SOLOMON BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody/Assessment Unit (AU): Limestone Creek - Salt Creek (Minneapolis) - Upper Solomon River - Lower Solomon River
Water Quality Impairment: Sulfate

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Solomon River

County: Cloud, Dickinson, Jewell, Lincoln, Ottawa, Mitchell, Saline and Smith

HUC 8: 10260015

HUC 11 (HUC 14s)**:** (*see* **Figure 1**)

010 (040, 050, 060, 070, 080 and 090)
020 (030, 040, 050, 060 and 070)
030 (010, 020, 030, 040, 050, 060, 070 and 080)
040 (010, 020, 030, 040, 050 and 060)
050 (010, 020, 030, 040 and 050)
060 (010, 060, 070 and 080)
070 (010, 020, 030, 040 and 050)

Drainage Area: 1,552.9 square miles

Main Stem Segment: WQLS: Lower Solomon River AU; 1, 3, 5, 6, 8 and 12 in part (Solomon River) starting at confluence with the Smoky Hill River on the west side of Dickinson County and traveling upstream to downstream boundary of HUC14 10260015030050 in southwest Cloud County (**Figure 2**).

WQLS: Salt Creek (Minneapolis) AU; 27, 29 and 30 (Salt Creek) starting and confluence with the Solomon River in south-central Ottawa County and traveling upstream to headwaters in southwest Mitchell County (**Figure 2**).

WQLS: Upper Solomon River AU; 12 in part, 14,16 and 23 (Solomon River) starting at downstream boundary of HUC14 10260015030050 in southwest Cloud County and traveling upstream to Waconda Lake in northwest Mitchell County (**Figure 2**).

WQLS: Limestone Creek AU; 18 and 19 (Limestone Creek) starting at confluence with Solomon River just below Waconda Lake in northwest Mitchell County and traveling upstream to headwaters in central Jewell County (**Figure 2**).

Tributaries:

Lower Solomon R. AU (*see* **Figure 2**)	Coal Creek (2) Sand Creek (4) Antelope Creek (58) Battle Creek (57) Lindsey Creek (7) Dry Creek (52) Yockey Creek (50) Mortimer Creek (49) Cris Creek (48)
Salt Cr. (Minneapolis) AU (*see* **Figure 2**)	Lost Creek (56) First Creek (28) Spring Creek (53) Second Creek (53) W. Elkhorn Creek (47) Rattlesnake Creek (31 and 32) Battle Creek (33) Fifth Creek (45) Little Creek (44) Antelope Creek (43)
Upper Solomon R. AU (*see* **Figure 2**)	Second Creek (51) Fourth Creek (46) Marshall Creek (42) Plum Creek (13) Dry Creek (37) Leban Creek (41) Mulberry Creek (36) Indian Creek (40) Turkey Creek (39) Frog Creek (34)
Limestone Cr. AU (*see* **Figure 2**)	Disappointment Cr (35) West Limestone Cr (20) Middle Limestone Cr (21) West Limestone Cr (22) Elm Cr (59)

Designated Uses:

Lower Solomon R. AU	Expected Aquatic Life Support, Primary Contact Recreation, Domestic Water Supply; Food Procurement; Ground Water Recharge; Industrial Water Supply Use; Irrigation Use; Livestock Watering Use for Main Stem Segments (Solomon River segments 1, 3, 5, 6, 8, 12)

Salt Cr. (Minneapolis) AU	Expected Aquatic Life Support, Primary Contact Recreation, Food Procurement Use for Main Stem Segments (Salt Creek segments 27, 29, 30)
Upper Solomon R. AU	Expected Aquatic Life Support, Primary Contact Recreation, Domestic Water Supply; Food Procurement; Ground Water Recharge; Industrial Water Supply Use; Irrigation Use; Livestock Watering Use for Main Stem Segments (Solomon River segments 12, 14, 16, 23).
Limestone Cr. AU	Expected Aquatic Life Support, Primary Contact Recreation, Domestic Water Supply; Food Procurement; Ground Water Recharge; Industrial Water Supply Use; Irrigation Use; Livestock Watering Use for Main Stem Segments (Limestone Creek segments 18, 19).
Impaired Use:	Domestic Water Supply (Potentially)
Water Quality Standard:	Domestic Water Supply: 250 mg/L at any point of domestic water supply diversion (K.A.R.28-16-28e(c) (3) (A); Livestock Watering: 1,000 mg/L (Table 1a of K.A.R. 28-16-28e(d)); In stream segments where background concentrations of naturally occurring substances, including chlorides and sulfates, exceed the water quality criteria listed in Table 1a of KAR 28-16-28e(d), at ambient flow, the existing water quality shall be maintained, and the newly established numeric criteria shall be the background concentration, as defined in KAR 28-16-28b(e). Background concentrations shall be established using the methods outlined in the "Kansas implementation procedures: surface water quality standards," dated August 6, 2001. (KAR 28-16-28e(b)(9)).

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Use under 2002 303(d): Not Supporting Domestic Water Supply Use.

Monitoring Sites: Station 266 at Niles (Lower Solomon River); Station 512 near Minneapolis (Salt Creek); Station 511 near Glasco (Upper Solomon River); Station 667 near Glen Elder (Limestone Creek).

Period of Record Used: 1990 – 2001 for Stations 266, 511 and 512; 1991 –1997, 1999 and 2001 for Station 667 (**Figures 3, 4, 5, and 6,** respectively). Site 266 also includes some historical USGS data in Figures 9, 12, 16, 19, 21 and 22.

Flow Record: Lower Solomon R.: Solomon River at Niles (USGS Station 068769001970 - 2002)

Salt Creek: Salt Creek near Ada (USGS Station 06876700; 1970 – 2002);

Upper Solomon R.: Solomon River near Simpson (USGS Station 06876070; 1990 – 2002)

Limestone Creek: White Rock Creek near Burr Oak (USGS Station 06853800; 1970 - 2002) flow duration matched to Limestone Creek at Glen Elder (USGS Site 06875820)

Long Term Flow Conditions:

Median Flows: Solomon River at Niles = 170 cfs
Salt Creek = 15.3 cfs
Solomon River at Simpson =138 cfs
Limestone Creek = 0.72 cfs

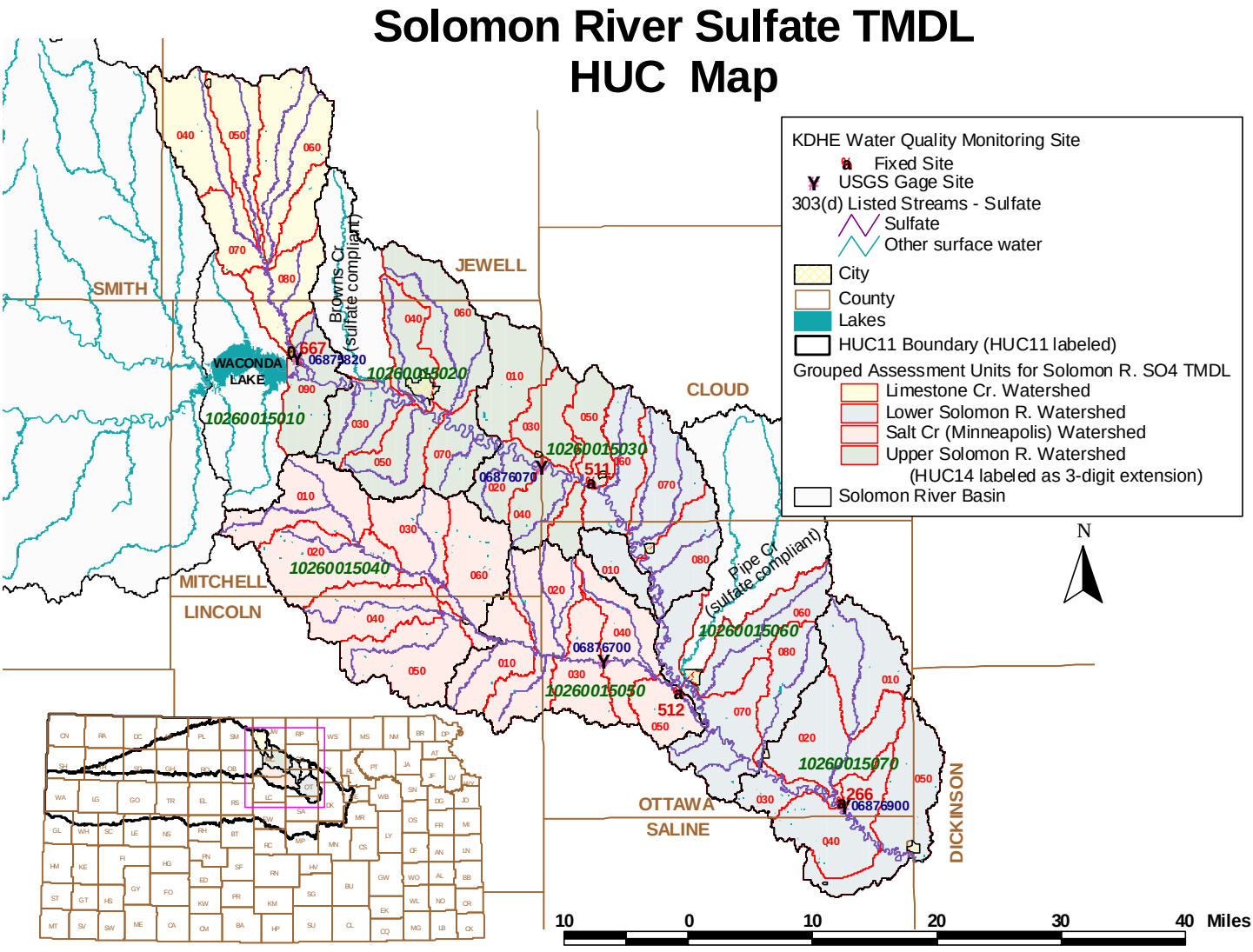

Figure 1

(The unimpaired Pipe and Browns Creek average sulfate were 83 and 163 mg/L, respectively.)

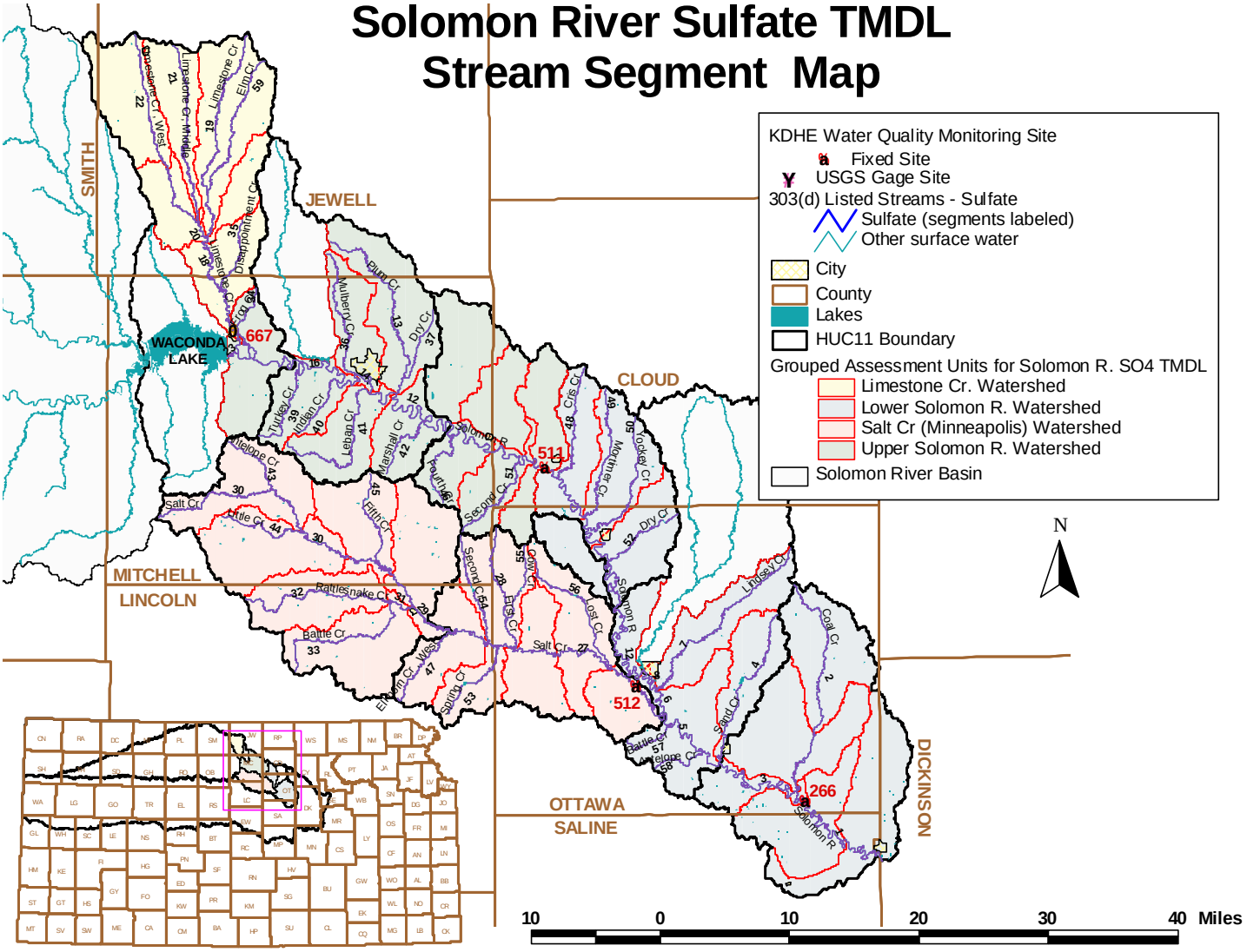
Solomon River Sulfate TMDL
Stream Segment Map
KDHE Water Quality Monitoring Site
Fixed Site
USGS Gage Site
303(d) Listed Streams - Sulfate
Sulfate (segments labeled)
Other surface water
City
County
Lakes
HUC11 Boundary
Grouped Assessment Units for Solomon R. SO4 TMDL
Limestone Cr. Watershed
Lower Solomon R. Watershed
Salt Cr (Minneapolis) Watershed
Upper Solomon R. Watershed
Solomon River Basin
SMITH
JEWELL
CLOUD
MITCHELL
LINCOLN
OTTAWA
SALINE
DICKINSON
WACONDA LAKE
667
511
512
266
N
10 0 10 20 30 40 Miles

