HYDROLOGY

PRECIPITATION

The average annual precipitation in the basin ranges from 31 inches in the northern part to 35 inches in the southern part (about 90 % in the form of rainfall, USDA 1981). About 70 % of the rainfall occurs in the 150-180 day growing season (USCOE 1973). Average annual snowfall ranges from 20 to 30 inches across the basin, increasing from south to north (USDA 1981, MDNR 1986b). Runoff ranges from four to six inches annually. Certain factors influence runoff severity such as soil erodibility, soil permeability, soil saturation, land cover, and the time-span over which the runoff occurs (MDNR 1986b). Runoff and discharge are primarily driven by rainfall (Figure 2; data from Graham, Missouri gauging station). Discrepancies in discharge, as a function of precipitation for Figure 2, were probably caused by snowmelt in February and localized heavy rainfall in the upper portion of the basin in June. The basin in Missouri is in the driest part of the state, and due to highly variable annual precipitation has been subject to extensive dry periods.

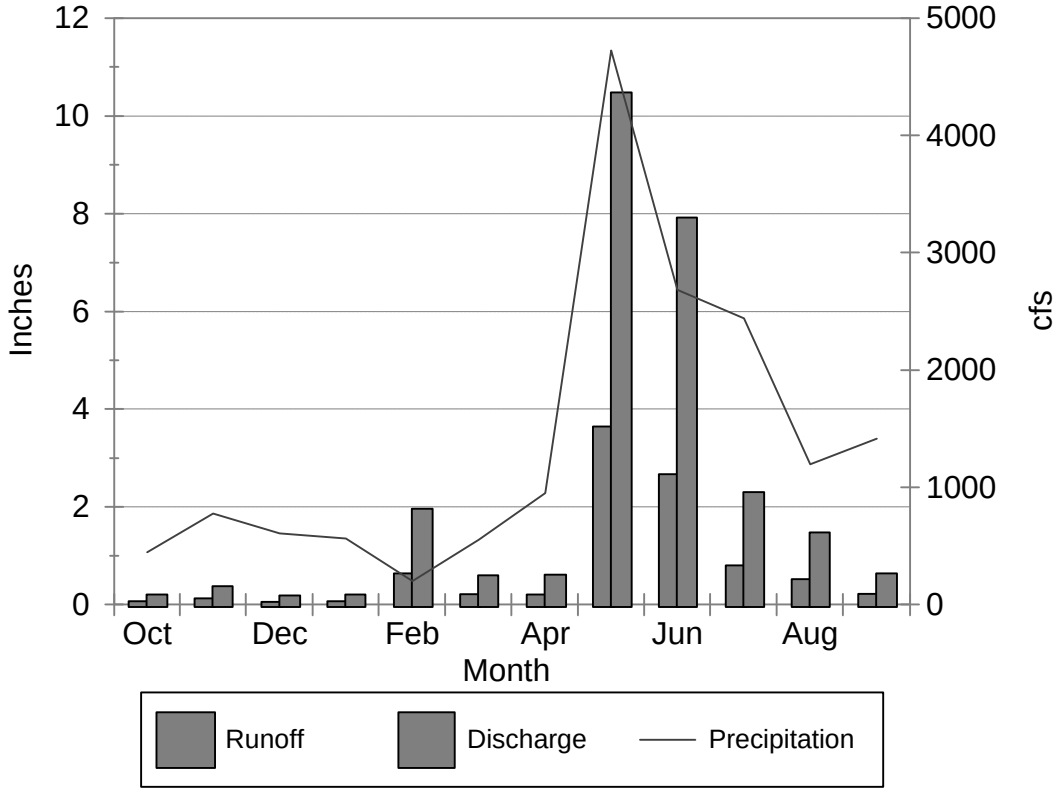


Figure 2. Discharge (cfs), precipitation (inches), and runoff (inches), for water year October

1995 through September 1996 (USGS 1997, NOAA website 1997).

GAUGING STATIONS

There are two active United States Geological Survey (USGS) gauging stations (Figure ga) and one active partial records gauging station in the Nodaway River basin. The three stations are all located on the mainstem Nodaway River near the towns of Graham, Missouri, Clarinda, Iowa, and Massena, Iowa (USGS 1995a, USGS 1996a). Inactive gauge stations are located near Villisca, Iowa, Burlington Junction, Missouri, and Oregon, Missouri. A complete listing of locations and details for all six can be found in Table 6.

