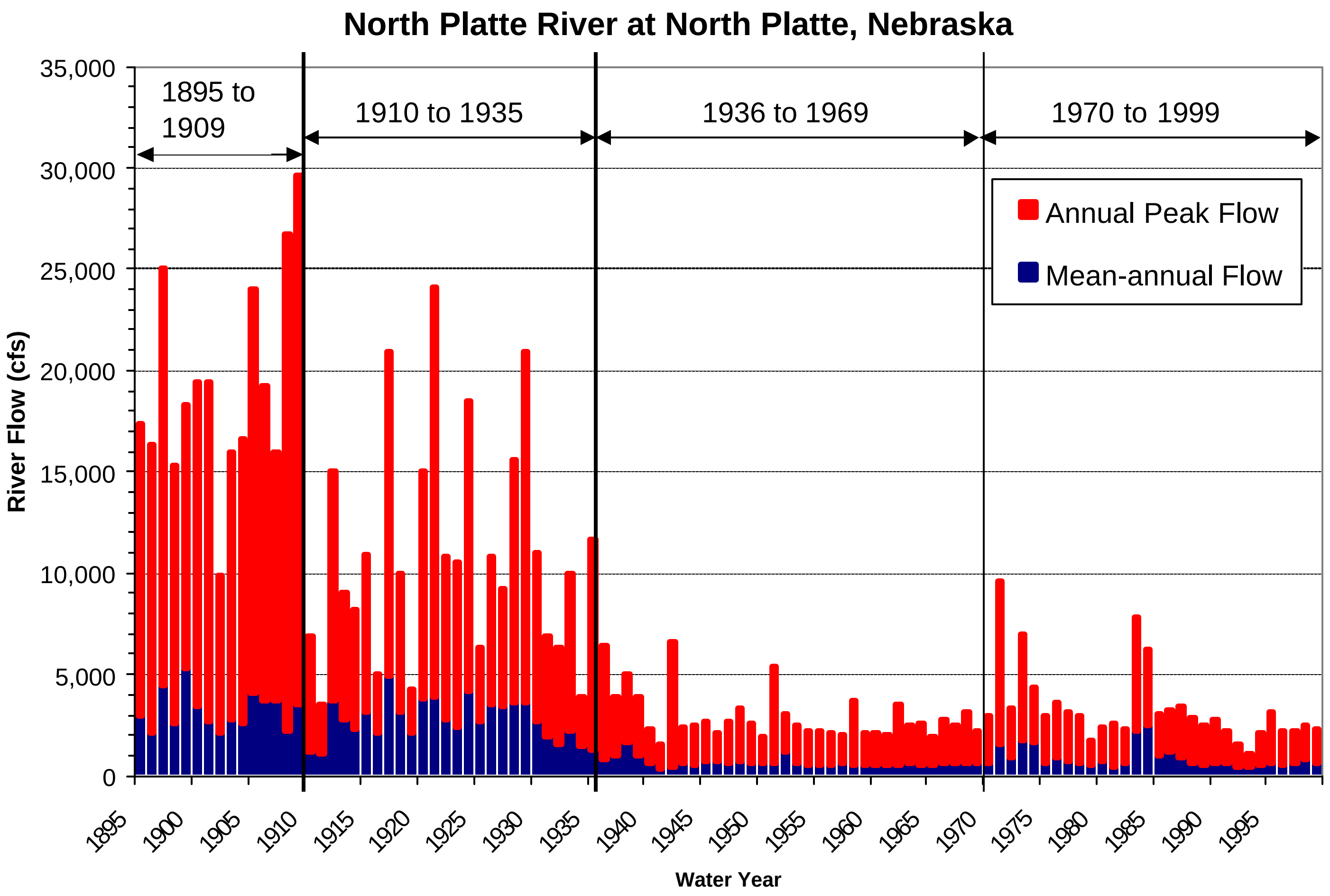

Figure 3. **Annual flow volume and annual peak flow for the North Platte River at North Platte, Nebraska.**