Figure 2

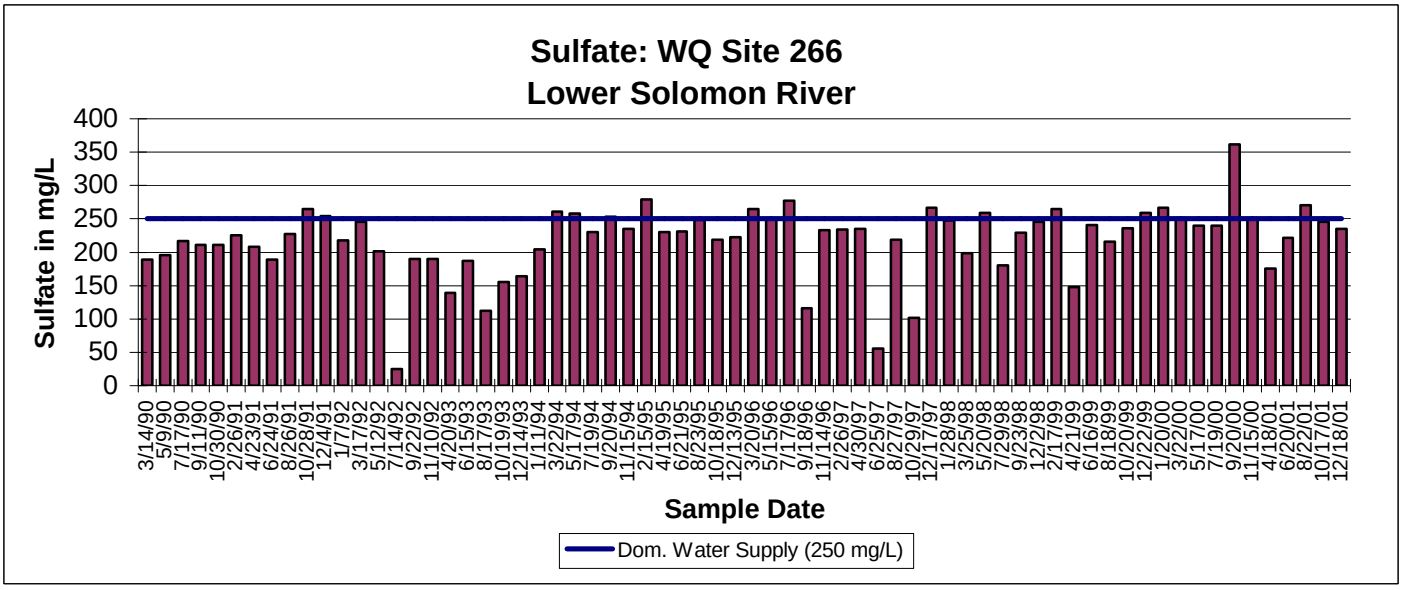

Figure 3

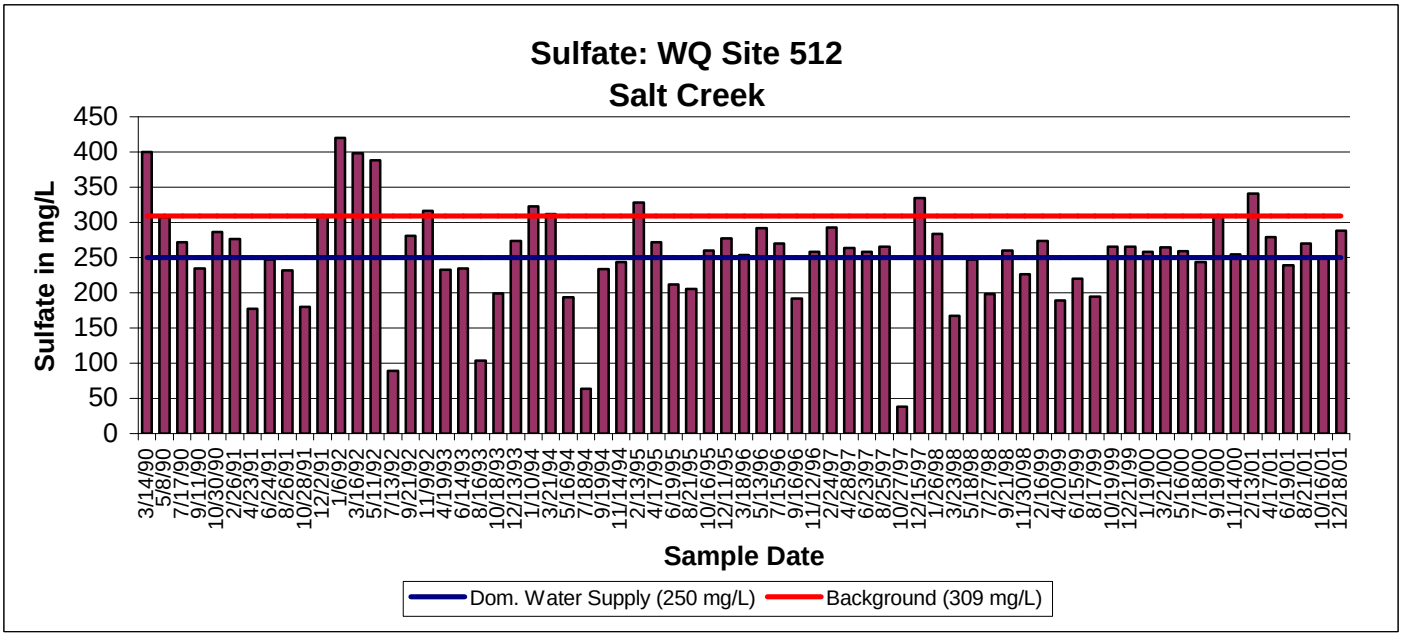

Figure 4

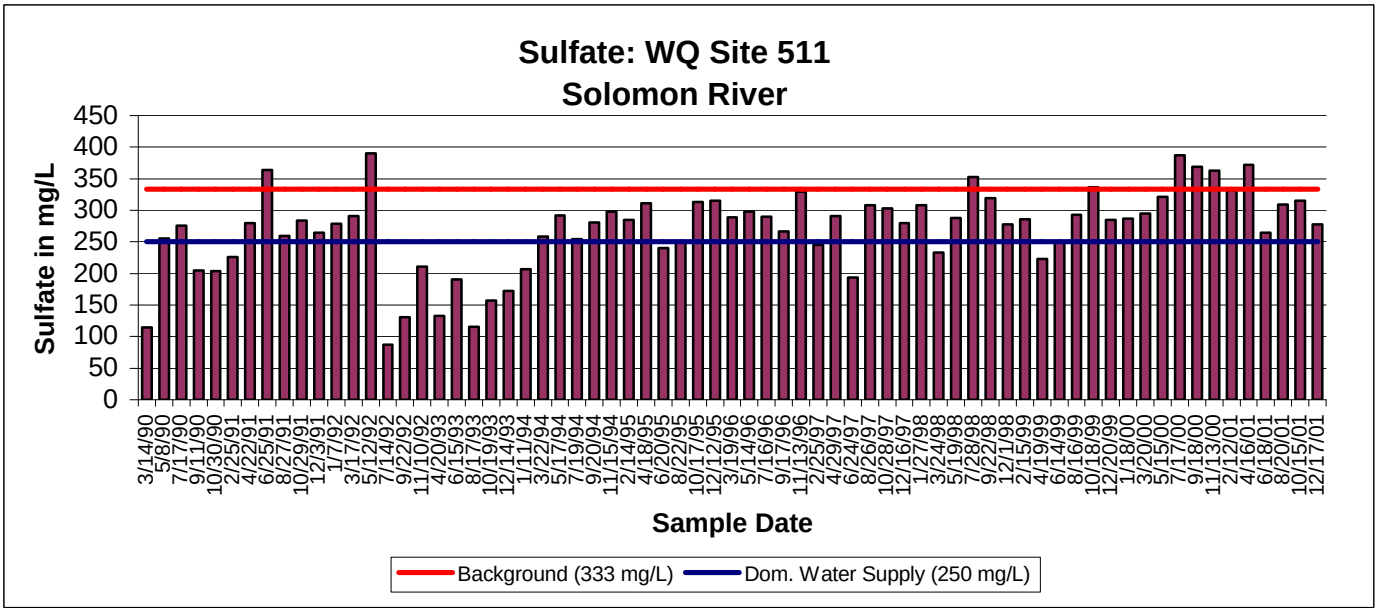

Figure 5

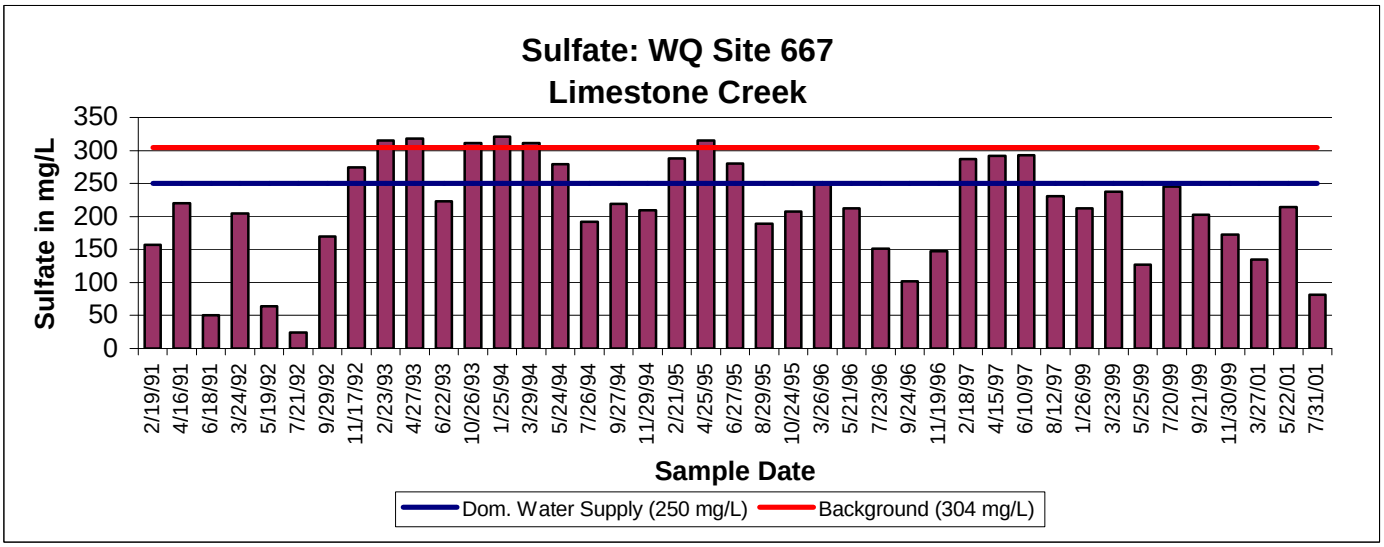

Figure 6

Current Conditions: Since loading capacity varies as a function of the flow present in the stream, this TMDL represents a continuum of desired loads over all flow conditions, rather than fixed at a single value. Sample data for each sampling site were categorized for each of the three defined seasons: Spring (Apr-Jul), Summer-Fall (Aug-Oct) and Winter (Nov-Mar). High flows and runoff equate to lower flow durations; baseflow and point source influences generally occur in the 75-99% range. Load curves were established for the Domestic Water Supply criterion by multiplying the flow values along the curve by the applicable water quality criterion and converting the units to derive a load duration curve of tons per day. These load curves represent the TMDL since any point along the curve denotes water quality for the standard at that flow. Historic excursions from the water quality standard are seen as plotted points above the load

curve. Water quality standards are met for those points plotting below the load duration curve (**Figures 24, 25, 26 and 27**).

Site 266: Excursions were seen in each of the three defined seasons and are outlined in **Table 1**. Seventeen percent of the Spring samples and 21% of Summer-Fall samples were over the domestic water supply criterion. Thirty-six percent of the Winter samples were over the domestic supply criterion. Overall, 25% of the samples were over the criteria. This would represent a baseline condition of partial support of the impaired designated use.

Table 1

NUMBER OF SAMPLES OVER SULFATE STANDARD OF 250 mg/L BY FLOW								
Station	**Season**	**0 to 10%**	**10 to 25%**	**25 to 50%**	**50 to 75%**	**75 to 90%**	**90 to 100%**	**Cum. Freq.**
Solomon River at Niles (266)	Spring	0	3	1	0	0	0	4/24 = 17%
	Summer/Fall	0	0	1	2	0	1	4/19 = 21%
	Winter	1	2	5	0	0	1	9/25 = 36%

Site 512: Excursions were seen in each of the three defined seasons and are outlined in **Table 2**. Forty-two percent of the Spring samples and 48% of Summer-Fall samples were over the domestic water supply criterion. Eighty-eight percent of the Winter samples were over the domestic supply criterion. Overall, 59% of the samples were over the criteria. This would represent a baseline condition of non-support of the impaired designated use.

Table 2

NUMBER OF SAMPLES OVER SULFATE STANDARD OF 250 mg/L BY FLOW								
Station	**Season**	**0 to 10%**	**10 to 25%**	**25 to 50%**	**50 to 75%**	**75 to 90%**	**90 to 100%**	**Cum. Freq.**
Salt Creek near Minneapolis (512)	Spring	0	0	5	3	1	1	10/24 = 42%
	Summer/Fall	0	0	1	4	1	2	8/19 = 42%
	Winter	0	3	10	5	4	1	23/26 = 88%

Site 511: Excursions were seen in each of the three defined seasons and are outlined in **Table 3**. Seventy-five percent of the Spring samples and 74% of Summer-Fall samples were over the domestic water supply criterion. Seventy-three percent of the Winter samples were over the domestic supply criterion. Overall, 74% of the samples were over the criteria. This would represent a baseline condition of non-support of the impaired designated use.