Table 6. Gauging stations located in the Nodaway River basin (USGS 1995a, USGS 1996a).

Station Number	Location (Township - Range - Section)	UTM Coordinates	Watershed Area (Mi.^{2})	Type	Record Period
06817700	Graham, MO, Nodaway River (62N-37W-9)	x - 323860 y - 4452000	1,380	D/Q	1982-Present
06817000	Clarinda, IA, Nodaway River (69N-36W-32)	x - 330060 y - 4511580	762	D/Q	1918-1925 1936-Present
06816290	Massena, IA, West Nodaway River (75N-34W- 33)	x - 352660 y - 4567240	23	C	1966-Present
06816500	Villisca, IA, West Nodaway River (71N-36W-28)	x - 332080 y - 4532600	342	D*	1918-1925
06817500	Burlington Junction, MO, Nodaway River (65N-37W-17)	x - 322860 y - 4479080	1,240	D*	1922-1983
06817800	Oregon, MO, Nodaway River (60N-37W-36)	x - 329420 y - 4426280	1,770	D/Q*	1968-1975 1977-1989

Station Type: D = Continuous record stream flow gauging station; C = Crest gauging station; Q = Water quality station; * = Currently inactive.

PERMANENT AND INTERMITTENT STREAMS

There are 156 third order and larger streams in the Nodaway River basin (Appendix B). The permanence/intermittence of particular streams can be determined from 7.5 minute series topographical maps found in the coverage in Appendix C. Permanent streams are indicated with solid blue lines and intermittent streams are indicated with dashed blue lines. The mainstem Nodaway was classified as permanently flowing for 52 of its 61 miles in Missouri (Funk 1968). Based on current USGS 7.5 minute maps there are 485 miles of permanently flowing and 138 miles of intermittently flowing streams and rivers, fourth order or higher, in the Nodaway River basin. Most lower order streams in the basin are intermittent. Increased intermittence, resulting from lower base flows and sedimentation, is occurring throughout the basin.

Appendix B. Stream information for third order and larger streams from the Nodaway River basin obtained from 7.5 minute series, 1:24,000 scale, USGS topographic maps. (Original length and miles channelized for all streams fourth order and larger were estimated using 7.5 minute series, 1:24,000 scale, USGS orthophoto quadrangle maps).