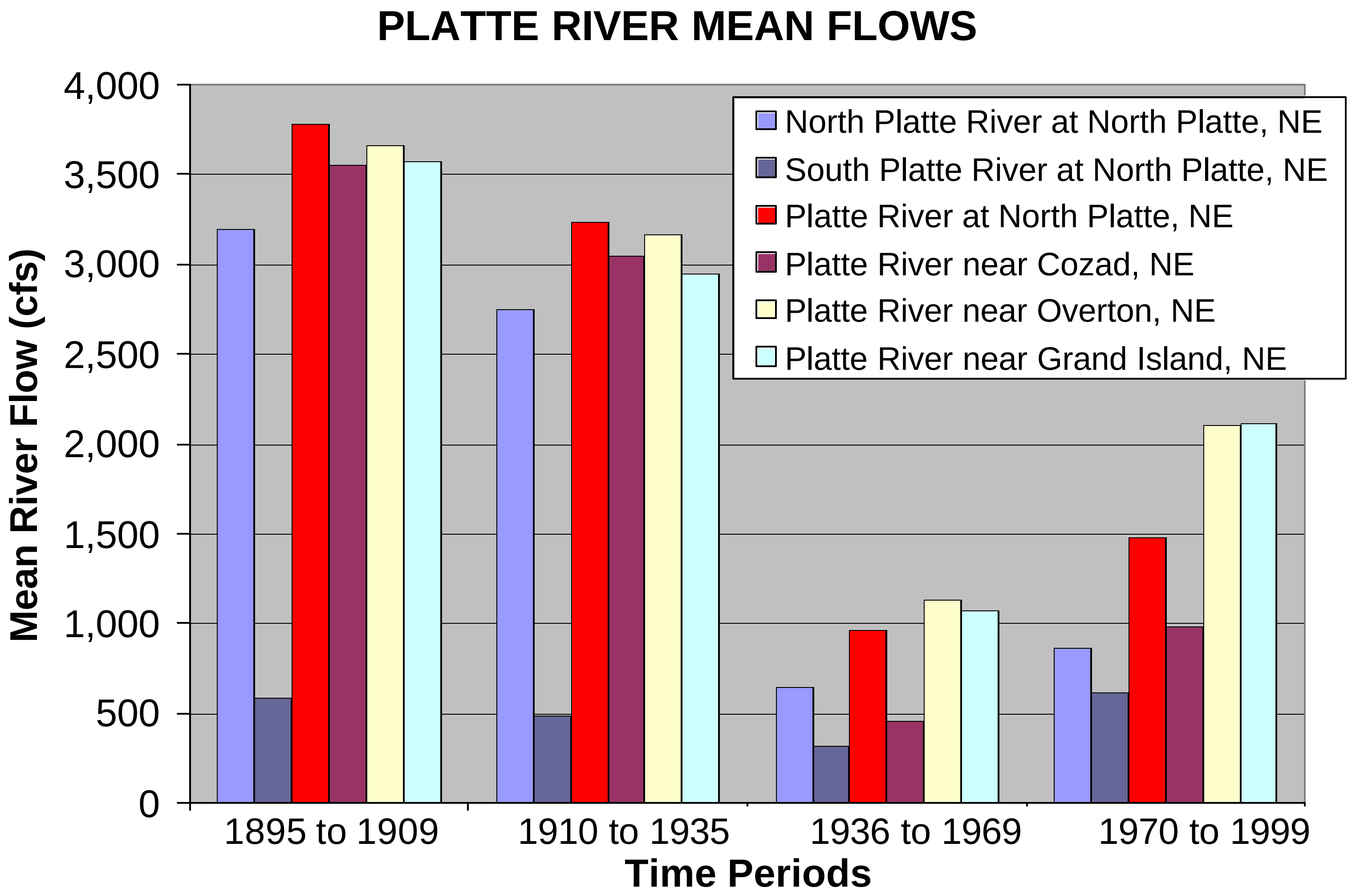

Figure 4. **Platte River mean flows**

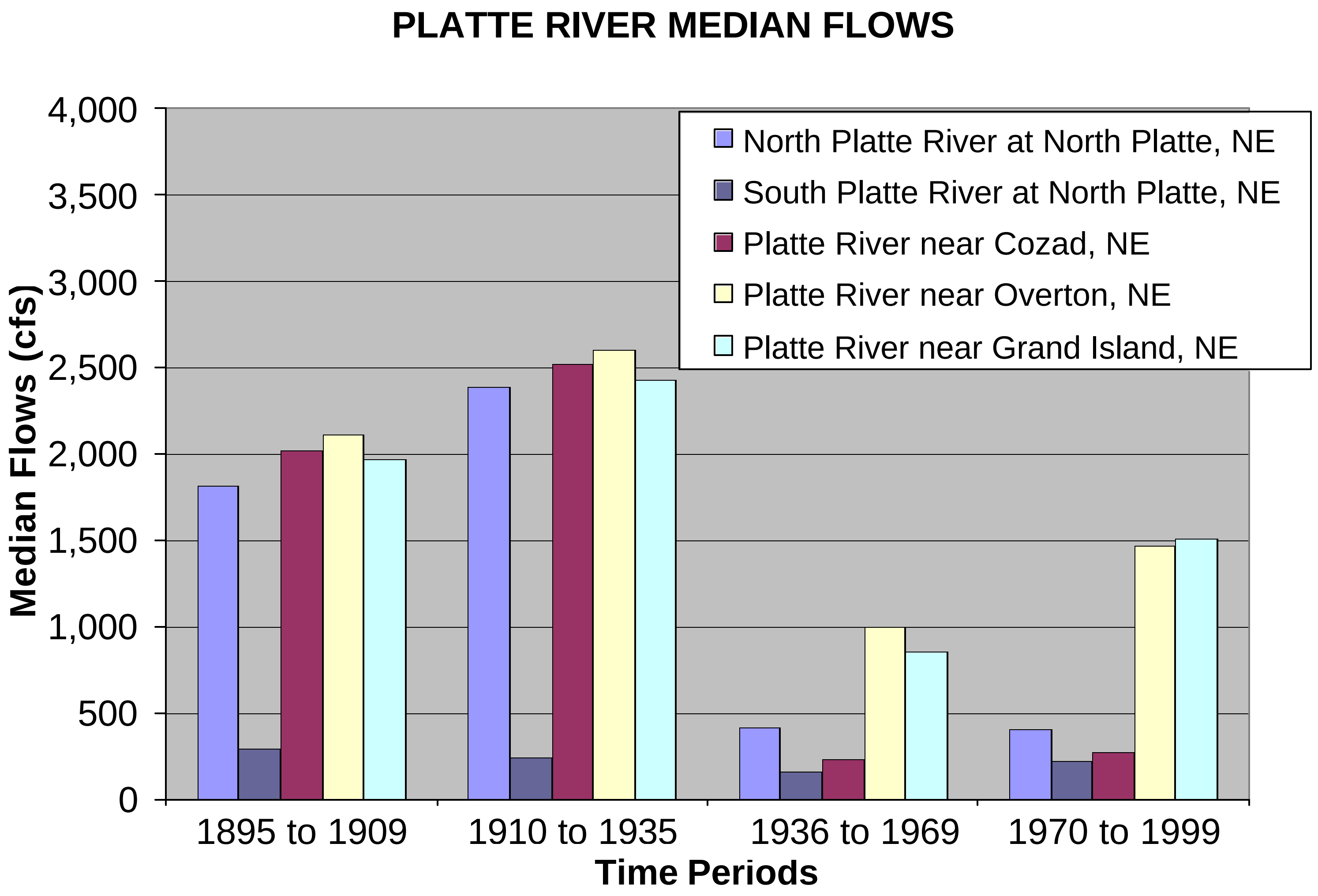

Figure 5. **Platte River median flows**

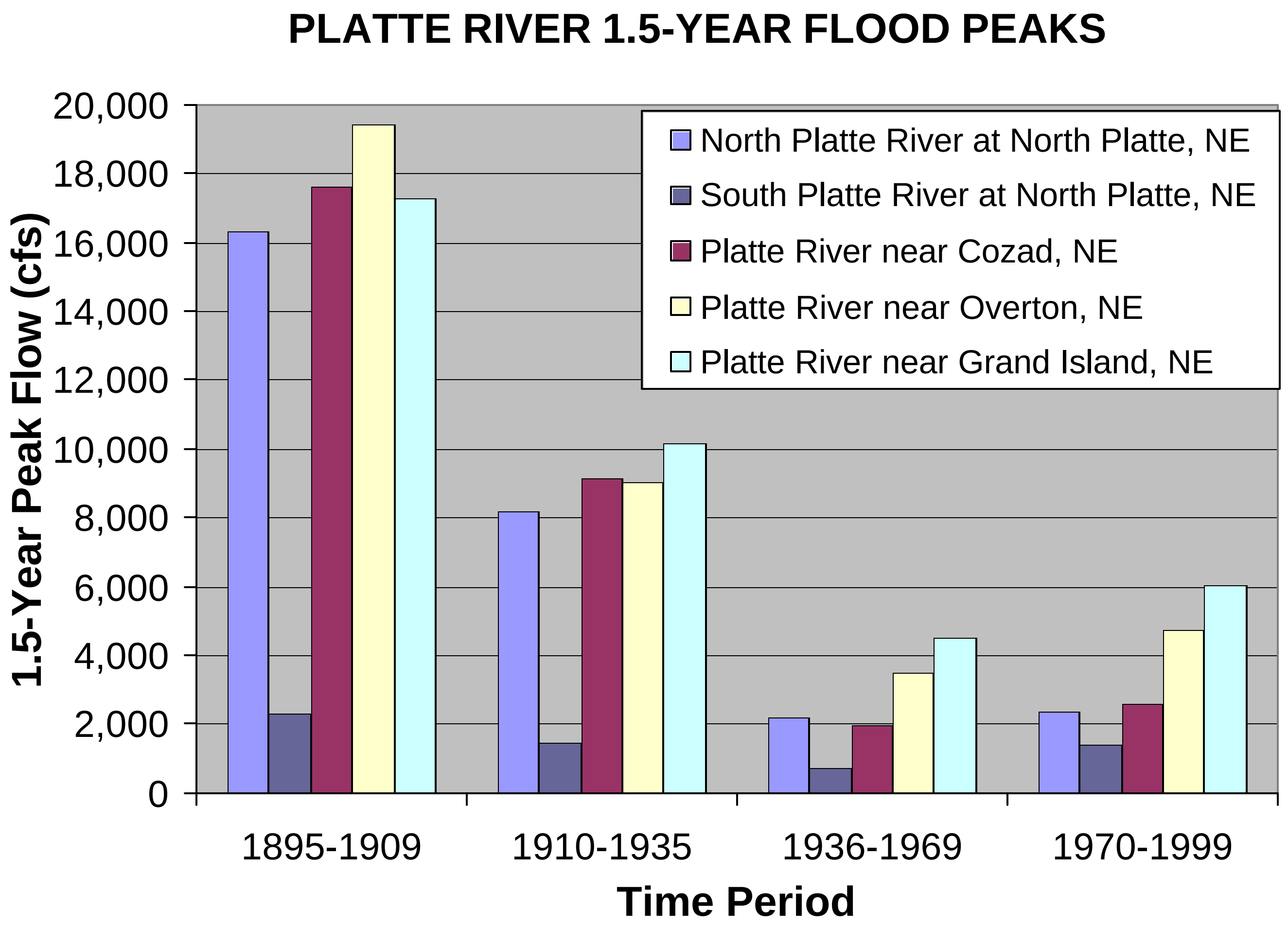

Figure 6. Platte River 1.5-year flood peak flows

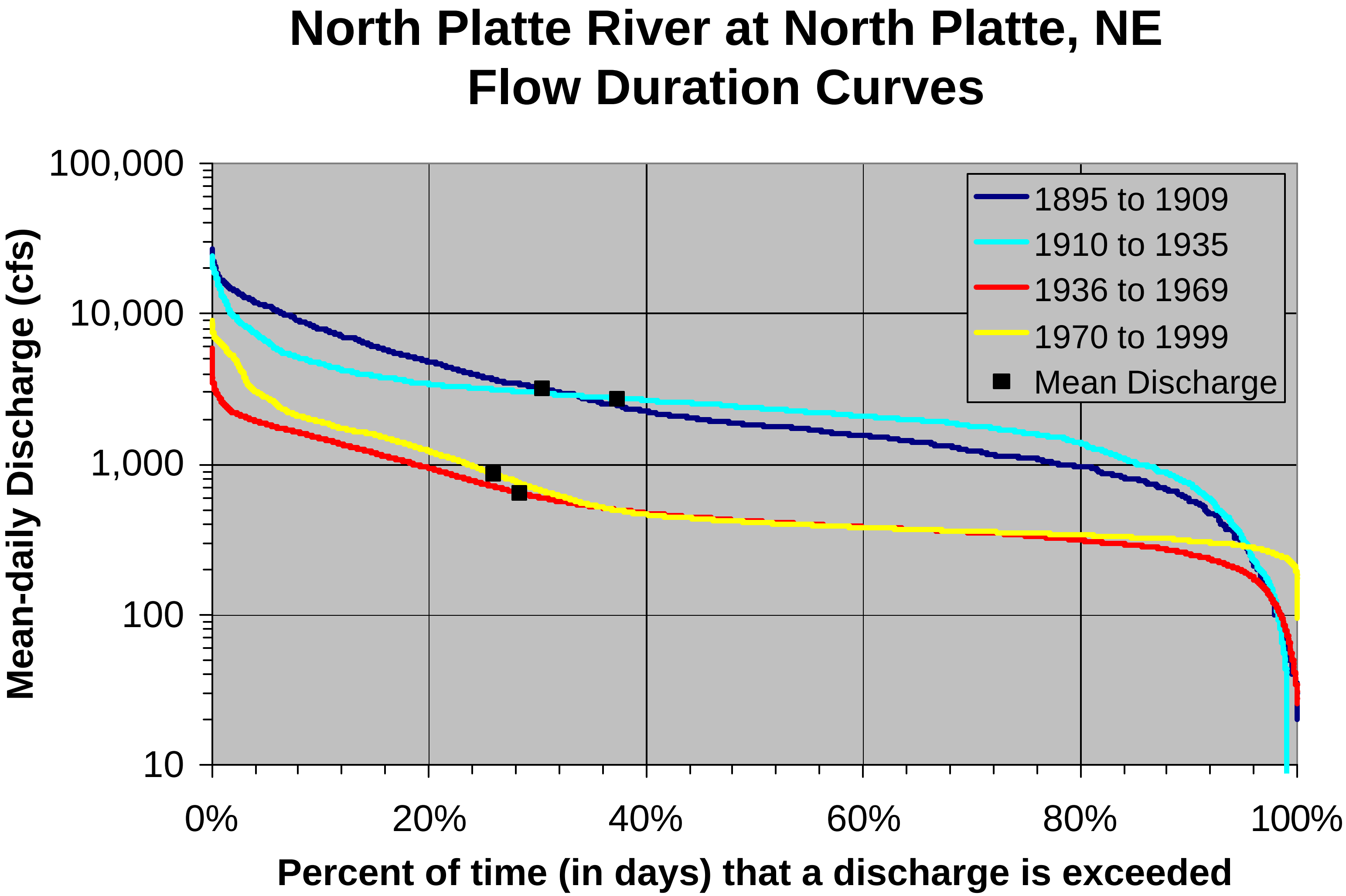

Figure 7. North Platte River at North Platte, Nebraska flow-durations curves