Table 3

NUMBER OF SAMPLES OVER SULFATE STANDARD OF 250 mg/L BY FLOW								
Station	**Season**	**0 to 10%**	**10 to 25%**	**25 to 50%**	**50 to 75%**	**75 to 90%**	**90 to 100%**	**Cum. Freq.**
Solomon River near Simpson (511)	Spring	0	4	5	3	4	2	18/24 = 75%
	Summer/Fall	1	0	2	6	4	1	14/19 = 74%
	Winter	1	1	9	2	3	3	19/26 = 73%

Site 667: Excursions were seen in each of the three defined seasons and are outlined in **Table 4**. Thirty-three percent of the Spring samples and 13% of Summer-Fall samples were over the domestic water supply criterion. Forty-seven percent of the Winter samples were over the domestic supply criterion. Overall, 34% of the samples were over the criteria. This would represent a baseline condition of non-support of the impaired designated use.

Table 4

NUMBER OF SAMPLES OVER SULFATE STANDARD OF 250 mg/L BY FLOW								
Station	**Season**	**0 to 10%**	**10 to 25%**	**25 to 50%**	**50 to 75%**	**75 to 90%**	**90 to 100%**	**Cum. Freq.**
Limestone Creek near Glen Elder (667)	Spring	0	4	2	0	0	0	6/18 = 33%
	Summer/Fall	1	0	0	0	0	0	1/8 = 13%
	Winter	0	4	2	1	0	0	7/15 = 47%

Desired Endpoints of Water Quality (Implied Load Capacity) at Sites 266, 512, 511 and 667 over 2008 – 2012

The ultimate endpoint for this TMDL will be to achieve the Kansas Water Quality Standards fully supporting Drinking Water Use. This TMDL will, however, be phased. The current standard of 250 mg/L of sulfate was used to establish the TMDL. However, the Solomon River system is subject to loading of sulfate from shales in the underlying Cretaceous bedrock (high gypsum and pyrite content) and from the discharge of naturally saline ground water from the Dakota aquifer underlying portions of the area. As such, the Solomon River, Salt Creek and Limestone Creek have elevated sulfate levels from this source. The natural background of sulfate, causes sulfate concentrations to rise above 250 mg/L frequently making compliance with the Standard problematic at Sites 512 and 667.

At Sites 511 and 266, current information indicates that the long-term increase in sulfate concentration with time is a result of increased water consumption from upstream watersheds (North and South Fork Solomon River watersheds) and along the main stem of the Solomon River itself. Therefore, the Phase Two target at Site 511 and 266 will also be based on the current standard applied to flows within the contributing portions of the Upper and Lower Solomon River watersheds. Additionally, there is a point of diversion for potable water present on the Solomon River (Segment 14, City of Beloit) to activate the domestic water criteria on this segment and an endpoint of 250 mg/L sulfate is needed on this segment at the point of diversion because of this.

The average sulfate concentration at Site 667 is not greater than the Phase One endpoint (250 mg/L), yet sulfate exceedances from natural sources do occur at a frequency great enough to cause this watershed to be impaired. At Site 512 the average sulfate is greater than the Phase One endpoint because of natural contributions to the sulfate load and the frequency of exceedance is even higher than that of Site 667. Because natural conditions cause the Standard to be unachievable at these two monitoring sites, an alternative endpoint is needed.

Kansas Implementation Procedures for Surface Water allow for a numerical criterion based on natural background to be established from flows less than median in-stream flow. The explicit stream criteria to supplant the general standard will be developed concurrent with Phase One of this TMDL following the appropriate administrative and technical Water Quality Standards processes. Meanwhile, a tentative endpoint has been developed from currently available information at water quality monitoring sites 512 and 667. The 80^{th} percentile of the sulfate concentrations at Site 512 for flows less than the median flow is 310 mg/L. . This value establishes the tentative endpoint at Site 512.

At Site 667 the 80th percentile of sulfate concentrations for flows less than median flow is actually slightly less than the Phase One endpoint, yet because of natural influences (explained in Section 3 of this TMDL) the 80th percentile of sulfate concentrations for flows *greater* than the median flow at Site 667 exceed the Phase One endpoint. Since the standard cannot be achieved at higher flows because of natural source contributions dual endpoints will be developed for Site 667. The first endpoint will be 250 mg/L and is applicable at flows below the median flow. The second endpoint will be 300 mg/L sulfate at Site 667 and is applicable for flows greater than the median flow at this site. These values establish provisional endpoints for Site 667.

The Phase Two TMDL will be based on the future standard applied to streams within the contributing portions of the Solomon River watershed to Sites 512 and 667.

Seasonal variation has been incorporated in this TMDL through the documentation of the seasonal consistency of elevated sulfate levels. Achievement of the endpoints indicate loads are within the loading capacity of the stream, water quality standards are attained and full support of the designated uses of the stream has been restored.

3. SOURCE INVENTORY AND ASSESSMENT

(Background and Historical Assessment based upon analysis provided by Don Whittemore, Kansas Geologic Survey and KGS Open-File Report 2003-49 also by Whittemore)

Sulfate background assessment: The main source of sulfate in Limestone Creek (Site 667) is from the natural weathering of the Upper Cretaceous bedrock within the watershed, especially the dissolution of small amounts of gypsum (hydrous calcium sulfate) and oxidation of the sulfide in pyrite (iron sulfide) in the Carlile and Graneros shales. This weathering of the Upper Cretaceous rocks also provides part of the sulfate source for the Solomon River near Glasco (Site 511), the Solomon River at Niles (Site 266), and Salt Creek near Minneapolis (Site 512) (**Figure 7**). In addition, the discharge of naturally saline ground water from the Dakota aquifer into the overlying alluvial aquifer and then into streams substantially contributes to the sulfate concentration in the Solomon River (Site 511 and 266) and Salt Creek (Site 512), especially during low flows. The main stretch of the Solomon River where saline ground water from the Dakota aquifer intrudes is between Glen Elder Dam and Site 511. The main area where saline water discharges from the Dakota aquifer into the Salt Creek watershed is upstream of the Ottawa-Lincoln county line, in southeastern Mitchell County and north-central Lincoln County.

The sulfate content of the saline intrusion water is usually a few to several hundred mg/L, and is about 0.2-0.5 times than that of the chloride concentration in the intrusion area. A third source of sulfate in the Solomon River is the high sulfate content of the outflow of Waconda Lake[1]. Evapotranspiration consumption of water in the drainage basin and evaporation from the surface of streams and lakes increases the sulfate concentration of the surface water contributing to and within Waconda Lake. The range and average sulfate content of water in and released from Waconda Lake was 184-303 mg/L and 257 mg/L, respectively, during 1990-2003, based on 4 lake surveys and the average values for 8 samples from the dam outlet in 2002 and 4 samples in 2003 (KGS outlet data is provided in KGS Open-File Report 2003-49 by Whittemore). Thus, the

[1] See sulfate TMDLs and their source assessments for Waconda Lake and the lower North and South Forks of the Solomon River for a description of the source of and factors affecting the sulfate concentration in those waters.

background sulfate concentration entering the Solomon River below the lake has exceeded 250 mg/L for much of the period of 1990-2003. The average and median sulfate concentrations of the Solomon River at Niles (Site 266) are less than the values for the river near Glasco (Site 511), indicating that the main sulfate sources are from Waconda Lake and between the lake and Glasco.

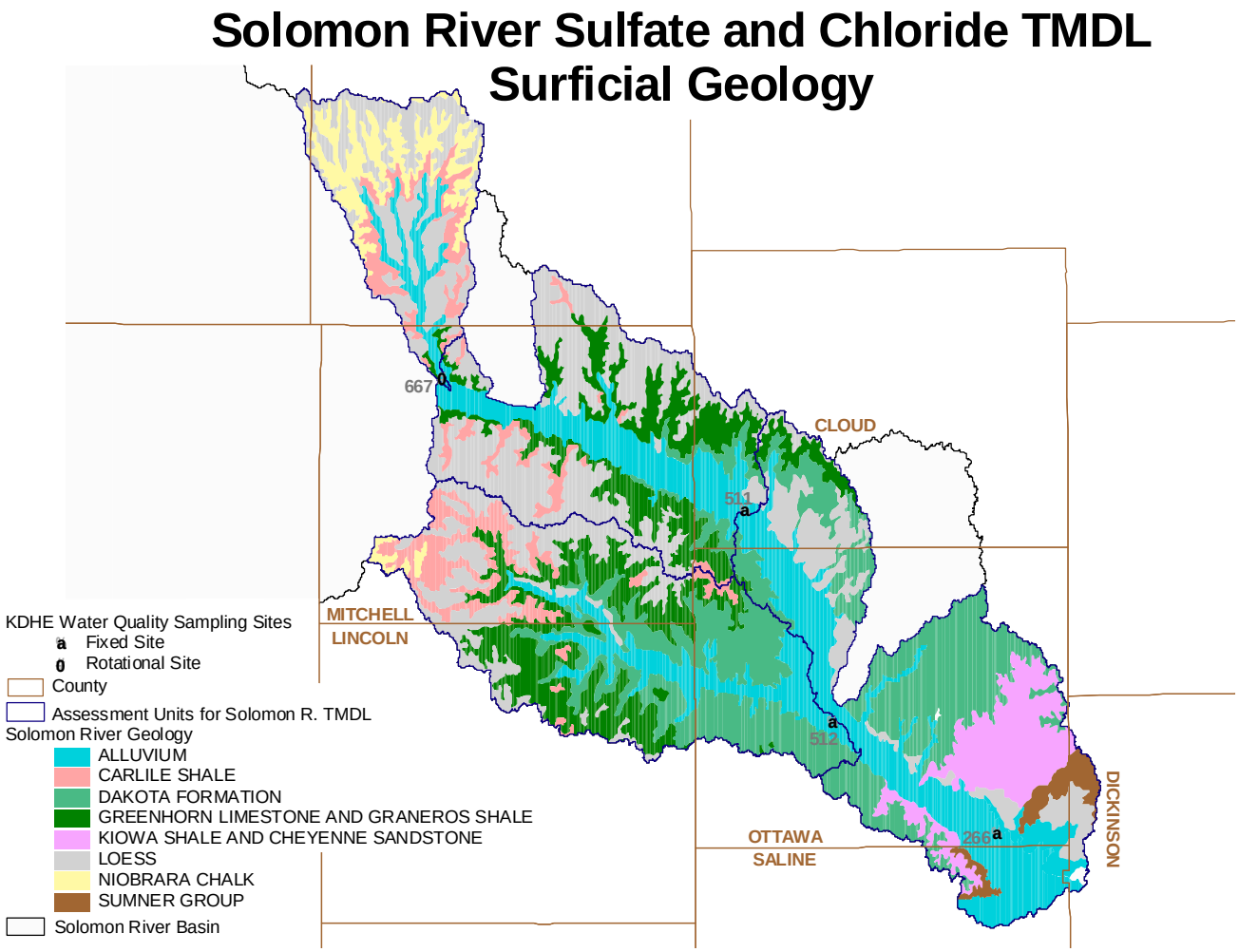

Figure 7

The sulfate/chloride ratio can be used to determine the predominant importance of the Upper Cretaceous sources of sulfate (the dominant source for waters draining into Waconda Lake and Limestone Creek and a partial source for Salt Creek and the Upper and Lower Solomon watersheds) in comparison with the source from the saline Dakota ground water (found primarily in the Salt Creek and Upper and Lower Solomon watersheds). The range for the sulfate/chloride mass ratio in Waconda Lake and outlet water was 2.3-3.5 during 1986-2003. The sulfate/chloride ratio was usually between 2 and 4 in Limestone Creek water (Limestone Creek has little to no sulfate loading from the Dakota groundwater sources) when sulfate concentrations exceeded 200 mg/L at Site 667 (**Figure 8**). Thus, the Upper Cretaceous sources of sulfate in waters with sulfate concentration greater than 200 mg/L generally had a sulfate/chloride ratio of 2-4.

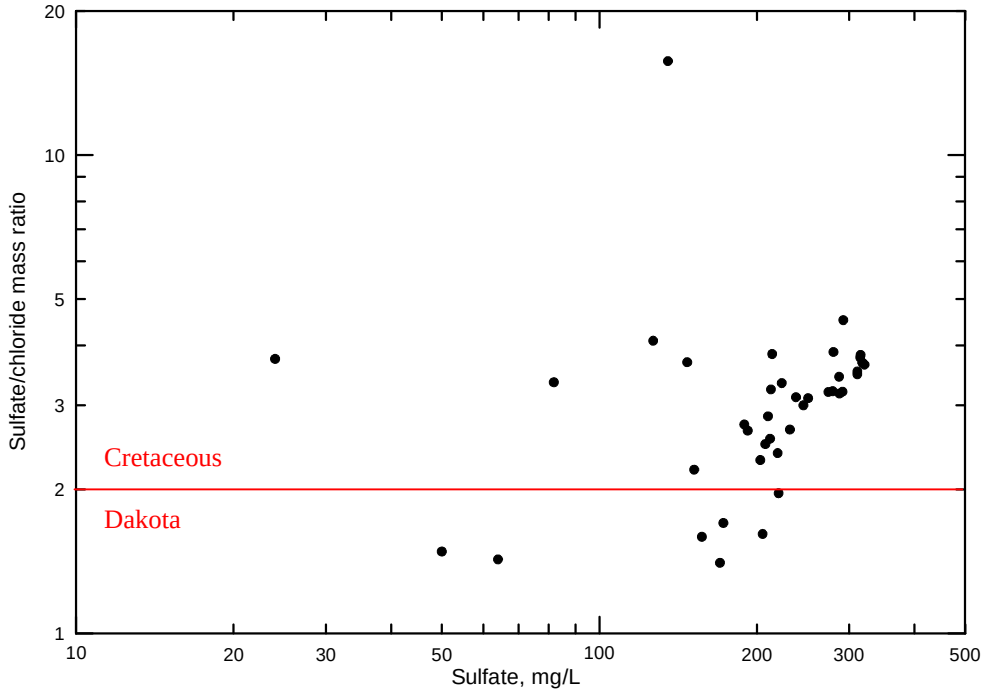

Figure 8

The source of the high *chloride* concentrations in the Upper and Lower Solomon River and Salt Creek watersheds is primarily intrusion of saline ground water from the Dakota aquifer. Graphs of the sulfate/chloride ratio versus chloride concentration all show a decreasing ratio with increasing chloride content in the Solomon River near Glasco (Site 511), at Niles (Site 266) and in Salt Creek near Minneapolis (Site 512) (**Figures 9, 10 and 11**, respectively). The sulfate/chloride mass ratio was <1.5 for chloride >200 mg/L at these three monitoring sites.