Stream Name	Max. Order	Location at Mouth T R S	Map Numbers[1]	Receiving Stream	Original Length (Mi.)	Current Length (Mi.)	Miles Channe l-ized
Nodaway River	6	59-36-29	M8,M7,L7, K7,J7,I7,H7, G7	Missouri River	116.5	64.0	46.7
Smith Creek	4	59-36-07	M8,M7	Nodaway River	7.2	5.9	1.5
Unnamed #01	3	59-37-11	M7	Smith Creek		1.7	
Lincoln Creek	4	60-37-25	M7,M8,L8	Nodaway River	16.5	13.8	2.2
Unnamed #02	3	60-36-27	M8	Lincoln Creek		3.0	
Unnamed #03	3	60-36-14	L8	Lincoln Creek		2.7	
Carroll Branch	3	60-37-23	L7,M7	Nodaway River		4.7	
Unnamed #04	3	60-37-23	L7,L8	Nodaway River		5.1	
Arapahoe Creek	5	61-36-31	L7,L8,K8	Nodaway River	16.9	12.6	6.7
Pedlar Creek	4	61-36-30	L7,L8,L9	Arapahoe Creek	11.2	9.4	2.8
Unnamed #05	3	61-36-22	L8	Pedlar Creek		4.8	
Unnamed #06	3	61-36-24	L8	Pedlar Creek		2.2	
Owl Creek	3	61-36-19	L7,L8,K8	Arapahoe Creek		9.5	
Newland Creek	3	61-36-09	L8,K8	Arapahoe Creek		8.4	
Unnamed #07	3	61-36-12	L8	Arapahoe Creek		1.9	
Unnamed #08	4	61-37-27	L7,L6	Nodaway River	7.0	6.7	0.4
Nichols Creek	3	61-37-33	L7	Unnamed #08		5.9	
Hickory Creek #1	3	61-37-22	L7,L6	Nodaway River		7.1	
Hog Creek	3	61-37-03	L7,K7,K6	Nodaway River		5.4	
Hayzlett Branch	3	62-37-35	K7,K8	Nodaway River		4.7	
Jenkins Creek	4	62-37-22	K7,K8,J8	Nodaway River	15.0	13.2	1.6
Unnamed #09	3	62-36-18	K8	Jenkins Creek		2.2	
East Fork #1	4	62-36-08	K8	Jenkins Creek		5.2	0.0
Unnamed #10	3	62-36-09	K8	East Fork #1		2.5	
Elkhorn Creek	4	62-37-22	K7,J7,J8	Nodaway River	20.4	18.5	1.7
East Branch	3	63-37-35	K7,K8,J8	Elkhorn Creek		8.8	
Highly Creek	4	62-37-16	K7,K6	Nodaway River		9.5	0.0
Unnamed #11	3	62-37-16	K7,K6	Highly Creek		5.7	
Bagby Creek	3	63-37-21	J7	Nodaway River		4.7	
Unnamed #12	3	63-37-16	J7	Nodaway River		2.8	
Unnamed #13	3	63-37-16	J7	Nodaway River		1.9	
Hickory Creek #2	3	63-37-08	J7,J6	Nodaway River		4.7	
Burr Oak Creek	3	64-37-33	J7,J6	Nodaway River		5.8	
Florida Creek	4	64-37-33	J7,J8,I8	Nodaway River	14.6	13.3	1.8
Unnamed #14	3	64-37-26	J7	Florida Creek		2.6	
Unnamed #15	3	64-37-24	J7,J8,I8	Florida Creek		5.7	
Unnamed #16	3	64-36-17	J8	Florida Creek		2.7	
Unnamed #17	3	64-37-21	J7,J6	Nodaway River		7.1	
Sand Creek	4	64-37-21	J7,I7,I8	Nodaway River	12.6	11.4	1.0
Unnamed #18	3	65-36-30	I7,I8	Sand Creek		2.3	
Unnamed #19	3	64-37-21	J7	Nodaway River		2.0	
Bowman Branch	3	64-37-16	J7,I7	Nodaway River		5.1	
Huff Creek	3	64-37-05	I7,J7,J6	Nodaway River		5.9	
Headrick Branch	3	65-37-32	I7,I6	Nodaway River		6.0	
Hagey Branch	3	65-37-29	I7,I6	Nodaway River		4.5	
Mill Creek	4	65-37-17	I7,H7,H6	Nodaway River	20.3	12.3	10.0
Unnamed #21	3	65-37-06	I7,I6	Mill Creek		4.2	
Moss Branch	3	66-37-20	H7	Mill Creek		7.3	