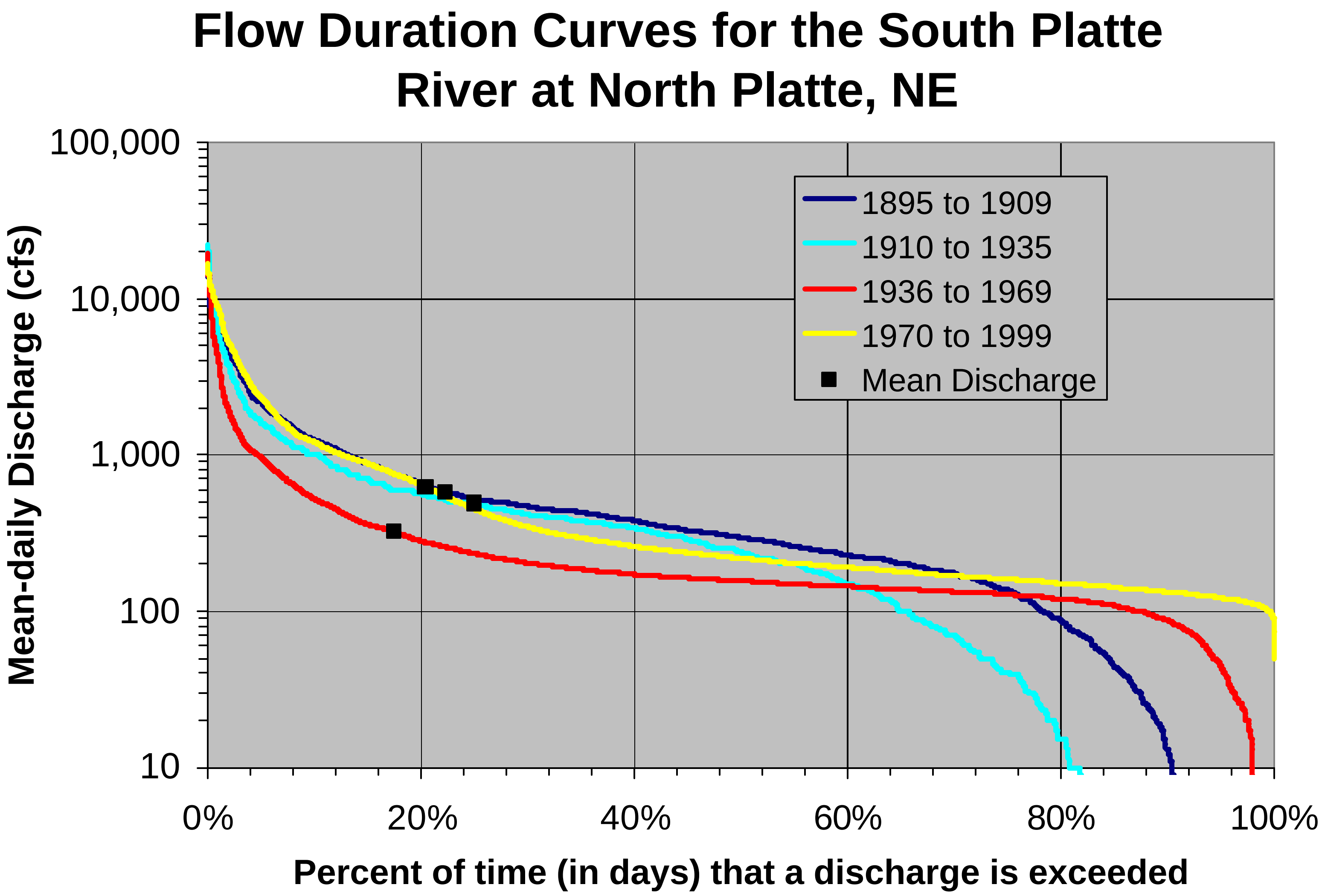

Figure 8. South Platte River at North Platte, Nebraska flow-durations curves

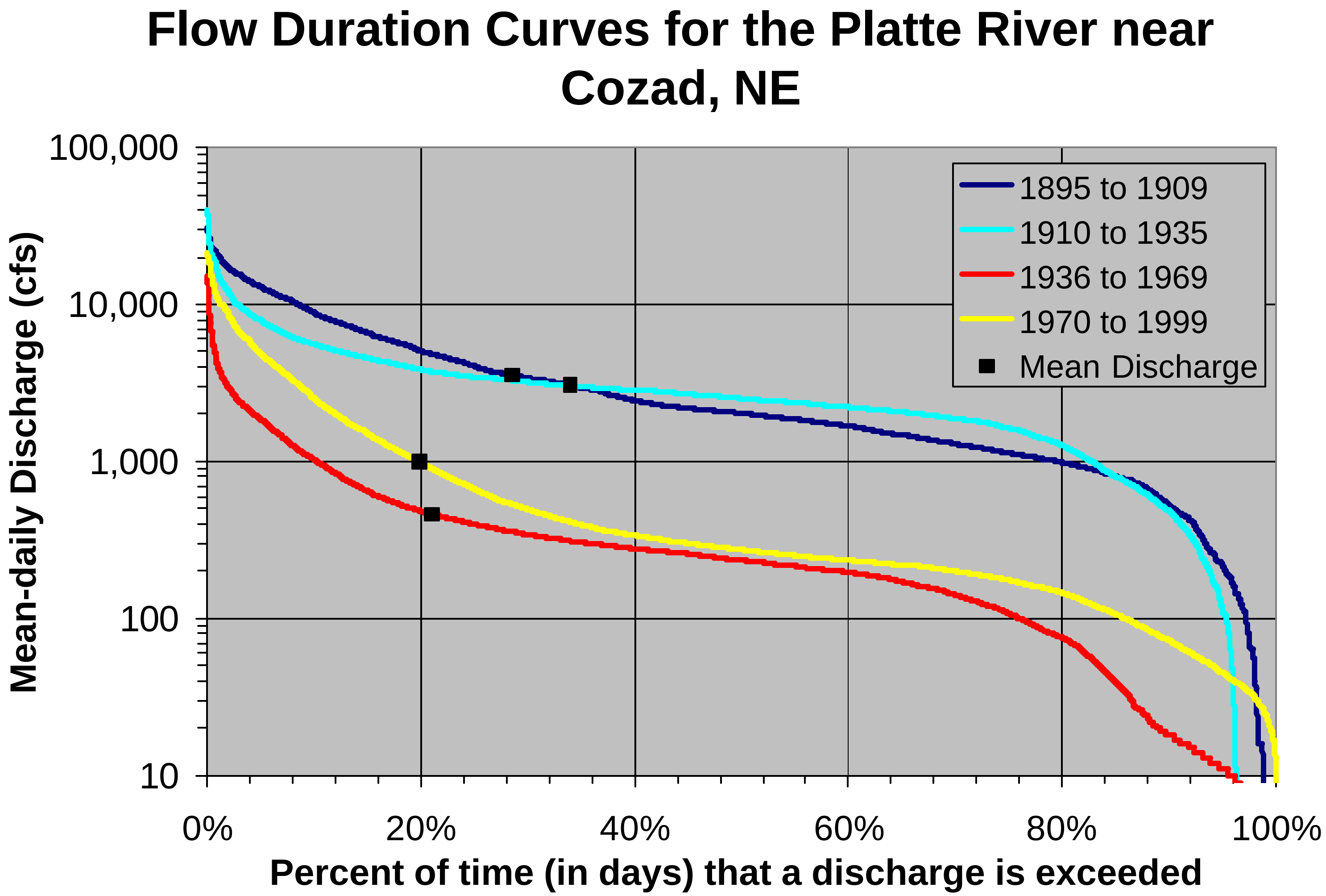

Figure 9. **Platte River near Cozad, Nebraska flow-durations curves**

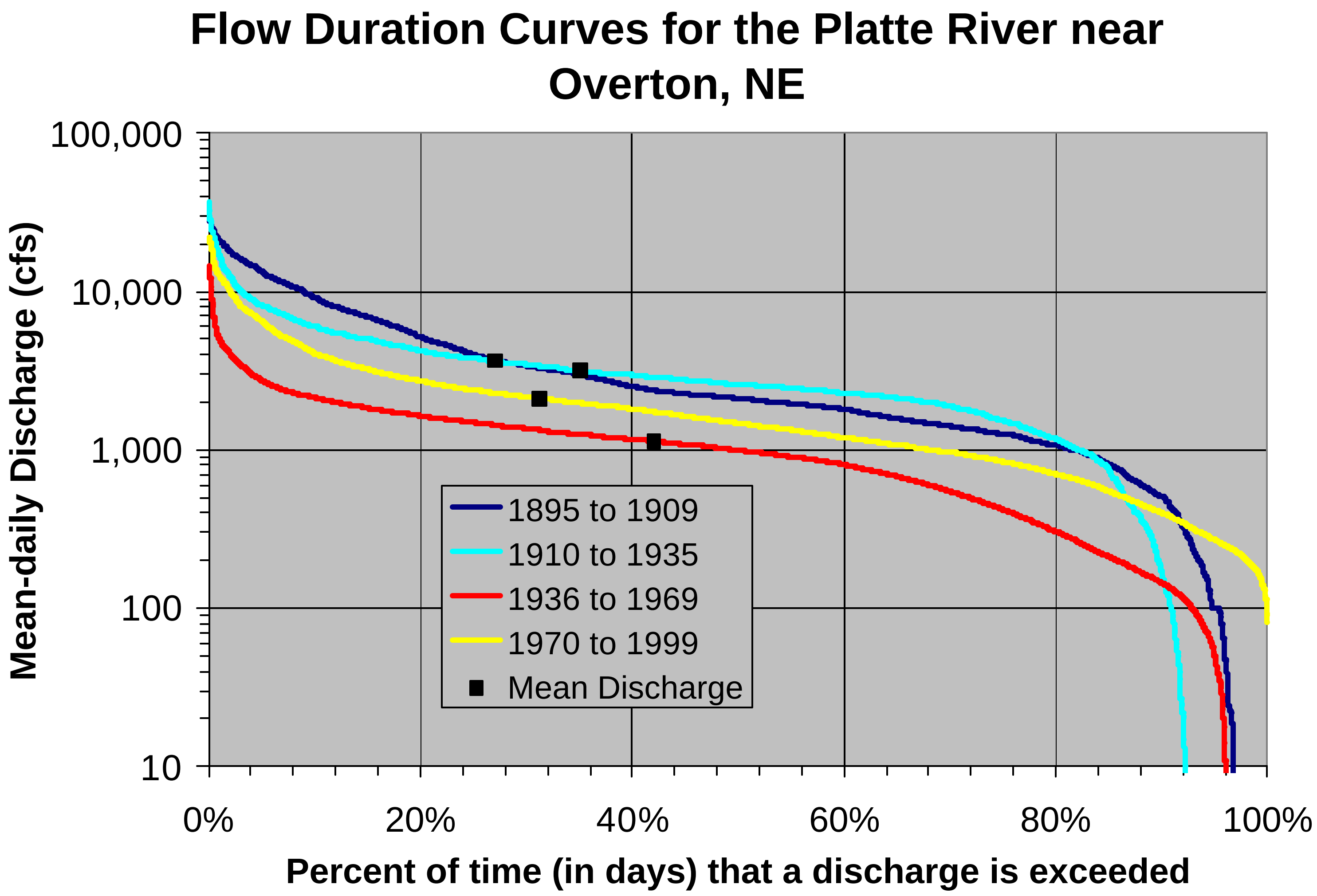