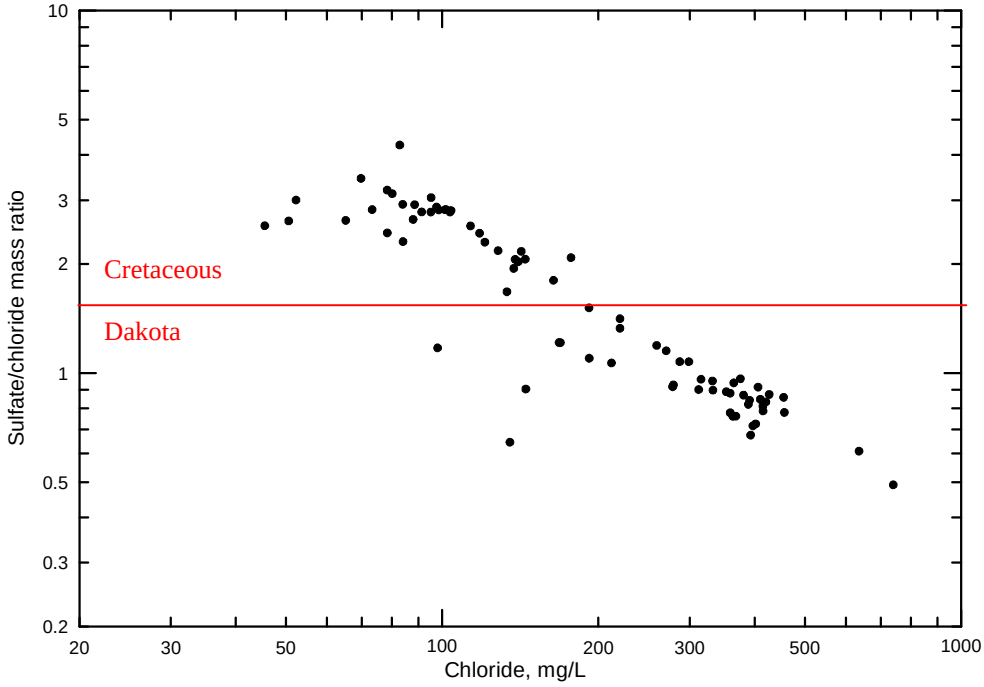

Figure 9

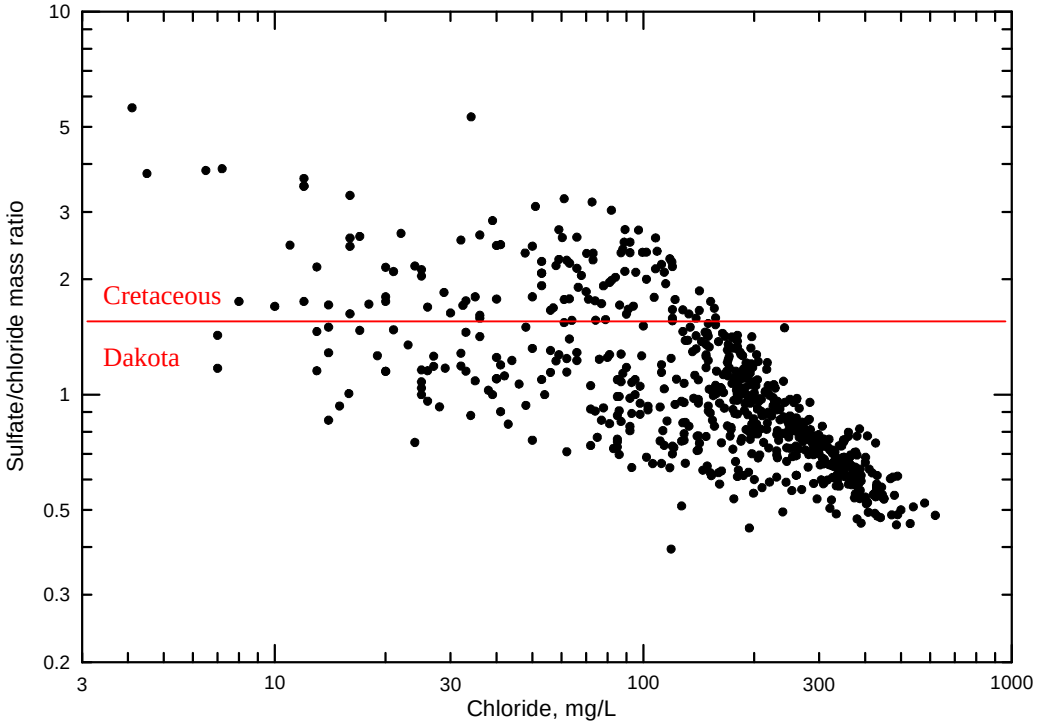

Figure 10

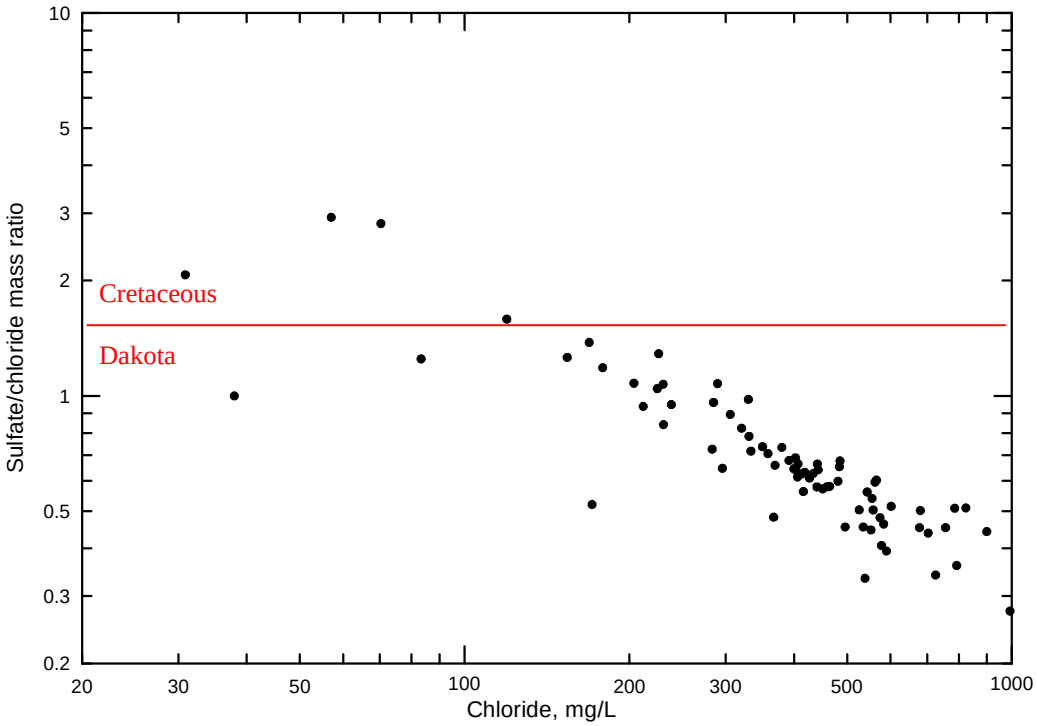

Figure 11

Figures 12 and 13 indicate that the sulfate/chloride ratio is nearly always between 0.4 and 4 for sulfate concentrations >200 mg/L in the Solomon River near Glasco (Site 512) and at Niles (Site 266).

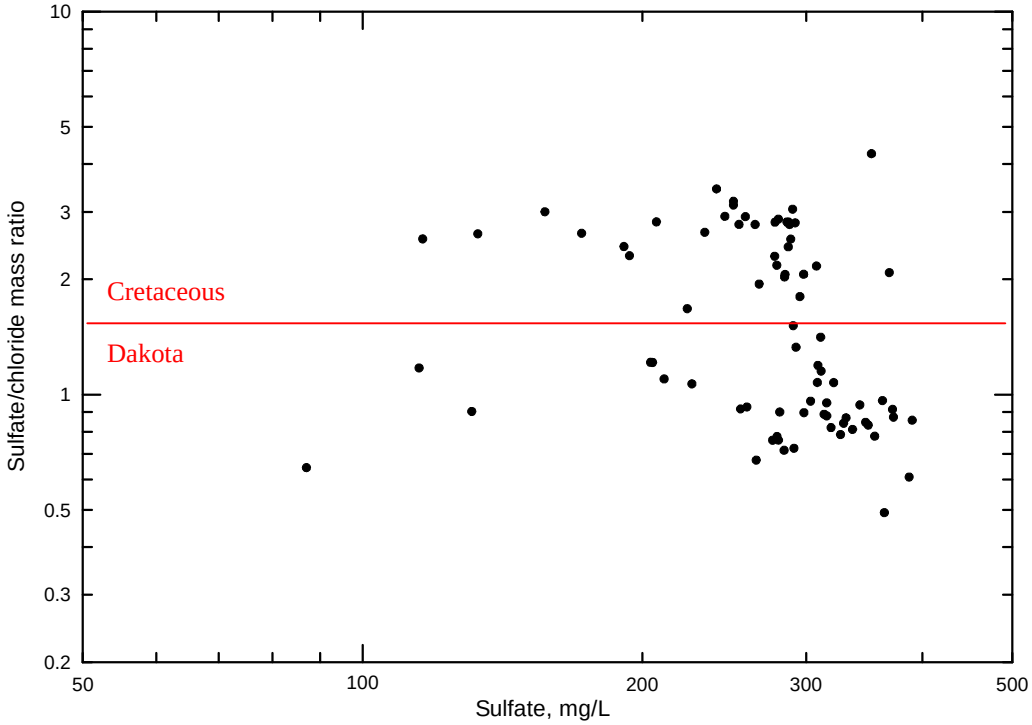

Figure 12 (Site 512)

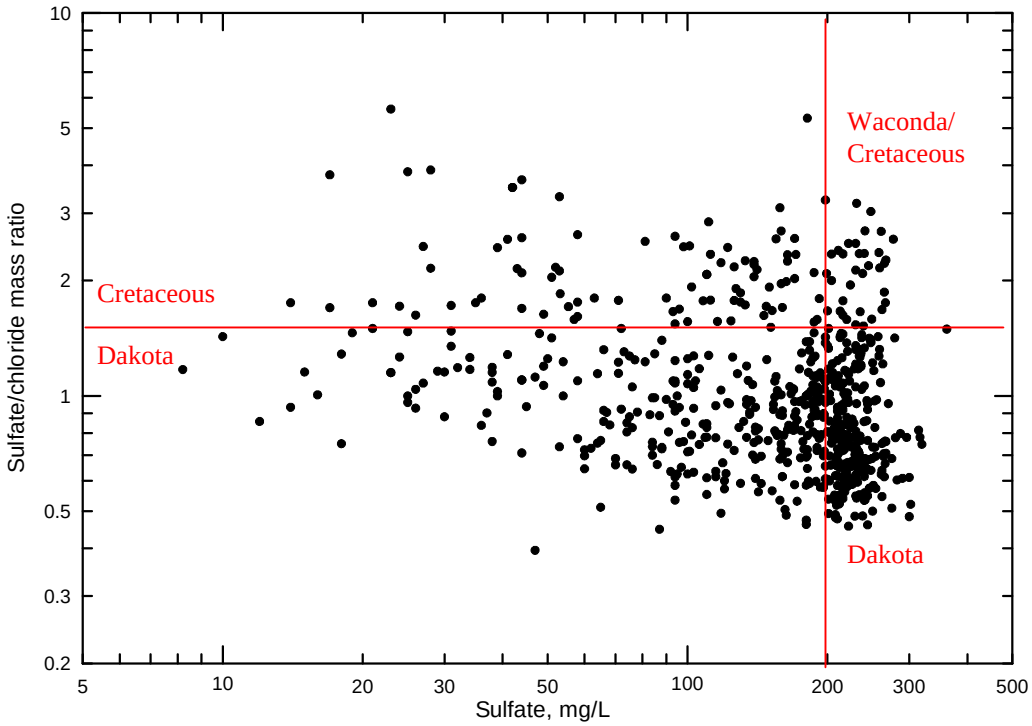

Figure 13 (Site 266)

If water in the Solomon River at monitoring sites 511 and 266 has chloride and sulfate concentrations greater than 200 mg/L and a sulfate/chloride ratio <1.5, the predominant source of sulfate is from the Dakota groundwater intrusion. If water at these sites has a sulfate content

>200 mg/L, a chloride concentration <200 mg/L, and a sulfate/chloride ratio >2, the predominant source of sulfate is from Waconda Lake outflow and the weathering of Upper Cretaceous rock within the Solomon River system below the lake. The sulfate source for waters with >200 mg/L sulfate content, chloride <200 mg/L, and sulfate/chloride ratio between 1 and 2 is a mixture without substantial predominance of one of the different types of sources. Site 512 on Salt Creek is not affected by outlet water from Waconda Lake. The sulfate/chloride mass ratio is usually <1.5 for Salt Creek water near Minneapolis with >200 mg/L sulfate content (**Figure 14**). This indicates that the intrusion of saline ground water from the Dakota aquifer provides the predominant source of sulfate in Salt Creek near Minneapolis when the sulfate level exceeds 200 mg/L.

In addition to the sources above, saltwater from the Permian Wellington Formation discharges into the overlying alluvial aquifer and then into the Solomon River downstream of Niles (Site 266) near the confluence with the Smoky Hill River. The source of the saltwater is dissolution of halite (sodium chloride) and anhydrite (calcium sulfate) in the Wellington strata. The sulfate and chloride concentrations exceed 2,000 mg/L and 10,000 mg/L, respectively, in the lower part of the alluvial aquifer of the Solomon River just west of Solomon and exceed 4,000 mg/L and 30,000 mg/L, respectively in the Permian Wellington Formation underlying the alluvium. Thus, part of the sulfate source in the river down stream of Site 266 immediately before joining the Smoky Hill River is derived from the Wellington saltwater intrusion.