Stream Name	Max. Order	Location at Mouth T R S	Map Numbers[1]	Receiving Stream	Original Length (Mi.)	Current Length (Mi.)	Miles Channel-ized
Unnamed #22	3	66-37-17	H7,H6	Mill Creek		4.9	
West Mill Creek	3	67-37-31	H6,G6,G7	Mill Creek		15.9	
Middle Mill Creek	3	67-37-29	H7,G7	Mill Creek		8.6	
East Mill Creek	3	67-37-29	H7,G7	Mill Creek		5.7	
Cuyhoga Creek	3	65-37-17	I7	Nodaway River		4.7	
Muddy Creek	3	65-37-04	I7,I8	Nodaway River		7.5	
Clear Creek	5	66-37-27	I7,H7,I8,H8	Nodaway River	17.9	15.6	3.8
South Fork Clear Creek	4	66-36-29	I8,H8	Clear Creek	22.4	16.8	8.6
Unnamed #23	3	66-36-33	I8	South Fork Clear Creek		3.3	
Unnamed #24	4	65-36-17	I8	South Fork Clear Creek	4.0	3.4	1.4
Unnamed #25	3	65-36-16	I8	Unnamed #24		1.8	
Unnamed #26	3	65-36-21	I8	South Fork Clear Creek		2.6	
Unnamed #27	3	65-36-22	I8	South Fork Clear Creek		4.6	
Unnamed #28	3	65-36-11	I8	South Fork Clear Creek		4.3	
Unnamed #29	4	66-36-22	H8	Clear Creek	7.4	7.0	0.4
Unnamed #30	3	66-36-14	H8	Unnamed #29		2.8	
Sink Creek	3	66-37-23	H7,H8	Nodaway River		5.7	
Unnamed #31	3	66-37-01	H7	Nodaway River		5.6	
Buchanan Creek	4	67-36-19	H7,H8,G8	Nodaway River	19.3	14.4	6.7
Unnamed #32	3	67-36-21	H8	Buchanan Creek		3.3	
Unnamed #33	3	68-36-36	G8	Buchanan Creek		3.3	
Unnamed #34	3	68-35-30	G8	Buchanan Creek		3.0	
Unnamed #35	3	67-36-19	H7	Nodaway River		2.5	
West Nodaway River	6	67-36-07	G7,F7,F8,E7, E8,D8,C8,C9, B9,C10,B10	Nodaway River	* 109.1	73.5	40.9
Unnamed #36	3	67-36-06	G7	West Nodaway River		2.7	
No Business Creek	3	68-37-36	G7	West Nodaway River		3.4	
South Branch	4	68-36-18	G7	West Nodaway River	6.2	5.9	0.5
Unnamed #37	3	68-36-18	G7	South Branch		4.3	
North Branch	3	69-36-29	G7,F7	West Nodaway River		5.3	
Ditch Number 10 (Neele Branch)	4	69-36-16	F8,F7,E7	West Nodaway River	13.1	12.1	1.6
Unnamed #38	3	69-37-12	F7	Neele Branch		3.3	
Wolf Run	3	70-36-09	F7,E7,E8,F8	West Nodaway River		5.7	
Unnamed #39	3	70-36-05	E7	West Nodaway River		4.0	
Middle Nodaway River	5	70-36-33	E8,D8,D9, D10,C10,C11, B11,B12,A11	West Nodaway River	* 85.7	59.5	35.6
Unnamed #40	3	71-36-11	E8	Middle Nodaway River		3.0	
Unnamed #41	3	71-36-01	E8	Middle Nodaway River		1.7	
Unnamed #42	3	72-35-21	D8,D9	Middle Nodaway River		2.4	
Unnamed #43	3	72-35-21	D8	Middle Nodaway River		4.1	
Unnamed #44	3	72-35-15	D9	Middle Nodaway River		3.4	
Show Creek	3	72-35-11	D9	Middle Nodaway River		6.7	

Stream Name	Max. Order	Location at Mouth T R S	Map Numbers[1]	Receiving Stream	Original Length (Mi.)	Current Length (Mi.)	Miles Channe l-ized
Unnamed #45	3	73-34-31	D9,D10	Middle Nodaway River		3.8	
Unnamed #46	3	73-34-28	D9,C9	Middle Nodaway River		3.9	
Unnamed #47	3	73-34-22	D10,C10,C9	Middle Nodaway River		4.6	
Unnamed #48	3	73-34-13	C10,D10	Middle Nodaway River		3.7	
Unnamed #49	3	73-34-12	C10	Middle Nodaway River		4.5	
Thompson Creek	3	73-34-12	C10	Middle Nodaway River		8.9	
West Fork	5	74-33-33	C10,B10,A10, A11	Middle Nodaway River	* 41.4	29.0	14.4
Unnamed #50	3	74-33-04	C10,B10	West Fork		6.5	
Rutt Branch	4	75-33-15	B10,B11,A11	West Fork	* A	10.2	
Unnamed #51	3	75-32-06	B11	Rutt Branch		3.7	
Unnamed #52	3	76-32-31	B11	Rutt Branch		3.8	
Ninemile Creek	3	75-33-04	B10,B11,A11	West Fork		9.5	
Unnamed #53	3	76-33-18	A10	West Fork		2.4	
Unnamed #54	3	76-33-18	A10,A11	West Fork		9.3	
Unnamed #55	3	77-33-31	A10	West Fork		3.4	
Unnamed #56	3	77-33-32	A10	West Fork		4.4	
Unnamed #57	3	74-33-27	C11	Middle Nodaway River		4.1	
Unnamed #58	3	74-32-06	C11,B11	Middle Nodaway River		4.9	
Unnamed #59	3	75-32-33	B11,B12	Middle Nodaway River		5.2	
Unnamed #60	3	75-32-01	B12	Middle Nodaway River		3.2	
Unnamed #61	3	76-32-36	B12	Middle Nodaway River		4.1	
Dunns Creek	3	71-36-04	E8,E7	West Nodaway River		5.6	
Unnamed #62	3	72-36-33	E8,D8	West Nodaway River		2.4	
Longs Branch	3	72-36-16	D8	West Nodaway River		9.5	
Sin Creek	3	73-36-33	D8,D9	West Nodaway River		11.1	
Sevenmile Creek	4	73-36-33	D8,D7,C7,B7, B8,C8,B9, B10,A10	West Nodaway River	* 57.6	38.6	24.8
Unnamed #63	3	73-36-29	D7	Sevenmile Creek		3.9	
Unnamed #64	3	73-36-20	D7,C7	Sevenmile Creek		3.2	
Rose Creek	3	73-36-05	C7,C8	Sevenmile Creek		8.1	
Unnamed #65	3	73-36-06	C7	Sevenmile Creek		4.6	
Unnamed #66	3	75-36-32	B7	Sevenmile Creek		3.8	
Unnamed #67	3	75-36-33	B8	Sevenmile Creek		4.4	
Hoyts Branch	3	75-35-29	B8,B9	Sevenmile Creek		8.0	
Unnamed #68	3	76-34-32	B9,B10	Sevenmile Creek		4.9	
Unnamed #69	3	76-34-28	B9,A9	Sevenmile Creek		4.1	
Threemile Creek	3	74-36-35	C8	West Nodaway River		9.3	
Williams Creek	4	74-36-35	C8,C9,C10	West Nodaway River	22.1	18.3	5.3
Petersons Creek	3	73-35-04	C8,C9	Williams Creek		4.8	
Moore Creek	3	73-35-01	C9	Williams Creek		5.2	
Unnamed #70	3	74-35-30	C8,C9	West Nodaway River		4.7	