Figure 10. **Platte River near Overton, Nebraska flow-durations curves**

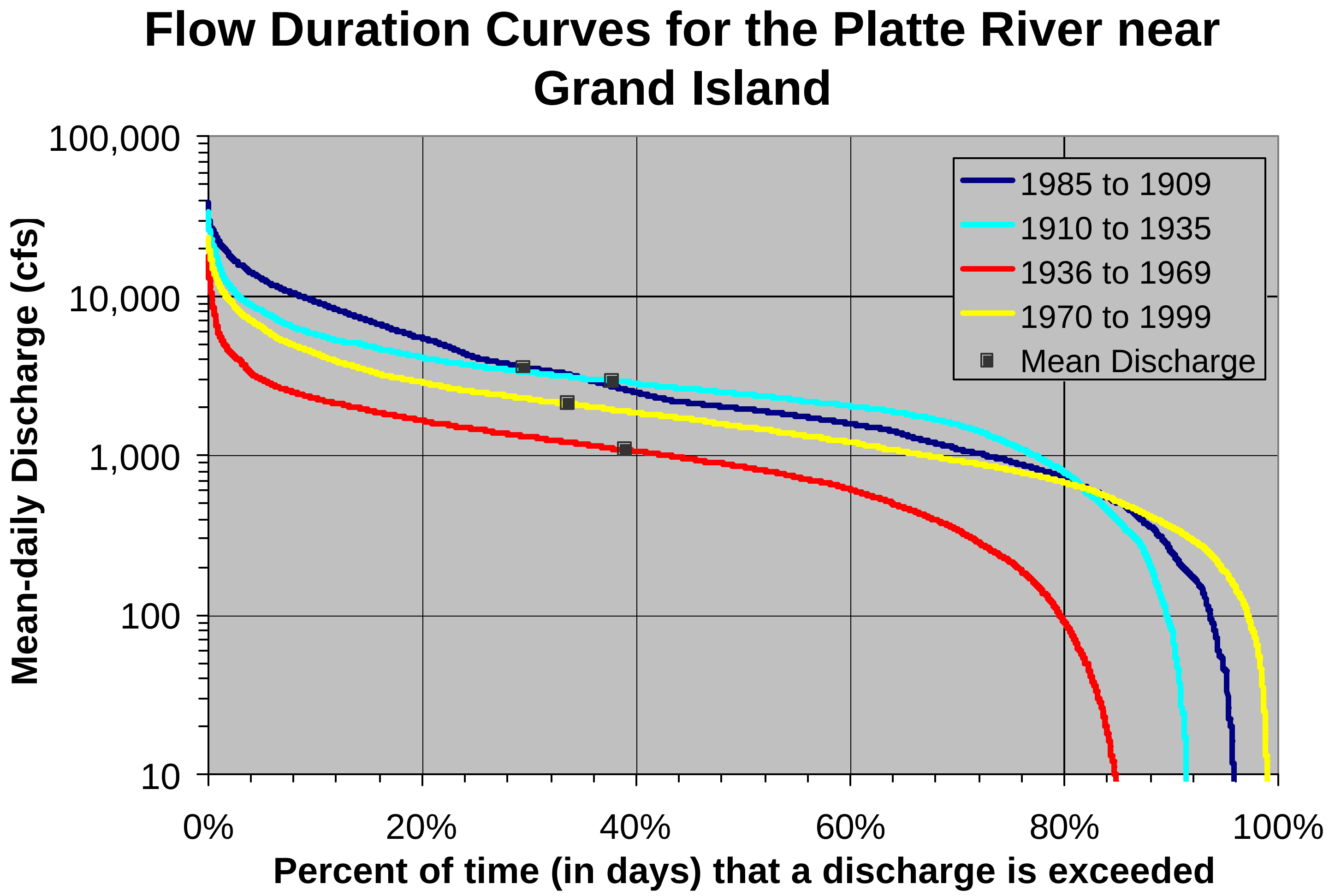

Figure 11. **Platte River near Grand Island, Nebraska flow-durations curves**

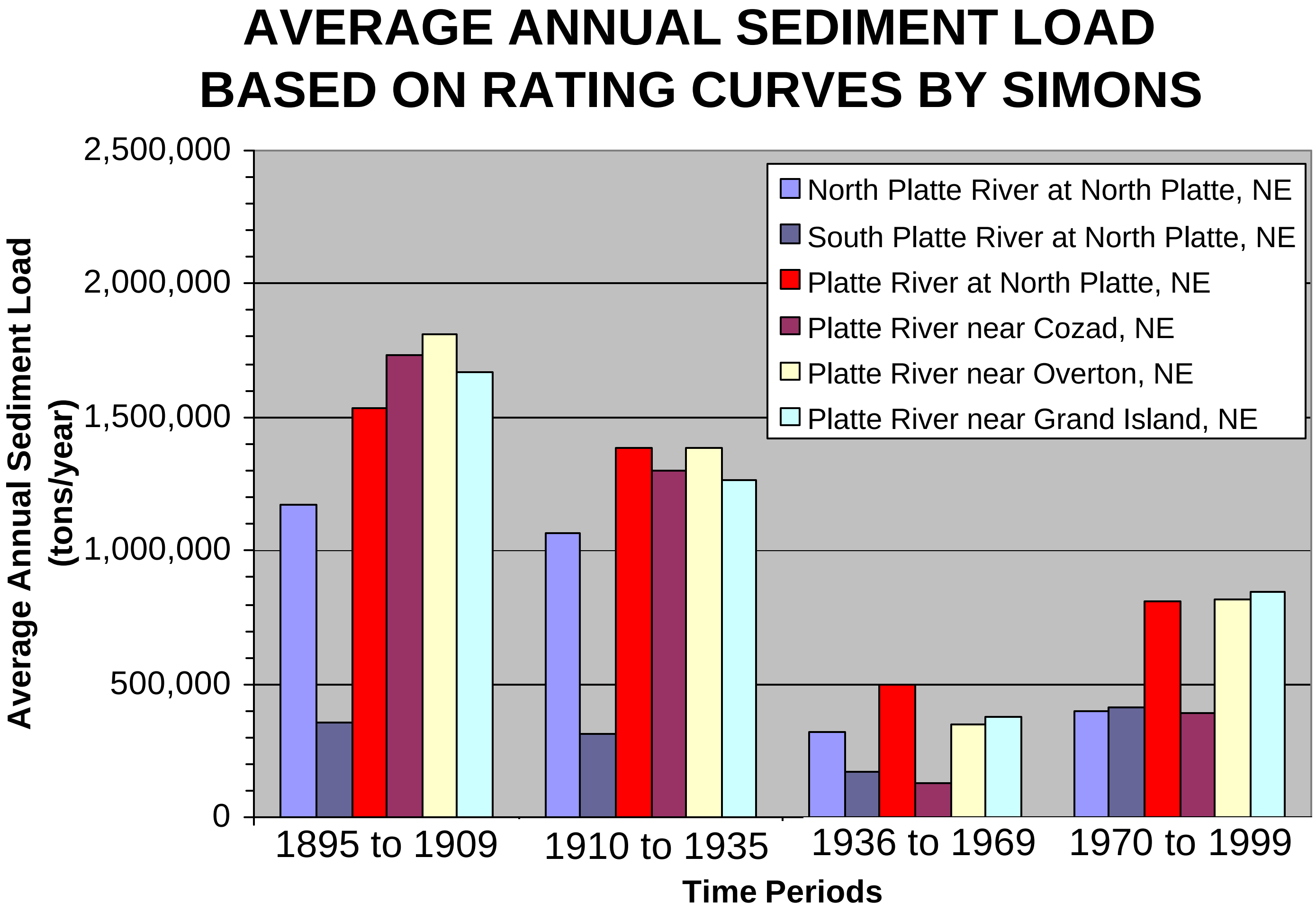

Figure 12. **Platte River mean annual sediment load based on sediment-discharge equations by Simons and Associates, Inc. (2000)**