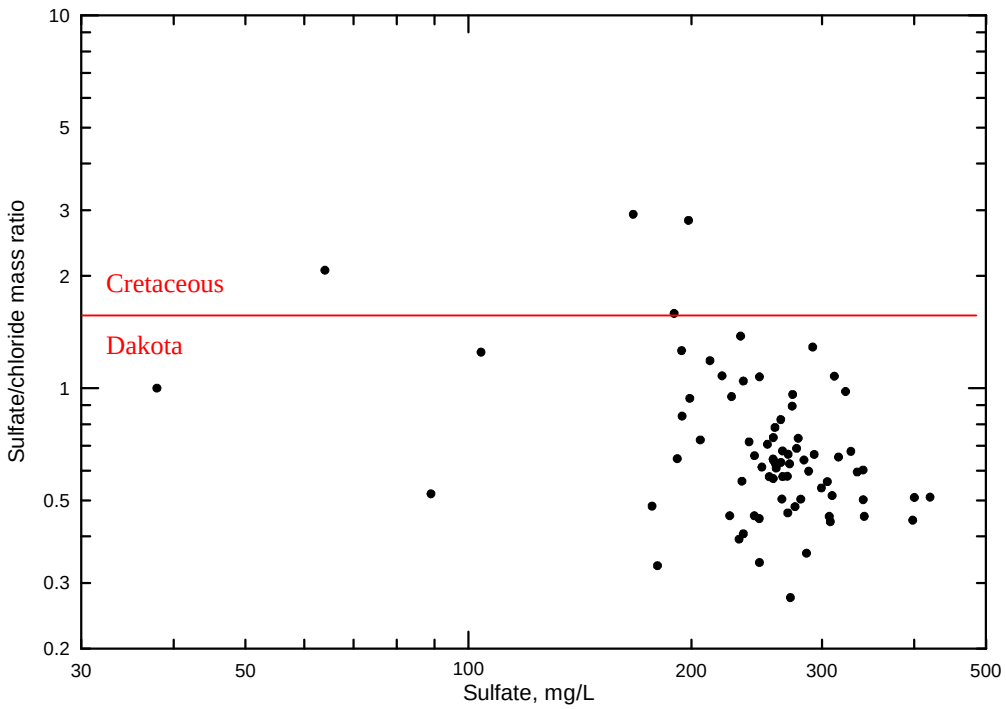

Figure 14

Natural factors controlling variations in sulfate: The sulfate concentration is highly variable in Limestone Creek (Site 667), the Solomon River near Glasco (Site 511) and at Niles (Site 266), and in Salt Creek near Minneapolis (Site 512) (**Figures 15-18**, respectively). The main cause of this variation is the large fluctuations in the amount of rainfall that runs off into the creeks and the Solomon River, which dilutes the more mineralized baseflow.

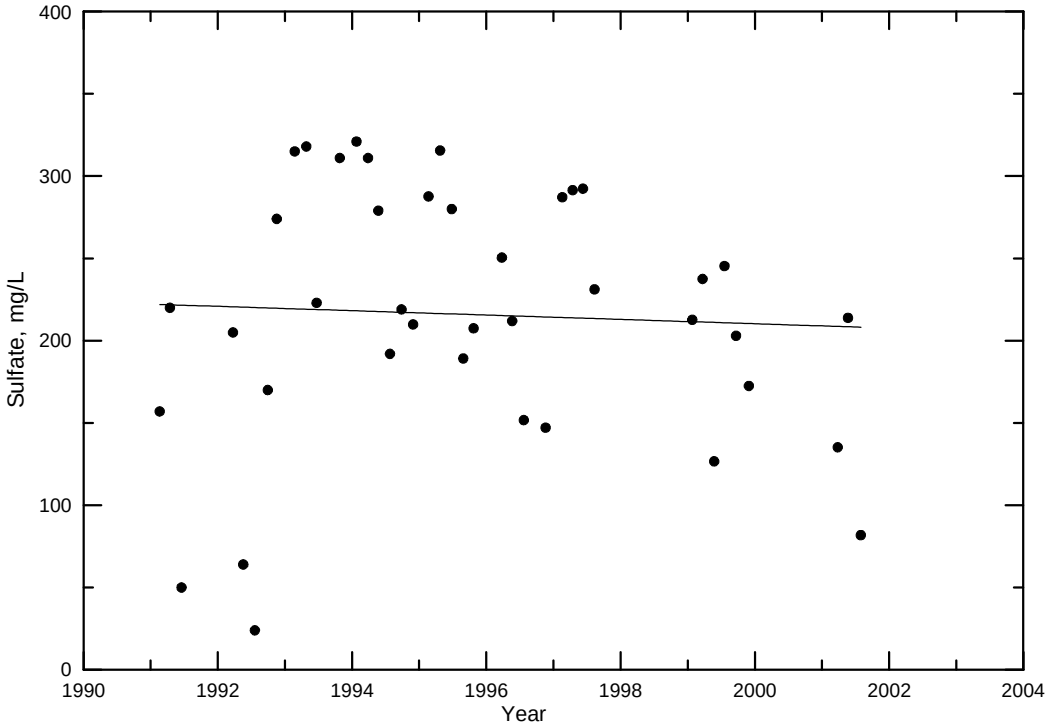

Figure 15 (Site 667; line is linear regression)

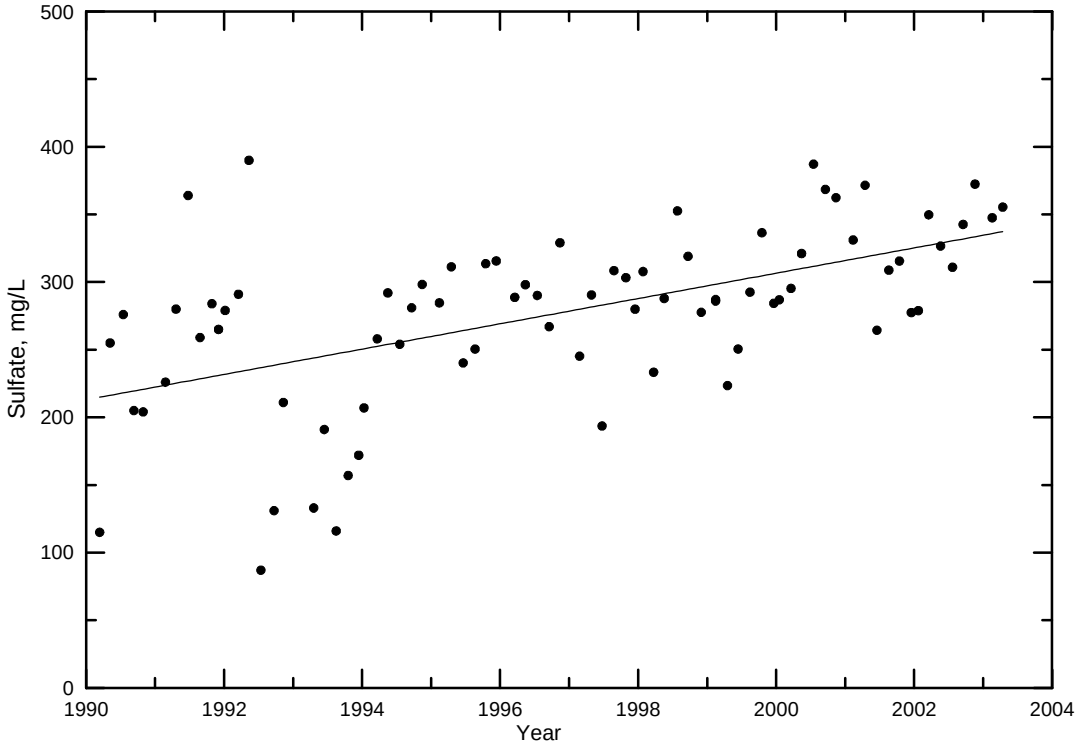

Figure 16 (Site 512; line is linear regression)

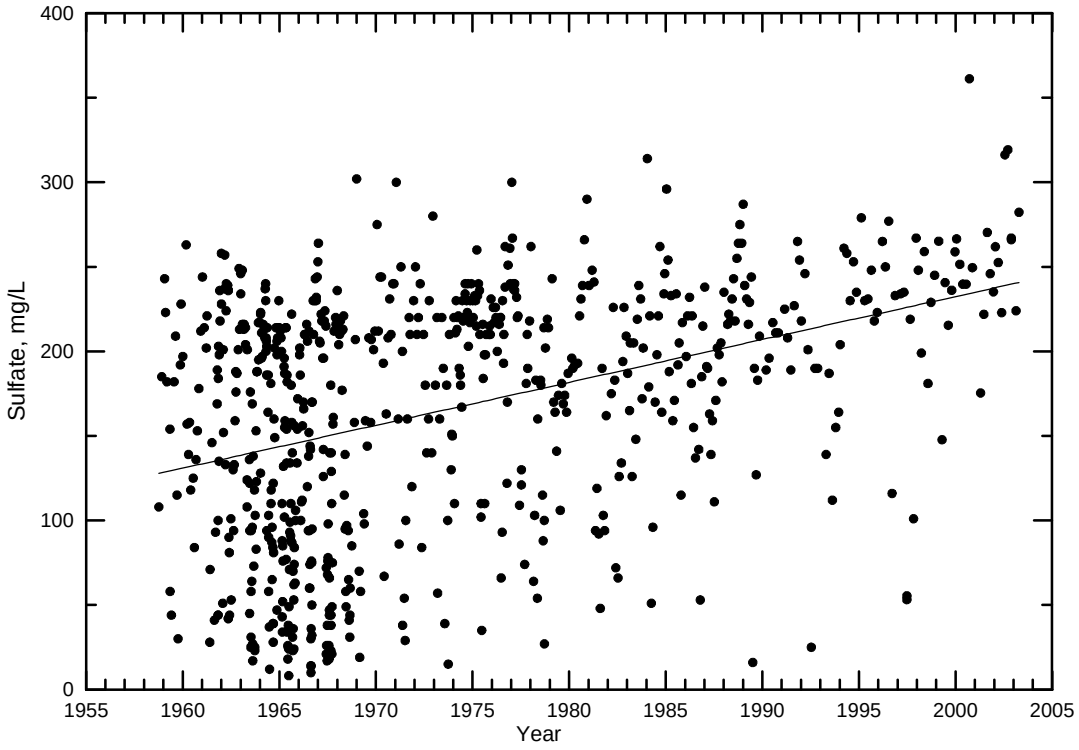

Figure 17 (Site 266; line is linear regression)

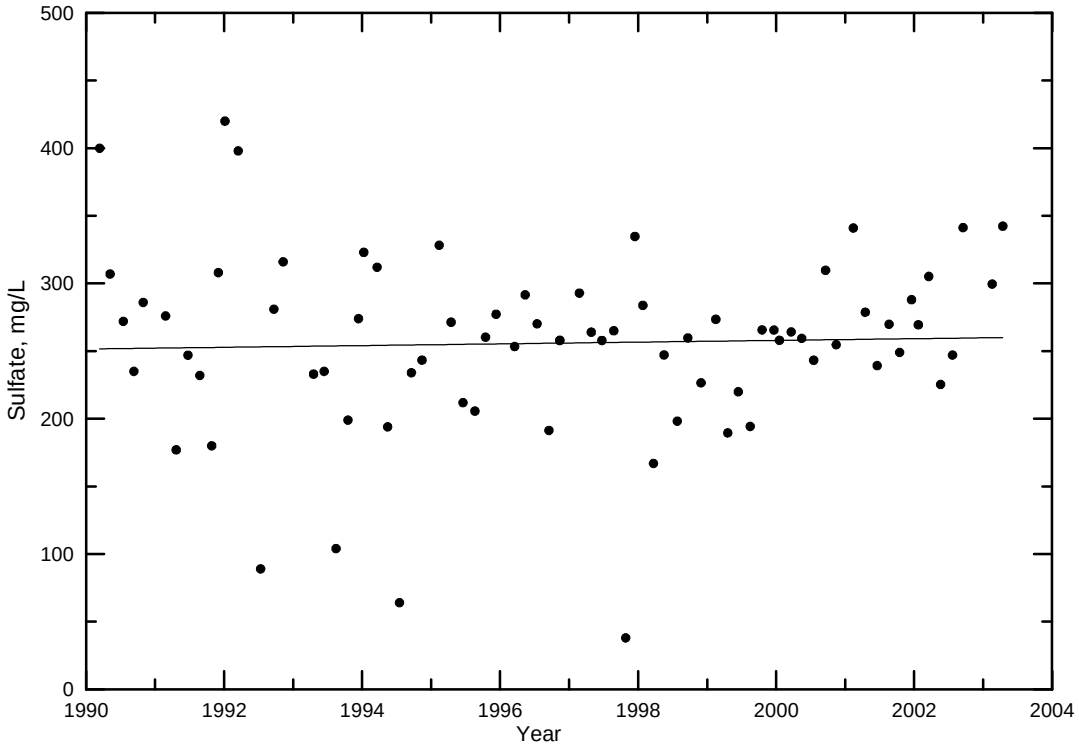

Figure 18 (Site 512; line is linear regression)

A general inverse relationship exists between flow in the Solomon River (Site 511 and 266) and Salt Creek (Site 512) and the sulfate content that is shown by the best-fit power curves through the data in (**Figures 19, 20 and 21**, respectively).