Stream Name	Max. Order	Location at Mouth T R S	Map Numbers[1]	Receiving Stream	Original Length (Mi.)	Current Length (Mi.)	Miles Channe l-ized
Whistlers Branch	3	74-35-16	C8,C9,B9	West Nodaway River		6.1	
Elm Creek	3	74-35-12	C9,C10	West Nodaway River		6.1	
Unnamed #71	3	75-34-32	C9,B9	West Nodaway River		4.8	
Unnamed #72	3	75-34-23	B10	West Nodaway River		4.3	
East Nodaway River	5	67-36-07	G7,G8,F8,E8, E9,E10,D10, D11,C11,C12	Nodaway River	121.8	73.4	48.9
Unnamed #73	3	69-36-34	G8,F8	East Nodaway River		4.4	
Unnamed #74	3	69-36-14	F8	East Nodaway River		2.7	
Unnamed #75	3	69-36-12	F8	East Nodaway River		3.0	
Unnamed #76	3	70-35-31	F8,F9	East Nodaway River		6.4	
Unnamed #77	3	70-35-19	F8,F9	East Nodaway River		5.4	
Long Branch	4	70-35-17	F8,E8,E9	East Nodaway River		9.0	0.0
Unnamed #78	3	70-35-09	E8,E9	Long Branch		3.4	
Unnamed #79	3	71-35-16	E8,E9	East Nodaway River		4.5	
Kemp Creek **	4	71-35-11	E9,D9,D10, D11,C11	East Nodaway River	25.3	20.1	8.9
Unnamed #80	3	73-33-27	D10,D11	Kemp Creek		3.9	
Unnamed #81	3	71-34-08	E9,D9	East Nodaway River		3.0	
Brown Branch	4	72-33-29	D10	East Nodaway River	6.1	5.8	0.2
Unnamed #82	3	72-33-16	D10	Brown Branch		3.1	
Unnamed #83	3	72-33-26	D11,E11	East Nodaway River		4.6	
Mt. Zion Branch	3	72-33-13	D11	East Nodaway River		6.2	
Unnamed #84	3	72-33-08	D11	East Nodaway River		3.6	
Unnamed #85	3	72-32-08	D11	East Nodaway River		4.7	
Cipra Branch	3	72-32-09	D11,D12	East Nodaway River		7.5	
East Fork #2	3	73-32-33	D11,D12,C12	East Nodaway River		12.0	
Kosar Branch	3	73-32-21	D11,C11	East Nodaway River		5.6	
Shanghai Creek	4	73-32-16	C11,C11,C12	East Nodaway River	18.1	12.9	8.0
Unnamed #86	3	73-32-03	C11,C12	Shanghai Creek		4.7	
Unnamed #87	3	74-32-34	C11	Shanghai Creek		6.4	

[1] - Index numbers of topographic maps used in calculating stream and river statistics for the Nodaway River Basin (see Appendix C).
* - Orthophoto quadrangle map coverage incomplete so distances are estimated using available coverages
**- Most of the altered distance is due to impoundment from Lake Icaria.
A - No orthophoto quadrangle map coverage available so estimates of alteration were not calculated.