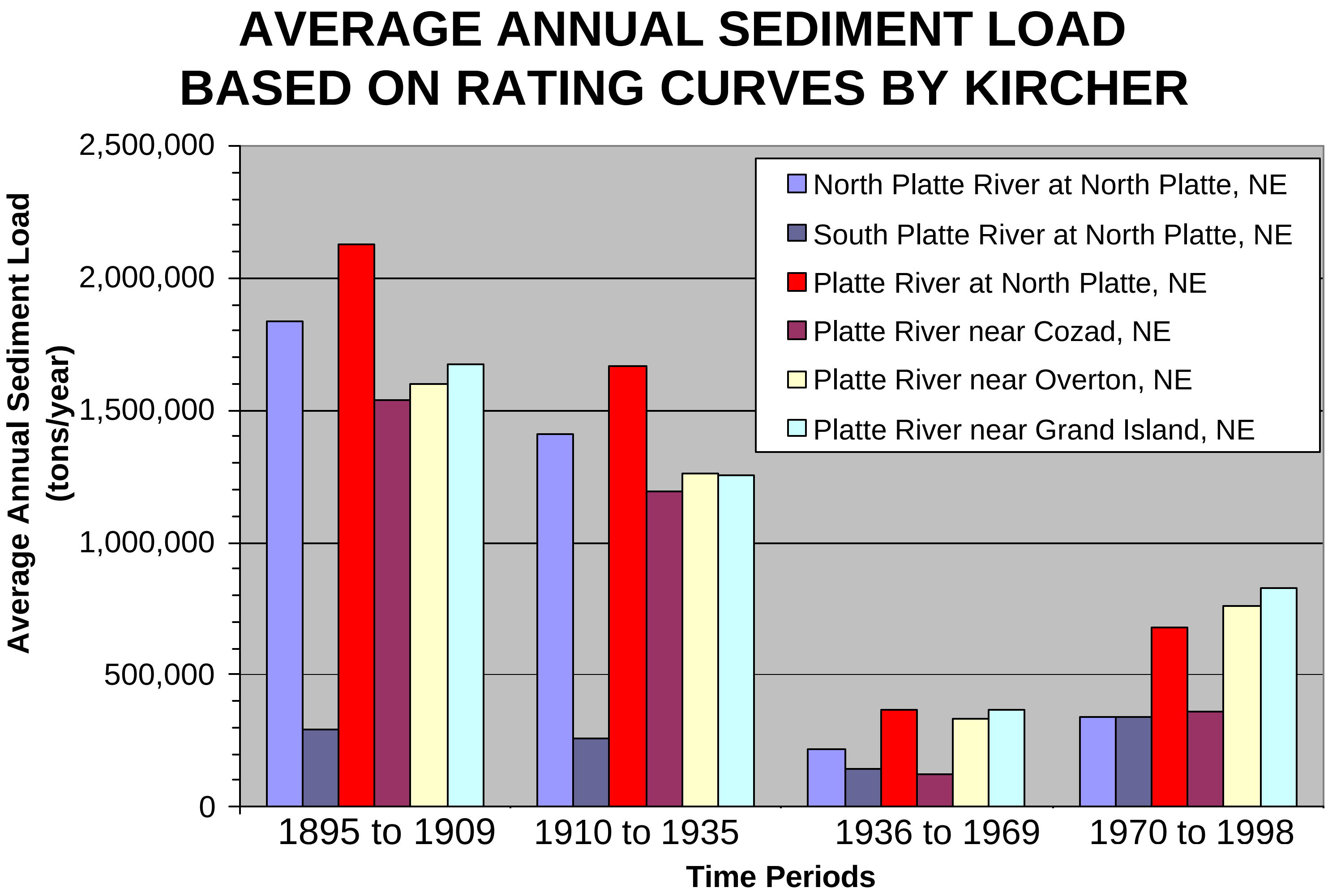

Figure 13. **Platte River mean annual sediment load based on sediment-discharge equations by Kircher (1983)**

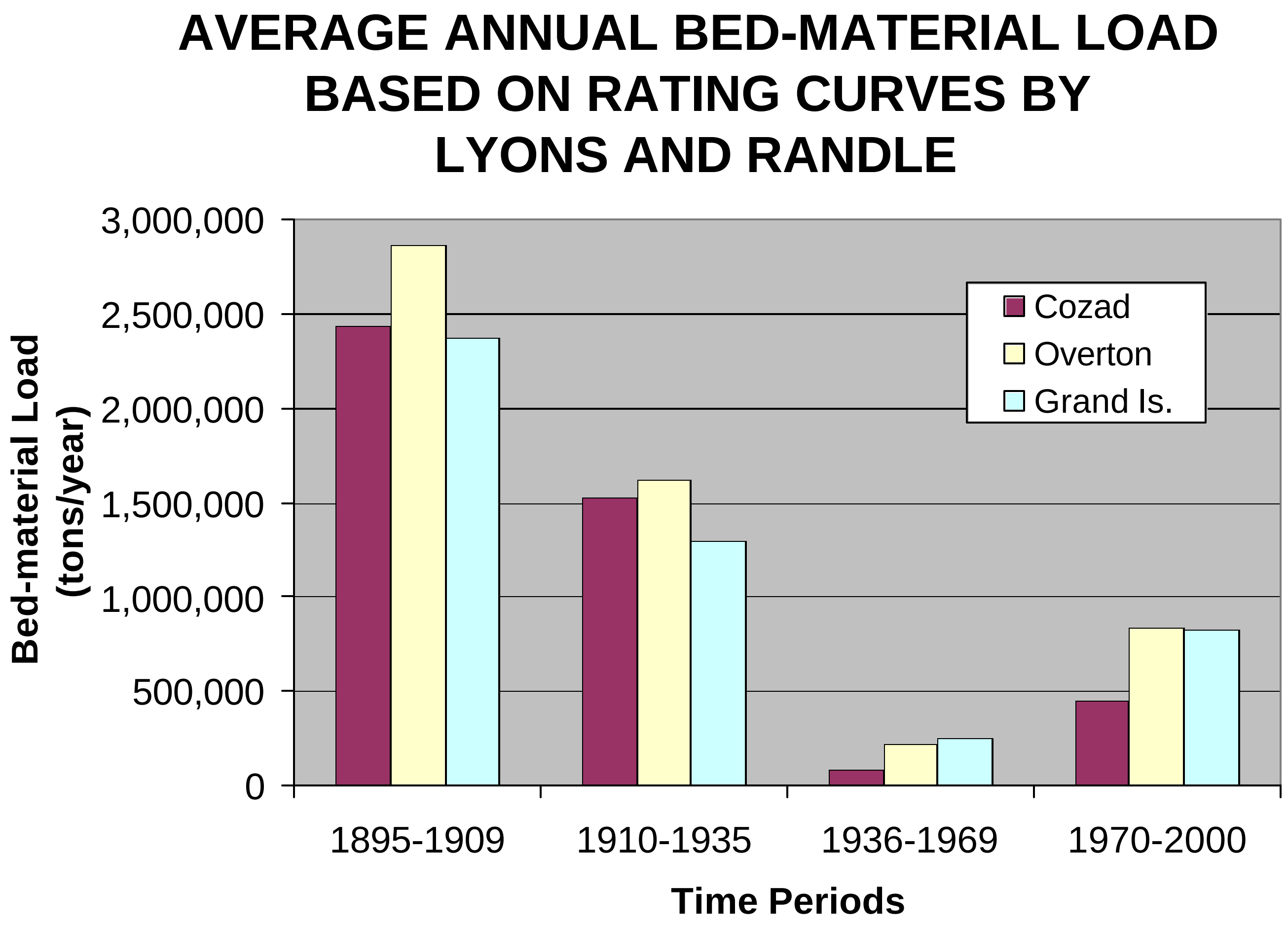

Figure 14. Platte River mean annual sediment load based on sediment-discharge equations by Lyons and Randle (1988)

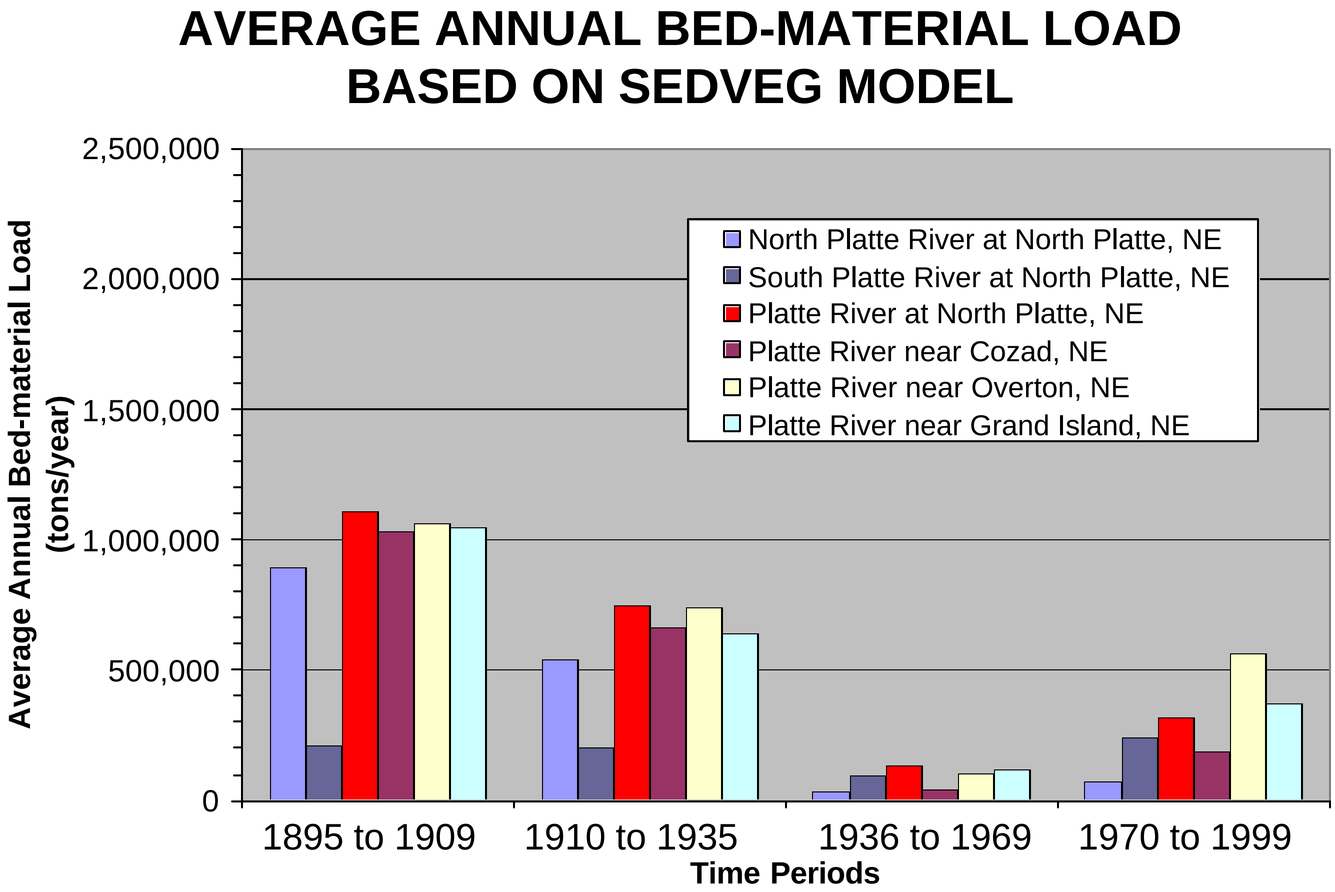

Figure 15. **Platte River mean annual bed-material load based on the sediment transport model by Murphy and Randle (2001)**