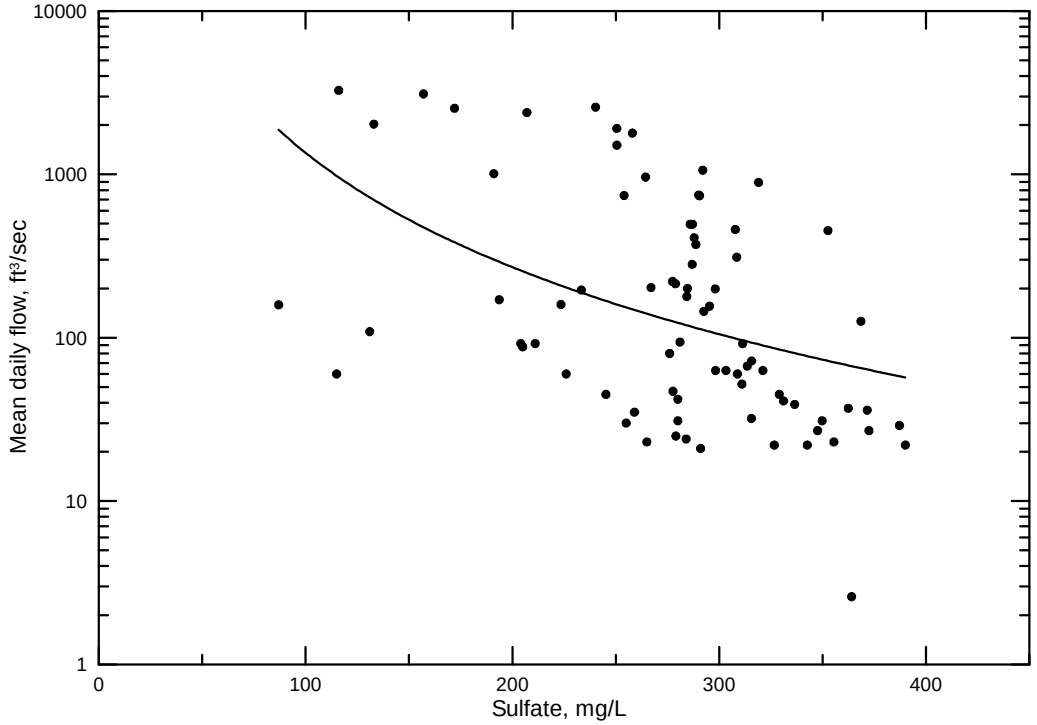

Figure 19 (Site 511)

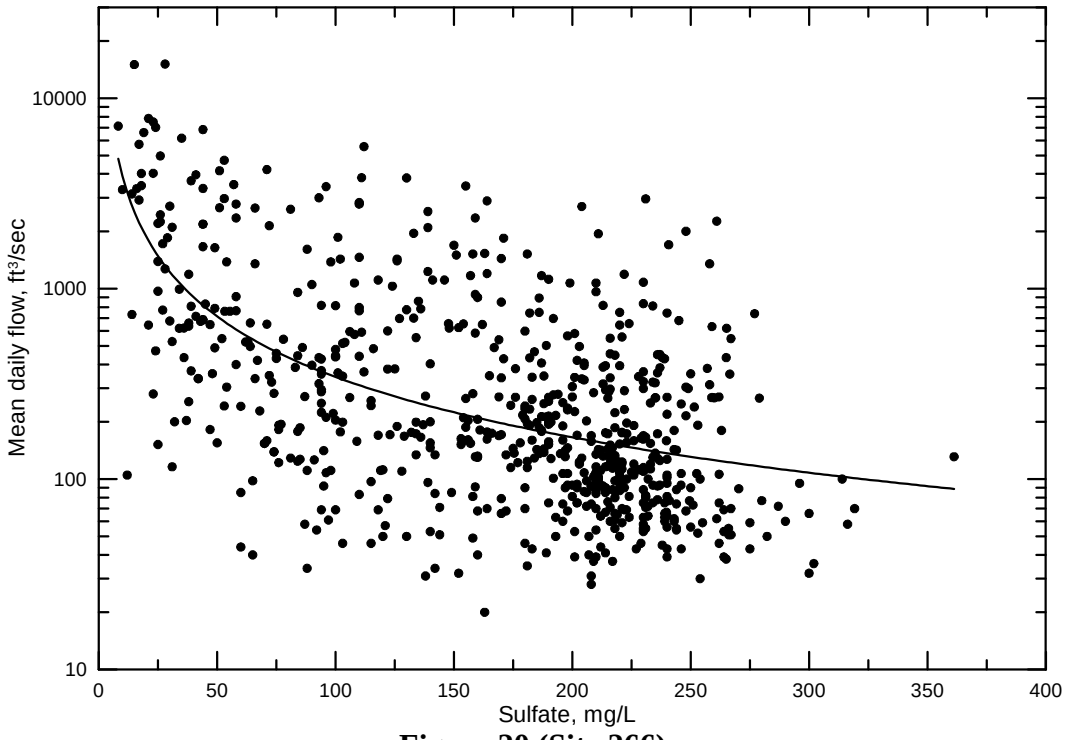

Figure 20 (Site 266)

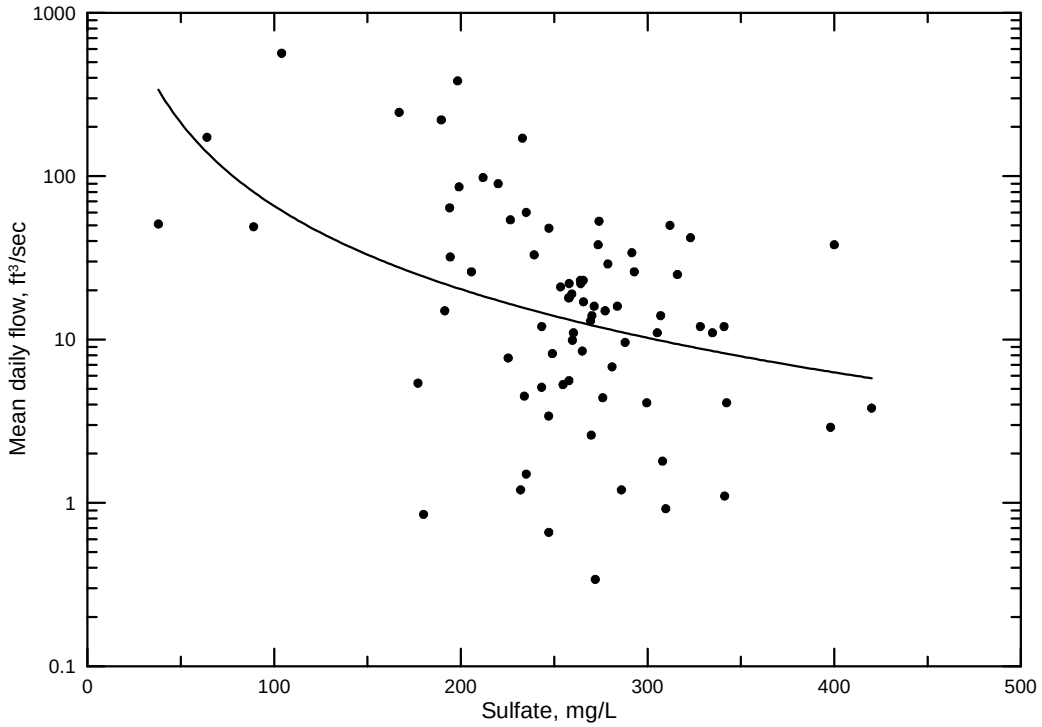

Figure 21 (Site 512)

These figures also illustrate that higher flows are often lower in sulfate content and represent the influence of runoff. However, the scatter of the points in these figures is large (substantially greater than for flow versus chloride concentration plots for the same monitoring sites), indicating that other factors are also important for controlling the sulfate content.

The amount of water released from Waconda Lake is an important factor affecting the variation in sulfate content of the Solomon River because the lake water has had a relatively high sulfate concentration during the last decade.

Accumulated sulfate salts at or near the surface in soils during dry periods are dissolved by precipitation and can runoff into streams. As a result, the runoff following a dry period would likely have a higher sulfate content than runoff that occurred after an extended rainy period and may be another factor affecting sulfate variability.

Phreatophytes in the riparian corridor of Limestone Creek, Salt Creek (Minneapolis), Upper Solomon River and Lower Solomon River watersheds may also have increased the sulfate concentration of shallow ground waters; concomitant increases in sulfate contents in the shallow ground water discharged to streams would also be expected.

Water Use: Most water use from the Upper Solomon River watershed (between Waconda Lake and Site 511) is for surface water irrigation, supplied predominately by releases from Waconda Lake. Total reported water use in 2001 was 21,941 acre-feet of which 19,750 acre-feet was for irrigation from surface water and 1,243 acre-feet was from groundwater. A total of 14,696 acres were irrigated. Therefore, surface water irrigation development in the Upper Solomon River watershed is significant (**Figures 22 and 23**).

Total water use in 2001 for the Lower Solomon River watershed was 3,643 acre-feet of which 109 acre-feet was from surface water sources and 1,971 was from groundwater sources. A total of 3,069 acres were irrigated.

In contrast, the Salt Creek (Minneapolis) watershed's total use was 591 acre-feet in 2001. Fifty-two acre-feet was used for irrigation from surface water sources and 523 acre-feet from groundwater sources. Only 828 acres were irrigated in the Salt Creek (Minneapolis) watershed.

There has been very little irrigation development in the Limestone Creek watershed as compared to other watersheds in the Solomon Basin. The 2001 water use reports for water rights in the watershed indicate only 38 acre-feet of water were use for irrigation (surface water source) purposes within the watershed on 38 acres; this out of a total use of only 237 acre-feet.

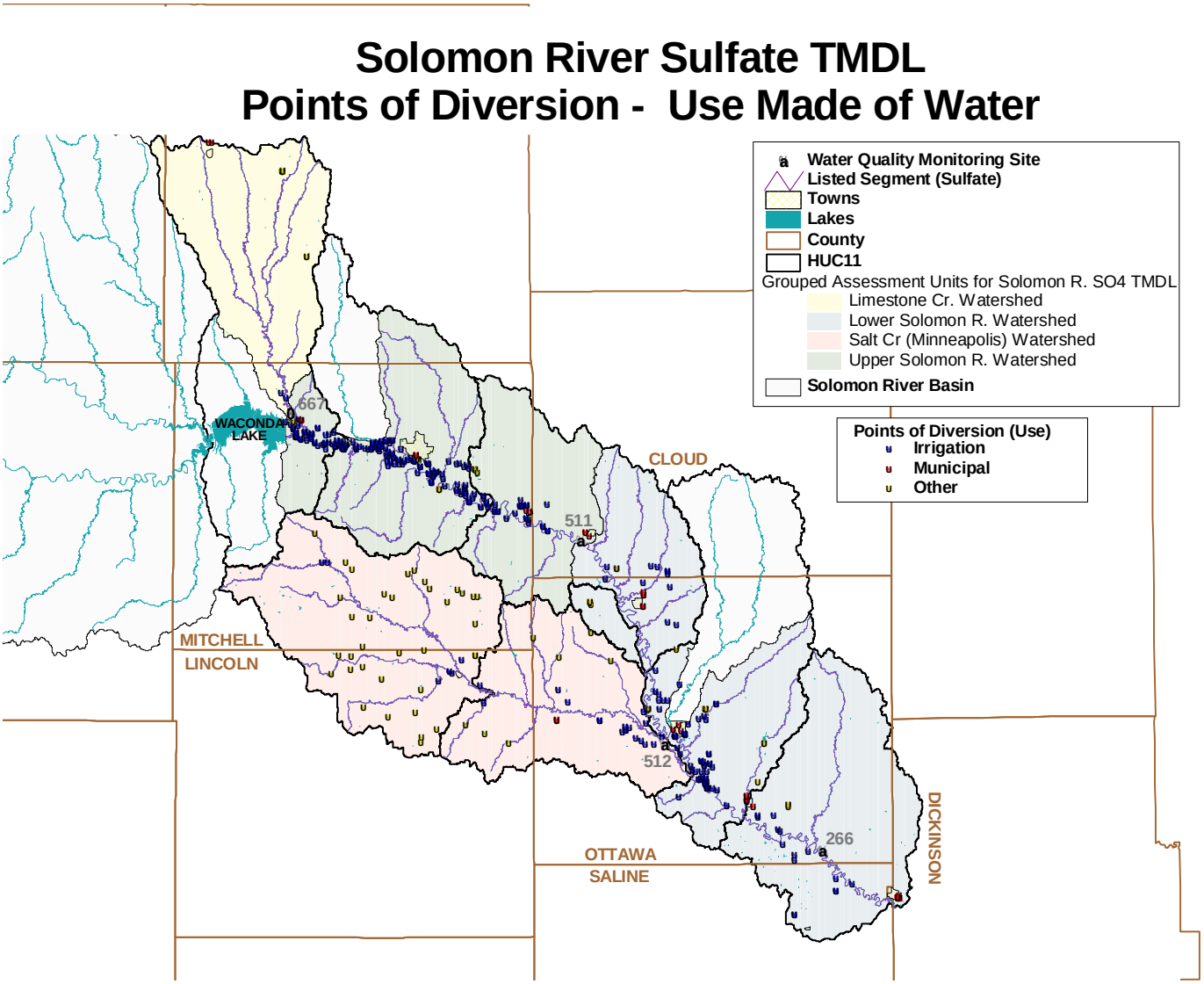

Figure 22

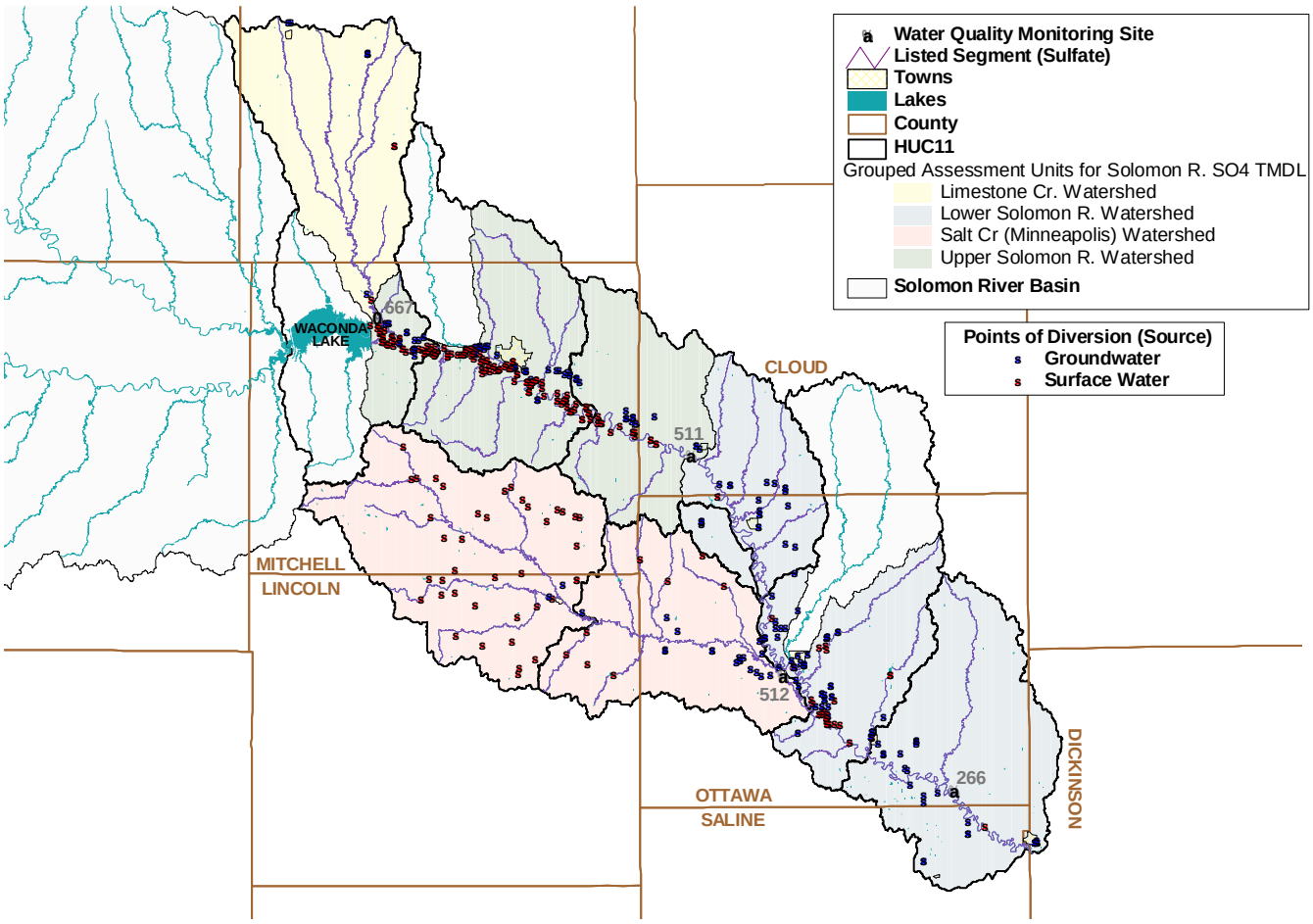

Figure 23

NPDES:

Limestone Creek Watershed (Site 667)

There are no NPDES municipal permitted wastewater dischargers within the Limestone Creek watershed that would contribute a sulfate load to Site 667 (**Figure 24**). The city of Glen Elder, although located within the Limestone Creek watershed, is located downstream of the watershed's monitoring site and therefore does not contribute a sulfate load to Site 667. The sulfate load from the city of Glen Elder will be considered in the Upper Solomon River watershed (see below). The city of Esbon has a non-discharging lagoon that may contribute a sulfate load to West Limestone Creek (Segment 22) under extreme precipitation events (stream flows associated with such events are typically exceeded only 1 - 5 % of the time). Such events would not occur at a frequency or of a duration that they would constitute a chronic impairment to the designated uses of the stream. All non-discharging lagoon systems are prohibited from discharging to the surface waters of the state. Under standard conditions of these non-discharging facility permits, when the water level of the lagoon rises to within two feet of the top of the lagoon dikes, the permit holder must notify KDHE. Steps may be taken to lower the water

level of the lagoon and diminish the probability of a bypass of sewage during inclement weather. Bypasses may be allowed if there are no other alternatives and 1) it would be necessary to prevent loss of life, personal injury or severe property damage; 2) excessive stormwater inflow or infiltration would damage the facility; or 3) the permittee has notified KDHE at least seven days before the anticipated bypass. Any bypass is immediately report to KDHE.

Upper Solomon Watershed (Site 511)

There are two NPDES municipal permitted wastewater dischargers contributing to the main stem within the Upper Solomon watershed upstream of Site 511 (**Figure 24**). These systems are outlined in **Table 5**. The city of Beloit has monthly effluent monitoring records for sulfate since the beginning of 2002. The average sulfate concentration was 326 mg/L with a range from 260 – 370 mg/L. From the same period, drinking water monitoring records and KGS data collected from the Beloit diversion point indicate the average sulfate concentration during this same period was 293 mg/L with a range from 263 – 325 mg/L. The average percent increase in sulfate concentration from drinking water to effluent is only about 10%.

It is assumed that lagoon systems will have a larger evaporation component that the mechanical plant utilized by the city of Beloit. Based on this assumption, a 1.5:1 sulfate ratio of effluent to drinking water will be used to estimate effluent sulfate concentrations for municipalities that do not sample their effluent for sulfate and rely on lagoon systems for treatment of their wastewater. This ratio represents the "Best Professional Judgment" as to the expected relationship between municipal source water and effluent sulfate concentrations discharged from lagoon systems.

The city of Glen Elder does not monitor their effluent for sulfate. The average sulfate concentration of their drinking water was 188 mg/L for 1997-2003. Using the estimated ratio of drinking water to effluent, Glen Elder's effluent should have approximately 285 mg/L sulfate.

Salt Creek (Minneapolis) Watershed (Site 512)

There are no NPDES municipal permitted wastewater dischargers within the Salt Creek (Minneapolis) watershed that would contribute a sulfate load to Site 512 (**Figure 24**). The city of Barnard has a non-discharging lagoon that may contribute a sulfate load to Salt Creek (Segment 29) under extreme precipitation events (stream flows associated with such events are typically exceeded only 1 - 5 % of the time). Such events would not occur at a frequency or of a duration that they would constitute a chronic impairment to the designated uses of the stream. All non-discharging lagoon systems are prohibited from discharging to the surface waters of the state. Under standard conditions of these non-discharging facility permits, when the water level of the lagoon rises to within two feet of the top of the lagoon dikes, the permit holder must notify KDHE. Steps may be taken to lower the water level of the lagoon and diminish the probability of a bypass of sewage during inclement weather. Bypasses may be allowed if there are no other alternatives and 1) it would be necessary to prevent loss of life, personal injury or severe property damage; 2) excessive stormwater inflow or infiltration would damage the facility; or 3) the permittee has notified KDHE at least seven days before the anticipated bypass. Any bypass is immediately report to KDHE.

Lower Solomon Watershed (Site 266)

There are four NPDES municipal permitted wastewater dischargers within the Lower Solomon watershed that would contribute a sulfate load to Site 266 (**Figure 24**). These systems are outlined in **Table 5.**

The city of Solomon also has a wastewater discharge in the Lower Solomon watershed and the city of New Cambria and KDOT have non-discharging lagoons in the Lower Solomon watershed. Each of these systems are located downstream of the watershed's monitoring site, cannot contribute a sulfate load to the sulfate impairment there and therefore will not be considered a sulfate load source within this TMDL.

The city of Glasco has a non-discharging lagoon that may contribute a sulfate load to Solomon River (Segment 12) under extreme precipitation events (stream flows associated with such events are typically exceeded only 1 - 5 % of the time). Such events would not occur at a frequency or of a duration that they would constitute a chronic impairment to the designated uses of the stream. All non-discharging lagoon systems are prohibited from discharging to the surface waters of the state. Under standard conditions of these non-discharging facility permits, when the water level of the lagoon rises to within two feet of the top of the lagoon dikes, the permit holder must notify KDHE. Steps may be taken to lower the water level of the lagoon and diminish the probability of a bypass of sewage during inclement weather. Bypasses may be allowed if there are no other alternatives and 1) it would be necessary to prevent loss of life, personal injury or severe property damage; 2) excessive stormwater inflow or infiltration would damage the facility; or 3) the permittee has notified KDHE at least seven days before the anticipated bypass. Any bypass is immediately report to KDHE.

None of the discharging facilities in the Lower Solomon River watershed monitor their effluent for sulfate. The City of Delphos rarely discharges and the City of Bennington has not shown a discharge since operation of their new lagoon facility began in 2000. The Minneapolis Power Plant operates from June 15 – September 15 annually.

Table 5

Discharging Facility	NPDES Permit	Stream Reach	Segment	Design Flow	Type
Glen Elder WTF	M-SO18-OO01	Limestone Cr	18	0.05 mgd	Lagoon
Beloit WTP	M-SO05-OO01	Solomon R	14	0.6 mgd	Mechanical
Delphos WTF	M-SO11-OO02	Solomon R	12	0.065 mgd	Lagoon
Minneapolis WTF	M-SO27-OO02	Lindsey Cr	7	0.234 mgd	Lagoon
Minneapolis Power Plant	I-SO27-CO02	Pipe Cr	9	0.327 mgd June 15 – Sept 15	Cooling
Bennington WTF	M-SO06-OO02	Sand Cr	4	0.088 mgd	Lagoon

The average sulfate concentration of the city of Delphos drinking water was 37 mg/L for 1997-2003. Using the estimated ratio of drinking water to effluent, Delphos' effluent should have approximately 56 mg/L sulfate. The average sulfate concentration of the City of Minneapolis and Bennington drinking water were 45 mg/L and 62 mg/L, respectively. The resulting effluent sulfate concentrations should be 68 mg/L and 93 mg/L, respectively. The Minneapolis Power Plant uses city water for once through, non-contact cooling purposes for peaking and emergency

power. Although some evaporation of the once through cooling water is expected, the concentration of sulfate should not be much higher than the source water (45 mg/L sulfate).

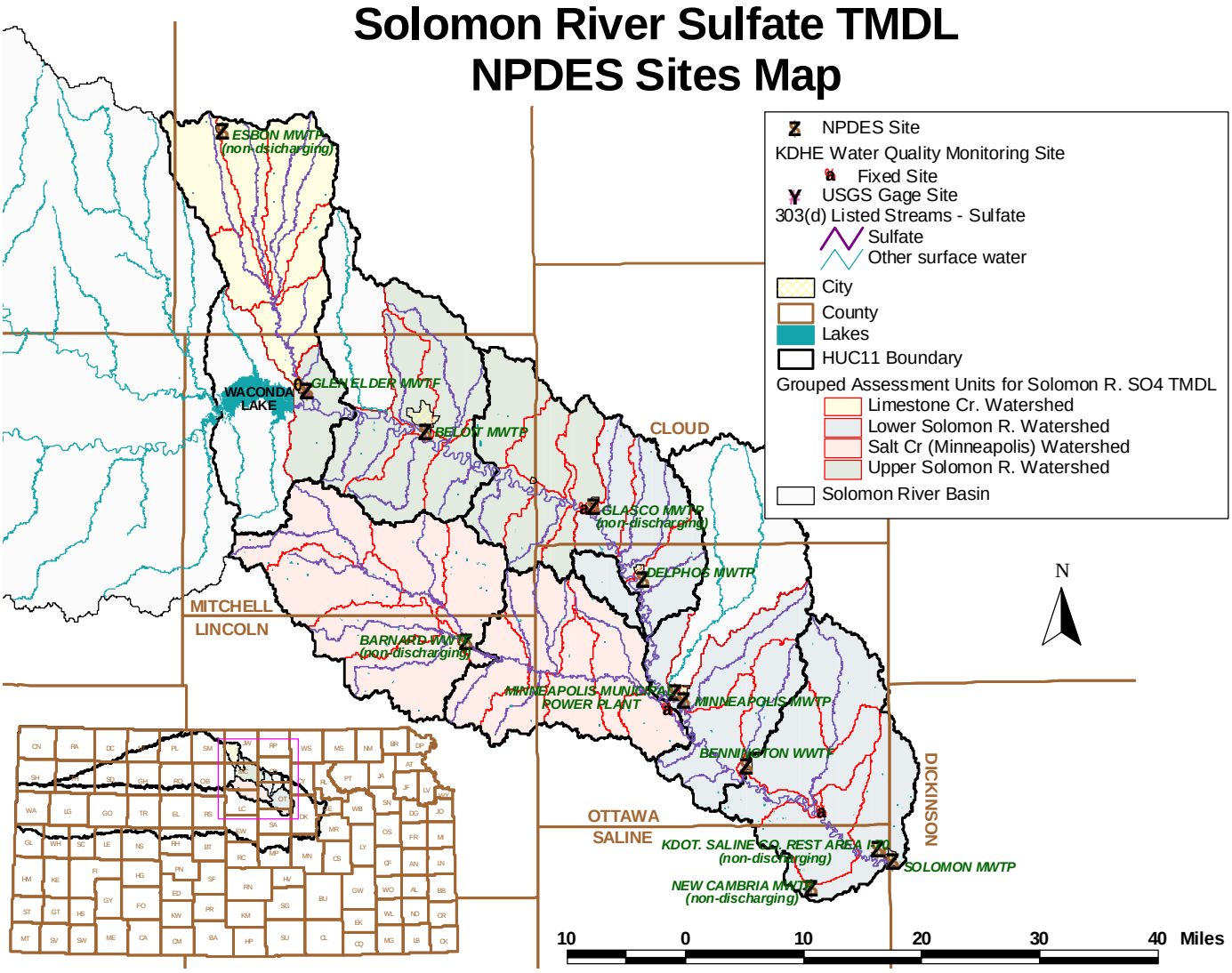

Figure 24

Contributing Runoff: The Limestone Creek watershed's average soil permeability is 1.1 inches/hour according to NRCS STATSGO database. Essentially the entire watershed produces runoff even under relatively low (1.71"/hr) potential runoff conditions (99.6%). Under very low (1.14"/hr) potential conditions, this potential contributing area is reduced to about 58%. Runoff is chiefly generated as infiltration excess with rainfall intensities greater than soil permeabilities. As the watersheds' soil profiles become saturated, excess overland flow is produced. Generally, storms producing less than 0.57"/hr of rain will only generate runoff from 8% of this watershed, chiefly from the lower half of the Limestone Creek watershed.

The Salt Creek watershed's average soil permeability is 1.0 inches/hour according to NRCS STATSGO database. The entire watershed produces runoff even under relatively low (1.71"/hr)

potential runoff conditions (100%). Under very low (1.14"/hr) potential conditions, this potential contributing area is reduced to about 55%. Runoff is chiefly generated as infiltration excess with rainfall intensities greater than soil permeabilities. As the watersheds' soil profiles become saturated, excess overland flow is produced. Generally, storms producing less than 0.57"/hr of rain will only generate runoff from 10% of this watershed, chiefly from the headwaters or the steeper slopes along the Salt Creek in the watershed.

The remaining balance of the Solomon River below Waconda Lake watershed's average soil permeability is 1.0 inches/hour according to NRCS STATSGO database. Essentially the entire watershed produces runoff even under relatively low (1.71"/hr) potential runoff conditions (99.5%). Under very low (1.14"/hr) potential conditions, this potential contributing area is reduced to about 67%. Runoff is chiefly generated as infiltration excess with rainfall intensities greater than soil permeabilities. As the watersheds' soil profiles become saturated, excess overland flow is produced. Generally, storms producing less than 0.57"/hr of rain will only generate runoff from 11% of this watershed, chiefly from steep slopes along the main stem in the watershed.