Appendix C. Index numbers and names for 7.5 minute series topographical maps covering the Nodaway River basin.

6	7	8	9	10	11	12	13
			ANITA (1971)	ADAIR SOUTH (1971)	CANBY (1971)	ROSSERDALE (1983)	**A**
	LEWIS (1971)	ANITA SW (1971)	MASSENA (1971)	FONTANELLE SW (1971)	FONTANELLE (1971)	GREENFIELD (1983)	**B**
	GRISWOLD NE (1978)	GRANT (1980)	DEWEY (1980)	BRIDGEWATER (1980)	NEVINVILLE (1980)	ORIENT (1980)	**C**
	WALLIN (1978)	MORTON MILLS (1980)	CARBON (1980)	CORNING NORTH (1980)	PRESCOTT (1980)	CRESTON WEST (1981)	**D**
	STANTON (1978)	VILLISCA (1980)	BROOKS (1980)	CORNING SOUTH (1980)	lENOX (1980)		**E**
	CLARINDA NORTH (1978)	HAWLEYVILLE (1980)	GUSS (1980)				**F**
COIN (1981)	CLARINDA SOUTH (1981)	NEW MARKET (1980)	LADOGA (1980)				**G**
BLANCHARD (1981)	CLEARMONT (1981)	HOPKINS SW (1980)					**H**
SKIDMORE NW (1981)	BURLINGTON JUNCTION	WILCOX (1985)					**I**
DOTHAM (1981)	SKIDMORE (1981)	MARYVILLE WEST (1984)					**J**
MOUND CITY (1981)	MAITLAND (1981)	BOLCKOW NW (1984)	BARNARD (1984)				**K**
KIMSEY CREEK (1981)	NEW POINT (1981)	FILLMORE (1984)	BOLCKOW (1984)				**L**
	FORBES (1972)	AMAZONIA (1972)	SAVANNAH (1978)				**M**

STREAM FLOW

The average discharge for the Nodaway River near Graham, MO from water years 1983-1996 was 1,011 cubic feet per second (cfs). The maximum instantaneous peak flow on the Nodaway near Graham was 78,300 cfs in 1993, and the maximum instantaneous peak flow on the West Nodaway was 31,100 cfs at Clarinda, IA in 1947 (Table 7). The Nodaway River makes up 0.4 % of the drainage area and about 1 % of the average annual flow of the Missouri River at their confluence.

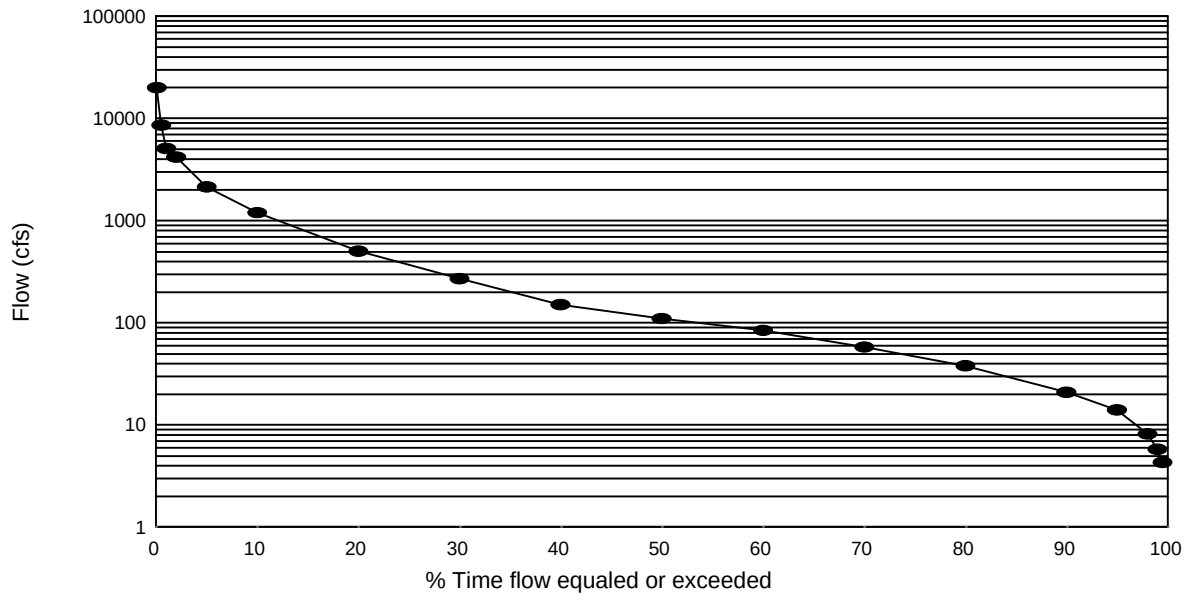
Table 7. Discharge information (cfs) for the total period of record at two gauge locations in the Nodaway River basin (USGS 1995a, USGS 1996a).