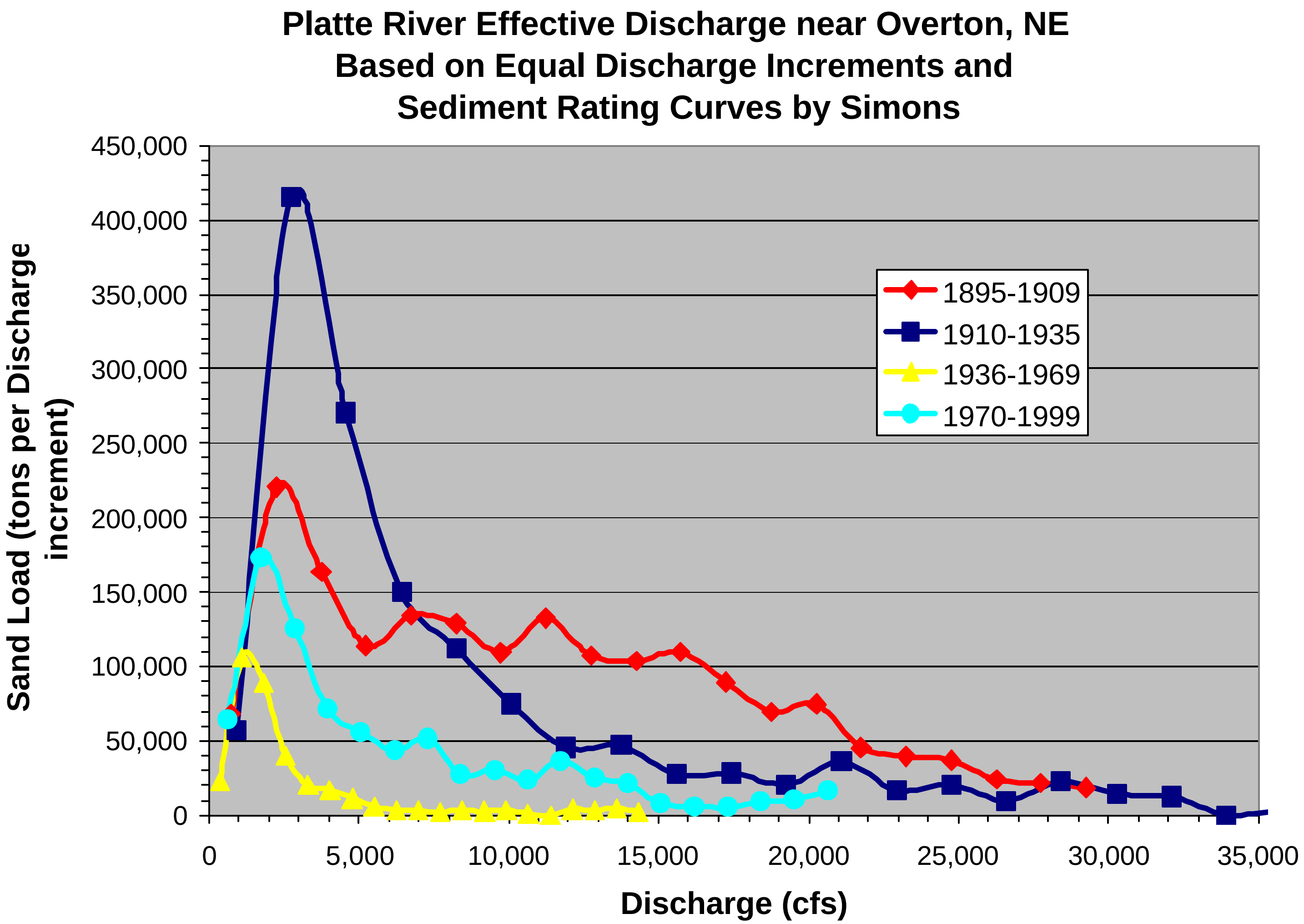

Figure 16. Platte River effective discharges for the Platte River near Overton, Nebraska, based on the equal discharge increment method.

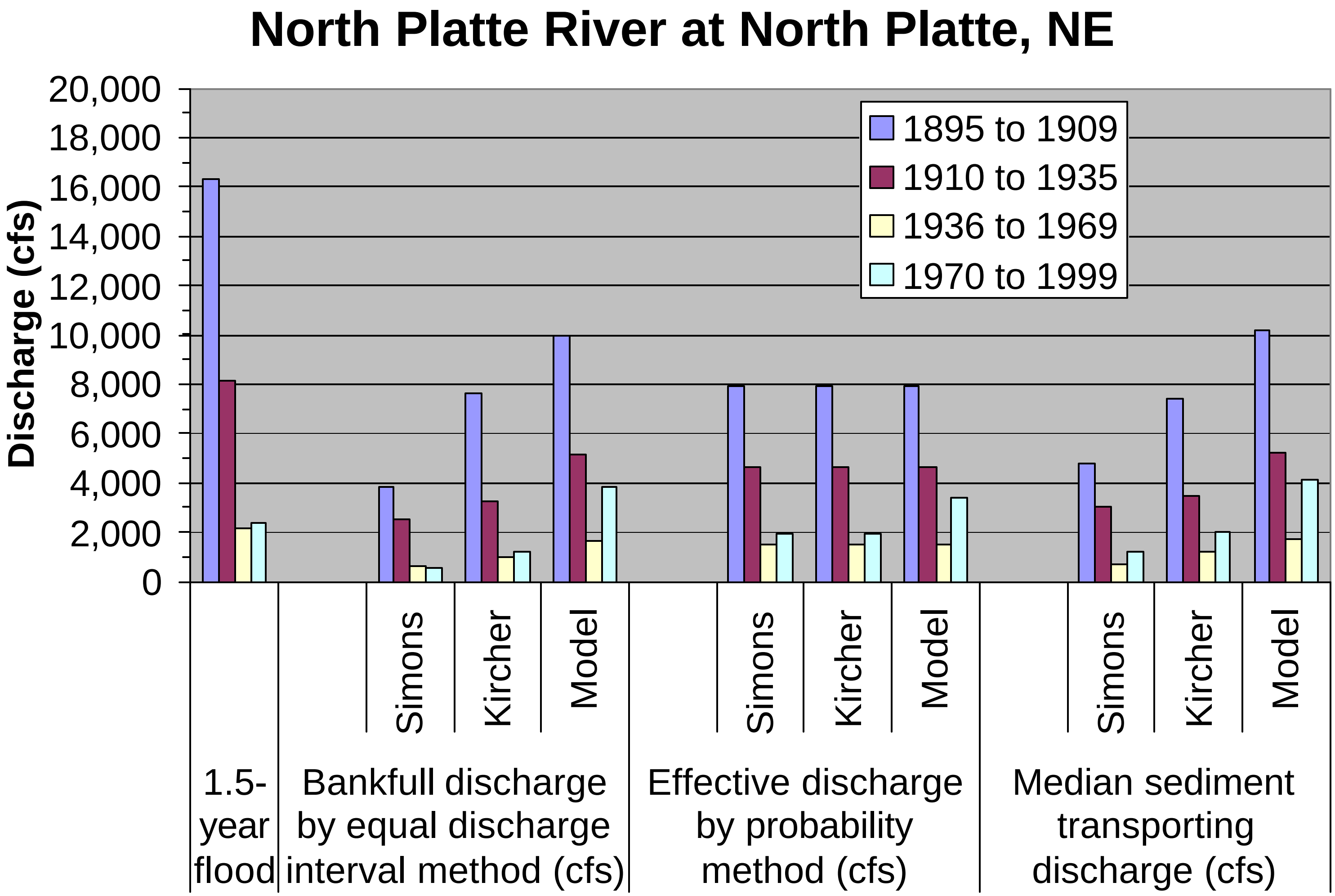

Figure 17. **Comparison of effective discharge results for the North Platte River at North Platte, Nebraska**

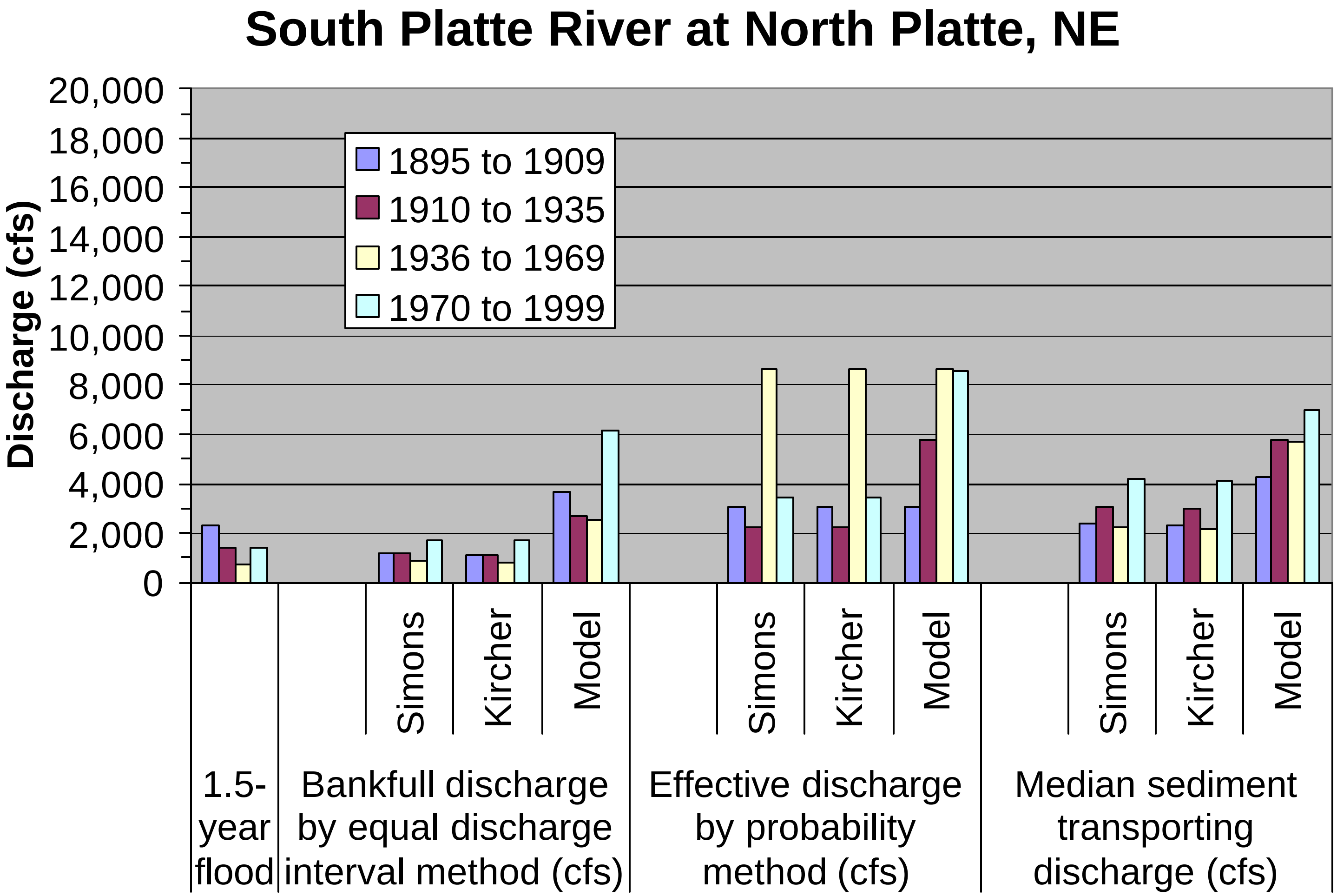

Figure 18. **Comparison of effective discharge results for the South Platte River at North Platte, Nebraska**