Location	Maximum Discharge	Minimum Discharge	Mean Discharge	10% Exceeds	50% Exceeds	90% Exceeds
Nodaway River Graham, MO	78,300 9-22-1993	23 9-9-1985	1,011	2,760	265	72
Nodaway River Clarinda, IA	31,100 6-13-1947	1.3 12-25-1923	380	820	100	19

The Nodaway River has contributed as much as 20 percent to the Missouri River flood crest when concurrent high flows occurred (USCOE 1973). Flood magnitude in cubic feet per second

for various recurrence intervals on the Nodaway River at Burlington Junction, Missouri was calculated to be: 12,300 for two year, 22,600 for five year, 30,500 for ten year, 41,200 for twenty-five year, 50,000 for fifty year, and 58,400 for 100 year flood events (Hauth 1974). The Nodaway River basin has highly variable flows as shown by its flow duration curve (Figure 3). Streams in the basin tend to rise and subside swiftly in response to precipitation events.

Figure 3. Flow duration curve for the Nodaway River near Burlington Junction, Missouri (Skelton 1976).



7-DAY Q_2 AND Q_{10} LOW FLOWS

Streams in the Dissected Till Plains Region, including the Nodaway River, have poor low flow potentials due to low hydraulic conductivity of area soils and poor land use practices. Low flows in the basin usually occur in the months of August, September, and October (Skelton 1976). Low flow characteristics can usually be generalized in plains streams based upon the size of the drainage area. Streams with basin areas less than 100 mi^2 will almost always have 7-day average minimum flows at recurrence intervals of two years (7-day Q_2) of zero. About 60 percent of plains streams with drainage areas of 100 to 200 mi^2 will have 7-day Q_2 of zero and the remainder will have 7-day Q_2 of 0.1 to 1.0 cfs. This method is unreliable for basins with drainage areas larger than 200 mi^2 and field observations are required. The 7-day average minimum flows at 10 year intervals (7-day Q_{10}) for drainage basins of 200 mi^2 or less are almost always zero. About 70 percent of plains streams with drainage areas or 200 to 1,000 mi^2 will have 7-day Q_{10} of

zero and the remainder will have 7-day Q_{10} of 0.1 to 1.5 cfs. For drainage basins larger than 1,000 mi^2 field observations of flow are required (Skelton 1976). Table 8 shows low flow data for reporting gauge stations in the Nodaway River basin.

Table 8. 7-day Q_2 and 7-day Q_{10} seasonal low flows for the Nodaway River basin (Skelton 1970).

Station Number	Station Location	Period of Record	Basin Area (mi^2)	7-day Q_2 (cfs)	7-day Q_{10} (cfs)
06817500	Burlington Junction, MO, Nodaway River	1922-1965	1,240	43	9.2
06817800	Oregon, MO, Nodaway River	1942-1943	1,770	58	10

DAM AND HYDROPOWER AND INFLUENCES

There are no major dams in the basin. There are a few moderate-sized reservoirs and a large number of small ponds in the Nodaway River basin. The larger bodies of water are public impoundments. Due to small size and ease of construction, the number of ponds can change very rapidly. Many ponds are built without needing permits and statistics on ponds are usually compiled by county rather than watershed. These factors complicate getting accurate, up-to-date information on ponds. Concern exists over the effects these ponds have on low-flow conditions as they intercept runoff and allow little or no adjustment for maintenance of stream flows.