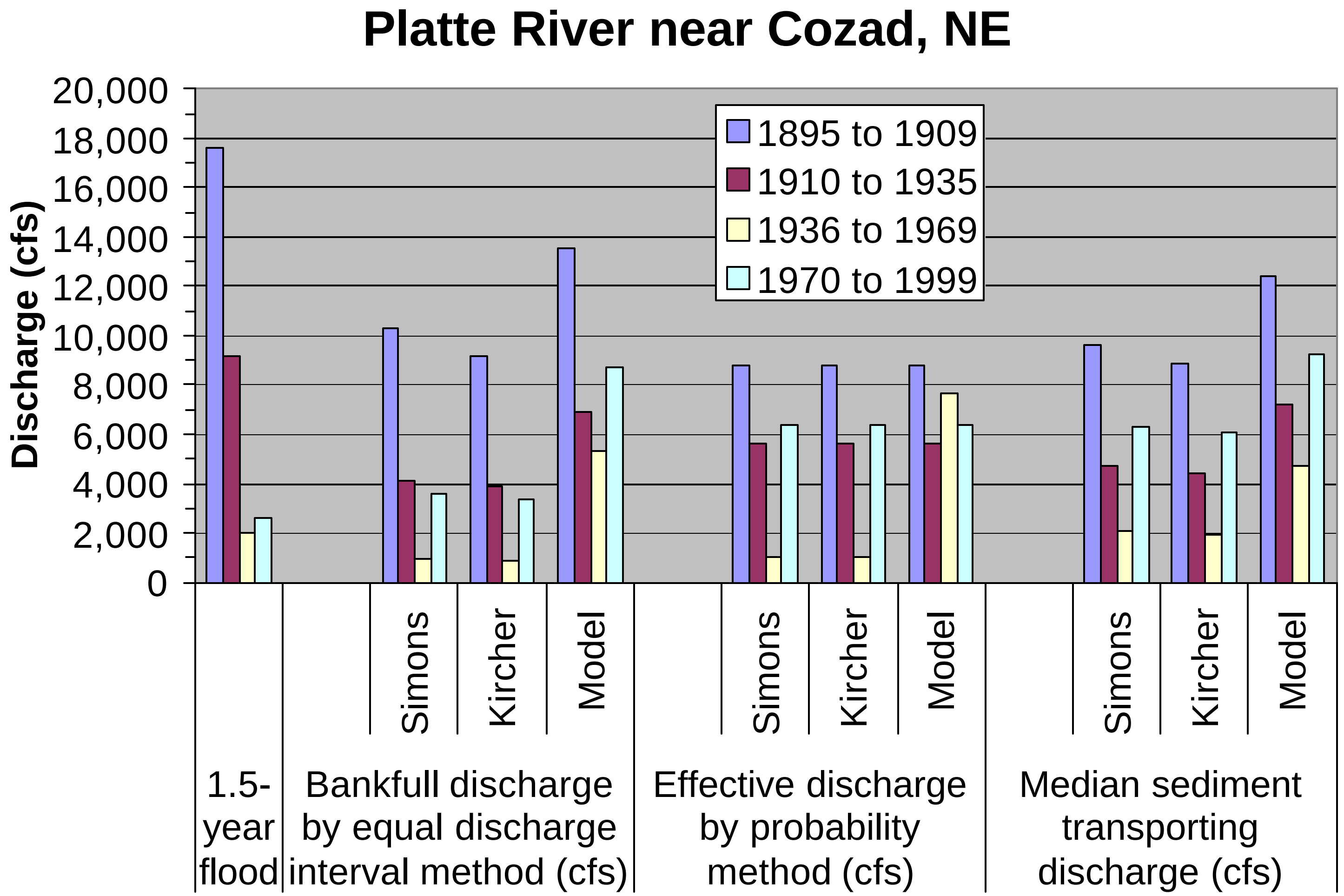

Figure 19. Comparison of effective discharge results for the Platte River near Cozad, Nebraska

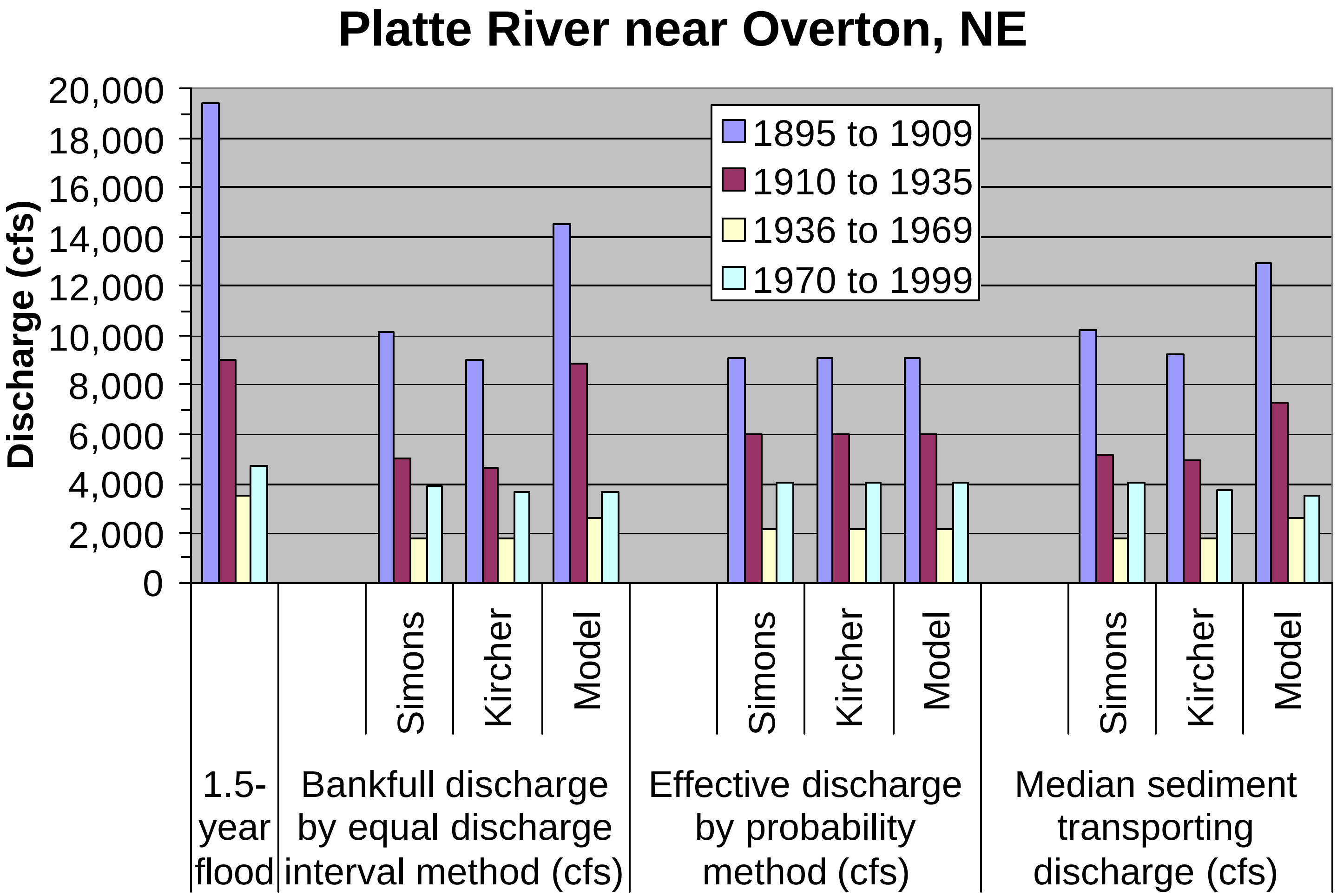

Figure 20. **Comparison of effective discharge results for the Platte River near Overton, Nebraska**