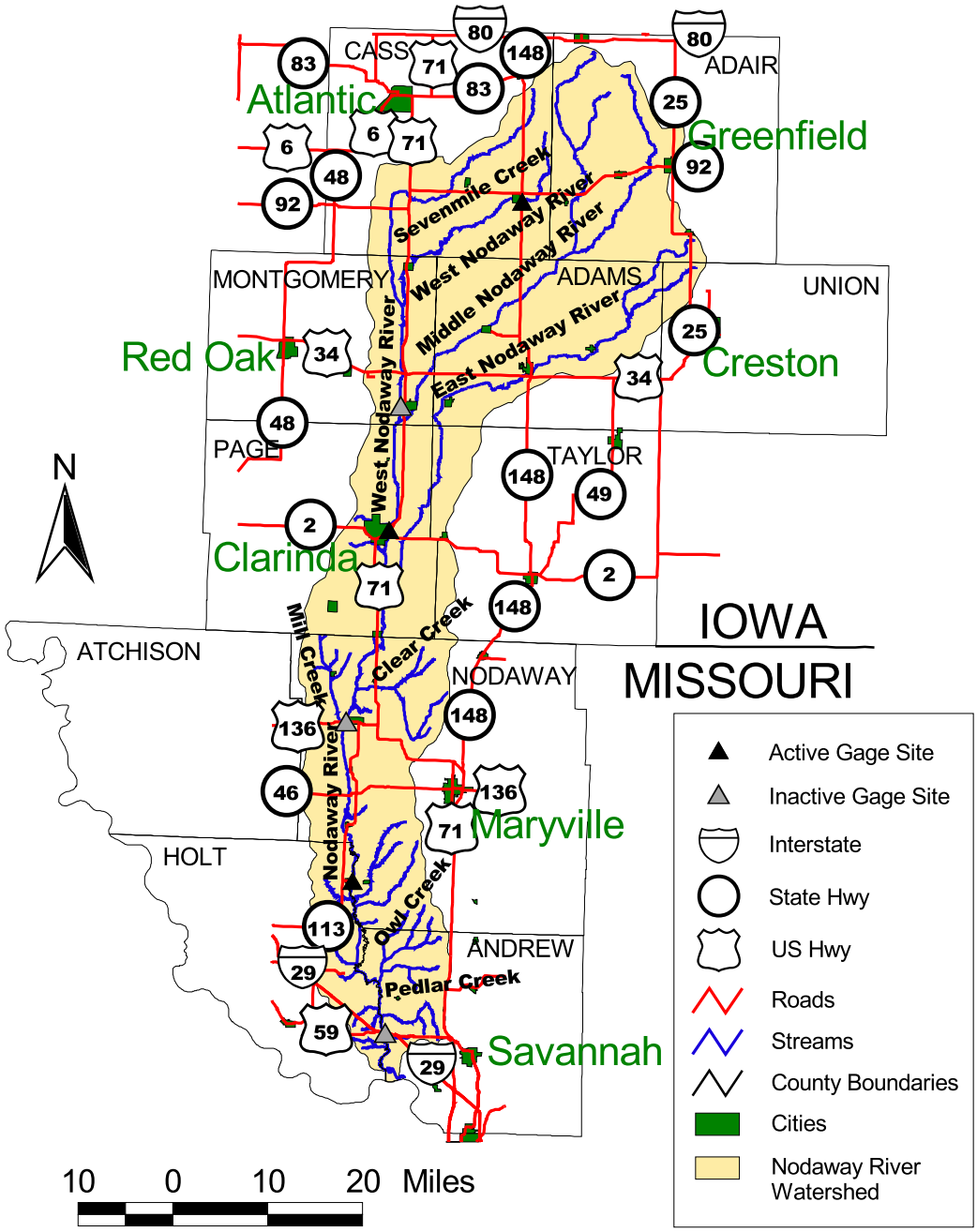


Figure ga. Active and inactive gage sites in the Nodaway River watershed.