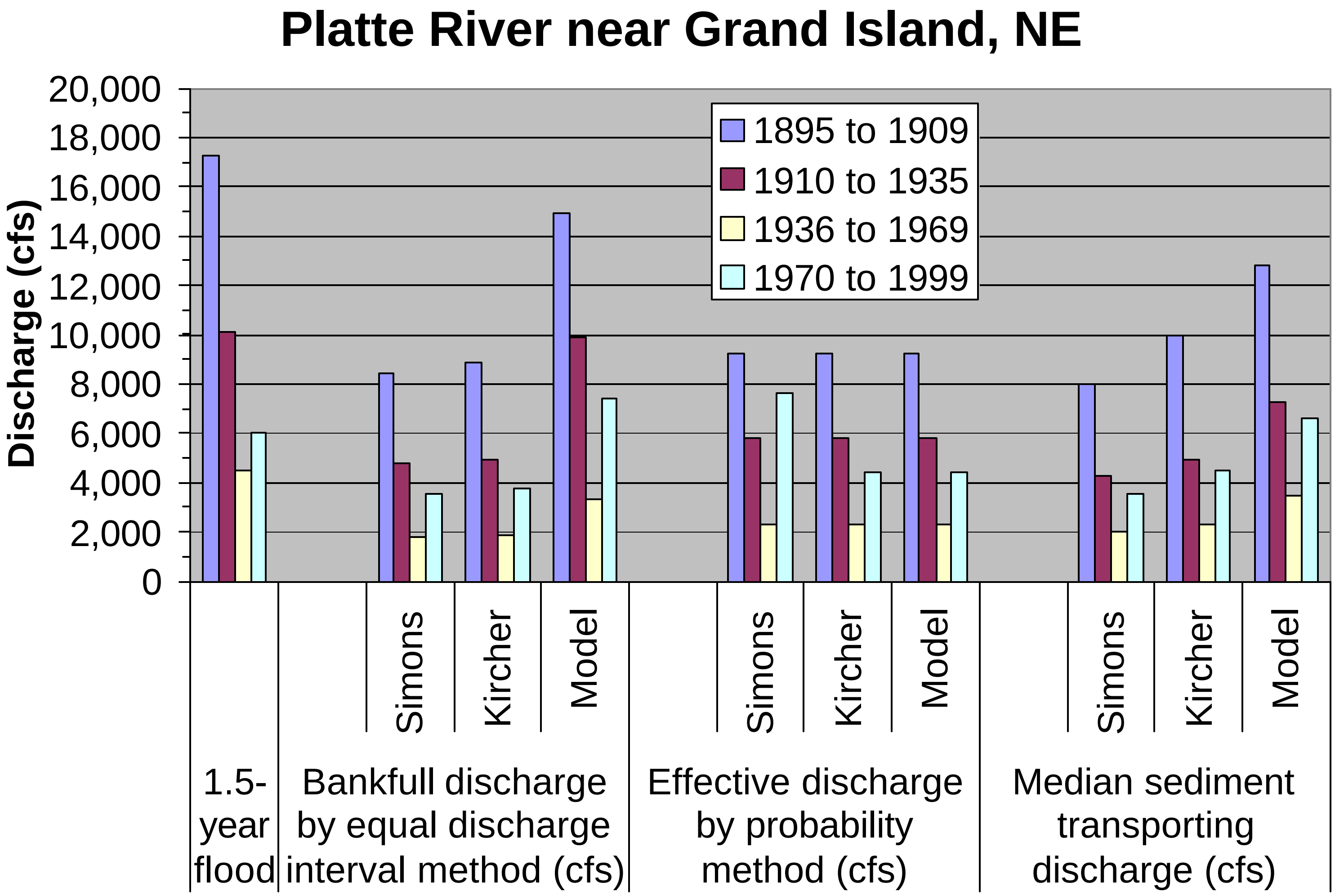

Figure 21. Comparison of effective discharge results for the Platte River near Grand Island, Nebraska.

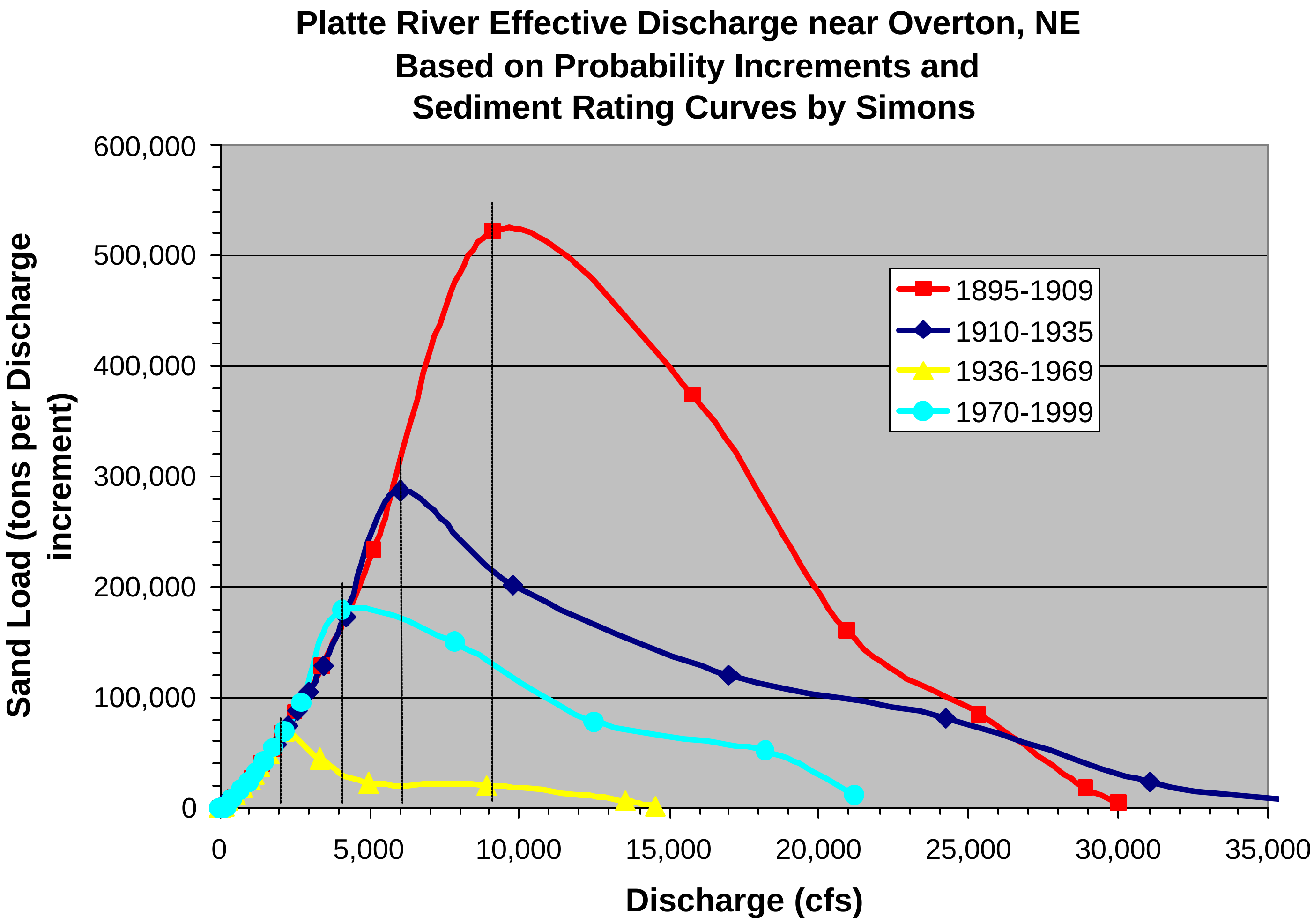

Figure 22. **Platte River effective discharges for the Platte River near Overton, Nebraska, based on the probability increment method.**

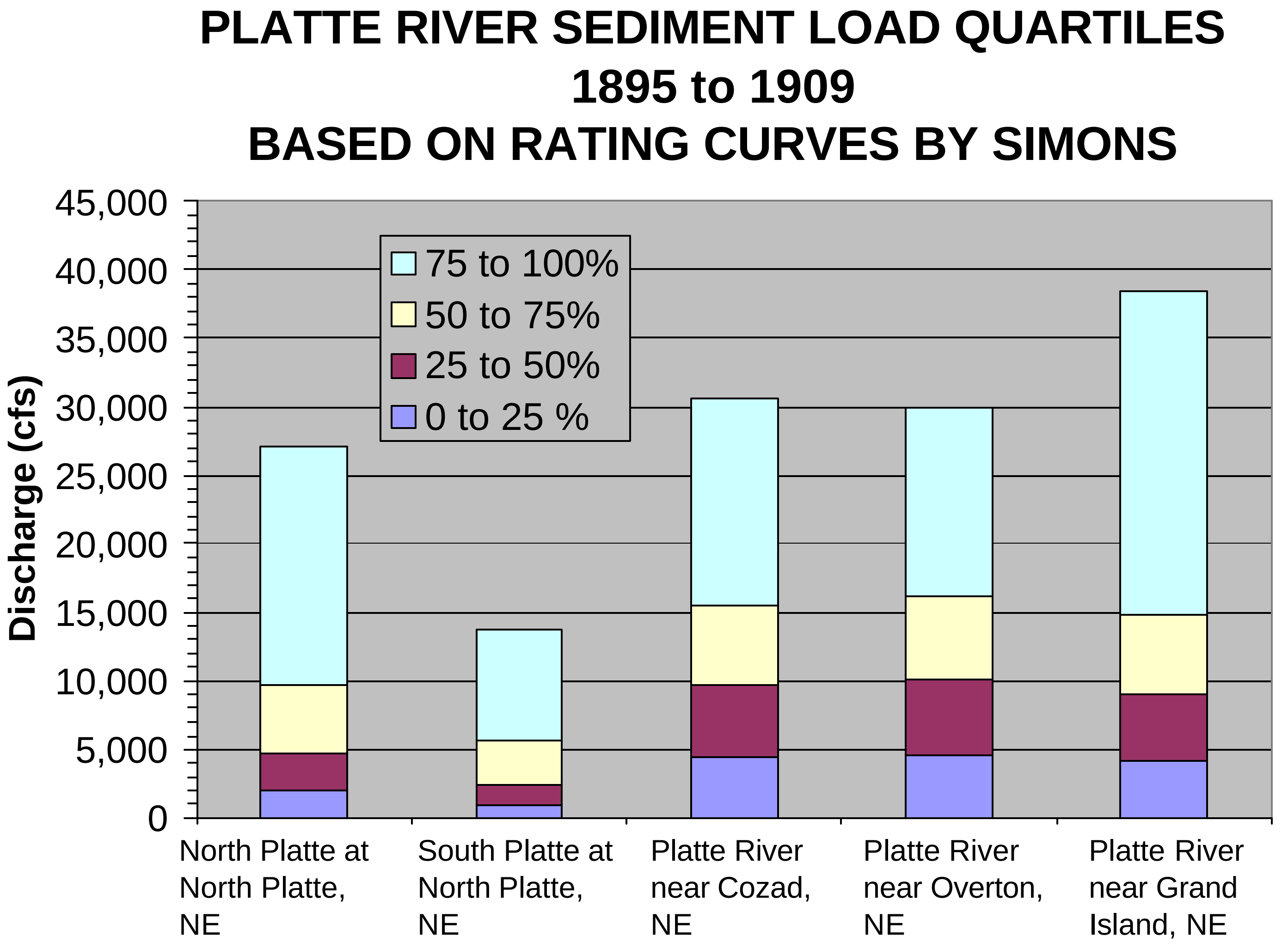

Figure 23. Quartiles of cumulative sediment load for various gauging stations along the Platte River.