4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

There is no evidence of significant anthropogenic sources that directly contribute to the elevated sulfate conditions in the Limestone Creek, Salt Creek, Upper Solomon River or Lower Solomon River watershed. Human activities may be causing enhanced consumption of water through increased evapotranspiration, which can raise the concentration of sulfate from natural sources at Sites 266 and 511. The sulfate concentration will continue to vary substantially from wet to dry climatic periods, in response to where precipitation falls within the drainage basin, and, in the case of the Upper and Lower Solomon River watersheds, how much water is released from Waconda Lake.

The sulfate content of the Limestone Creek watershed can be expected to often exceed 250 mg/L from natural causes, primarily during lower flows. The sulfate concentration of Salt Creek (Minneapolis) watershed can be expected to often exceed 250 mg/L from natural causes during low to moderate flows. The sulfate content of the Upper Solomon River watershed can be expected to exceed 250 mg/L most of the time, except during some periods of high flows. The sulfate concentration of the Lower Solomon River watershed can be expected to often exceed 250 mg/L, especially during low to moderate flows.

Point Sources:

<u>Site 667 (Limestone Creek Watershed)</u>
Due to a lack of discharging facilities contributing a sulfate load within the watershed a Phase One Wasteload Allocation (WLA) of zero is established (**Figure 25**). Any future NPDES and state permits will be conditioned such that discharges from the permitted facilities will not cause violations of applicable criteria. Non-discharging facilities will also have a WLA of zero. The City of Glen Elder is located within the Limestone Creek watershed, but discharges downstream of Site 667. The WLA for the City of Glen Elder is established within the Upper Solomon River watershed (Site 511).

Site 511 (Upper Solomon Watershed)

Since the city of Beloit relies upon the diversion of surface water from the Solomon River, the source and concentration of sulfate in their effluent is directly tied the river's sulfate concentration. Therefore, Beloit's WLA should be tied to the sulfate levels within the Solomon River. From the current average sulfate conditions in the Solomon River at Beloit (295 mg/L from KGS Open-File Report 2003-49, Table 3) and the estimate of the sulfate effluent concentration of Glen Elder (285 mg/L), a Phase One Wasteload Allocation of 1,601 lbs (0.8 tons) sulfate per day will be established by this TMDL for Site 511 and is based upon the design flows (Glen Elder 0.05 mgd, 123 lbs/day sulfate; Beloit 0.6 mgd, 1,478.1 lbs/day sulfate) of the point sources (**Figure 26**). The WLA for the city of Beloit would need to be revised with any long-term change in the Solomon River sulfate concentration at their diversion point.

Site 512 (Salt Creek (Minneapolis) Watershed)
Due to a lack of discharging facilities contributing a sulfate load within the watershed a Phase One Wasteload Allocation (WLA) of zero is established (**Figure 27**). Any future NPDES and state permits will be conditioned such that discharges from the permitted facilities will not cause violations of applicable criteria. Non-discharging facilities will also have a WLA of zero.

Site 266 (Lower Solomon Watershed)
A Wasteload Allocation of 1,492 lbs (0.75 tons) sulfate per day will be established by this TMDL for Site 266 at the 250 mg/L standard and is based upon the design flows (Delphos 0.065 mgd, 135 lbs/day sulfate; Bennington 0.088 mgd, 184 lbs/day sulfate; Minneapolis 0.234 md, 489 lbs/day sulfate; Minneapolis Power Plant 0.327 mgd, 683 lbs/day sulfate) of the point sources (**Figure 28**). Non-discharging facilities will have a WLA of zero.

Any future NPDES and state permits will be conditioned such that discharges from the permitted facilities will not cause violations of applicable. Ongoing inspections and monitoring of these systems will be made to ensure that minimal contributions have been made by these sources.

Non-Point Sources: The elevated sulfate concentrations predominately stem from geologic sources.

Site 667 (Limestone Creek Watershed)
The Load Allocation is based on the existing standard of 250 mg/L for all stream flow and is shown in **Figure 25.** From this, the load allocation is 0.49 tons sulfate per day at median flow (0.72 cfs). The LA using a background sulfate concentration of 300 mg/L is 0.59 tons per day at median flow for Site 667.

Site 511 (Upper Solomon Watershed)
The Load Allocation is based on the existing standard of 250 mg/L for stream flows in excess of point source design flows and is shown in **Figure 26.** From this, the load allocation is 92.35 tons sulfate per day at median flow (138 cfs).

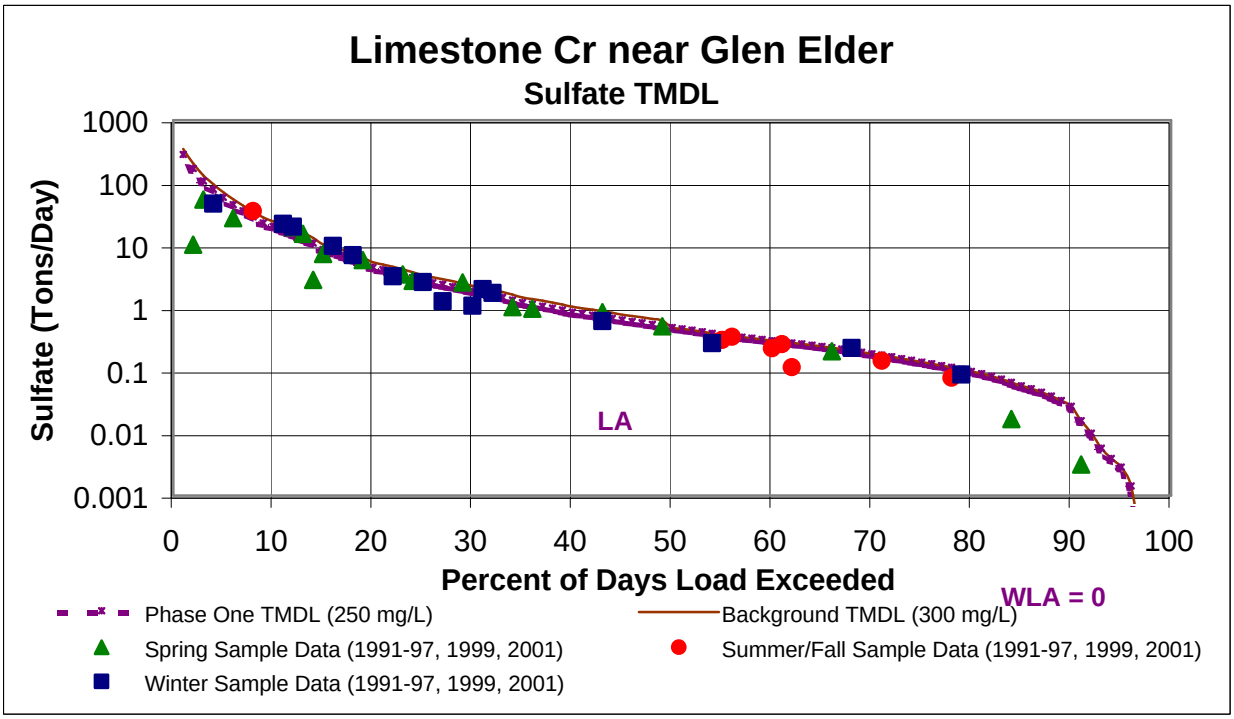

Figure 25

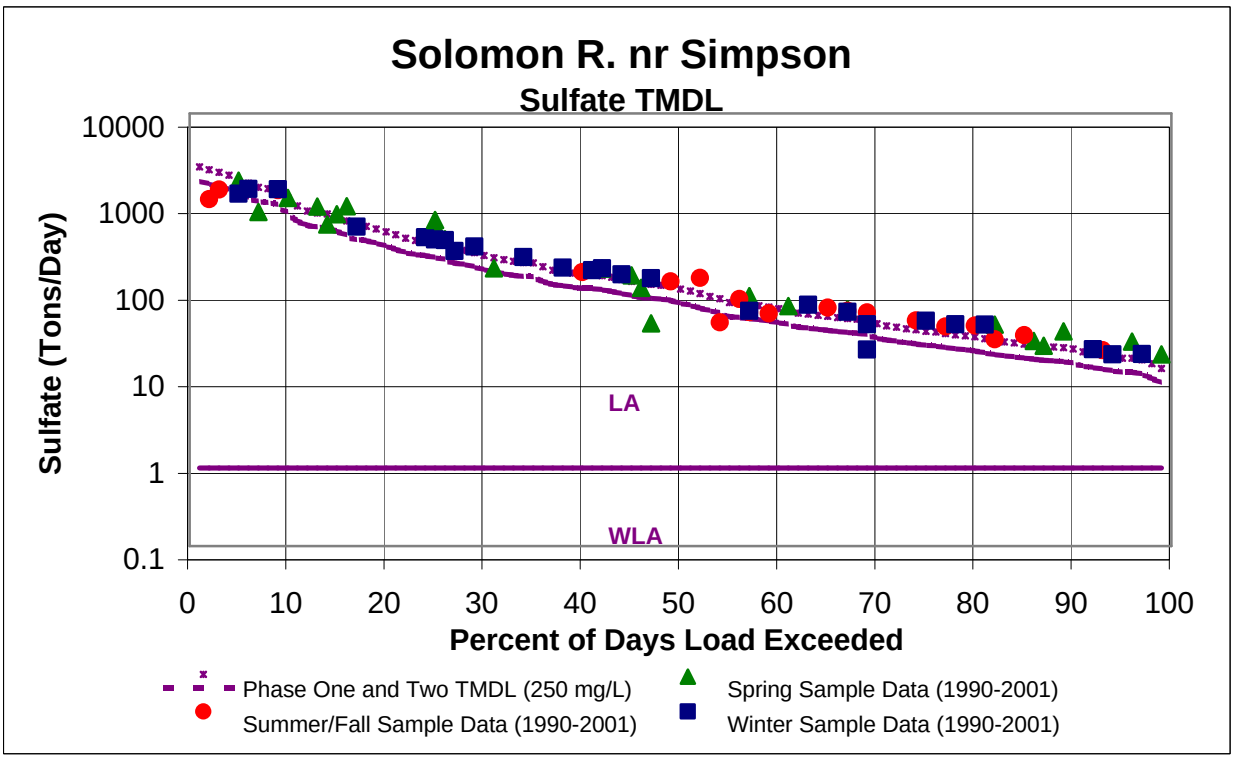

Figure 26

Site 512 (Salt Creek (Minneapolis) Watershed)
The Load Allocation is based on the existing standard of 250 mg/L for all stream flow and is shown in **Figure 27.** From this, the load allocation is 10.3 tons sulfate per day at median flow (15.3 cfs). The LA using a background sulfate concentration of 310 mg/L is 12.76 tons per day at median flow for Site 512.

Site 266 (Lower Solomon Watershed)
The Load Allocation is based on the existing standard of 250 mg/L for stream flows in excess of point source design flows and is shown in **Figure 28.** From this, the load allocation is 114 tons sulfate per day at median flow (170 cfs).

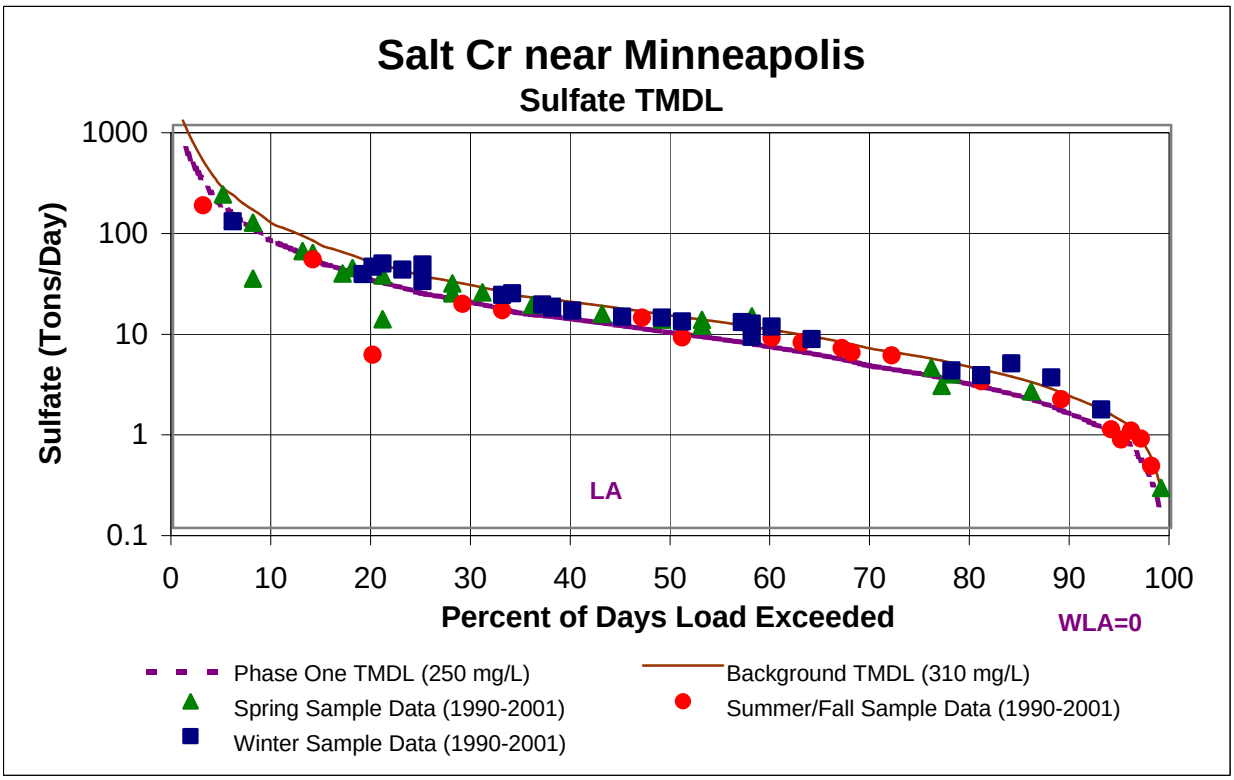

Figure 27

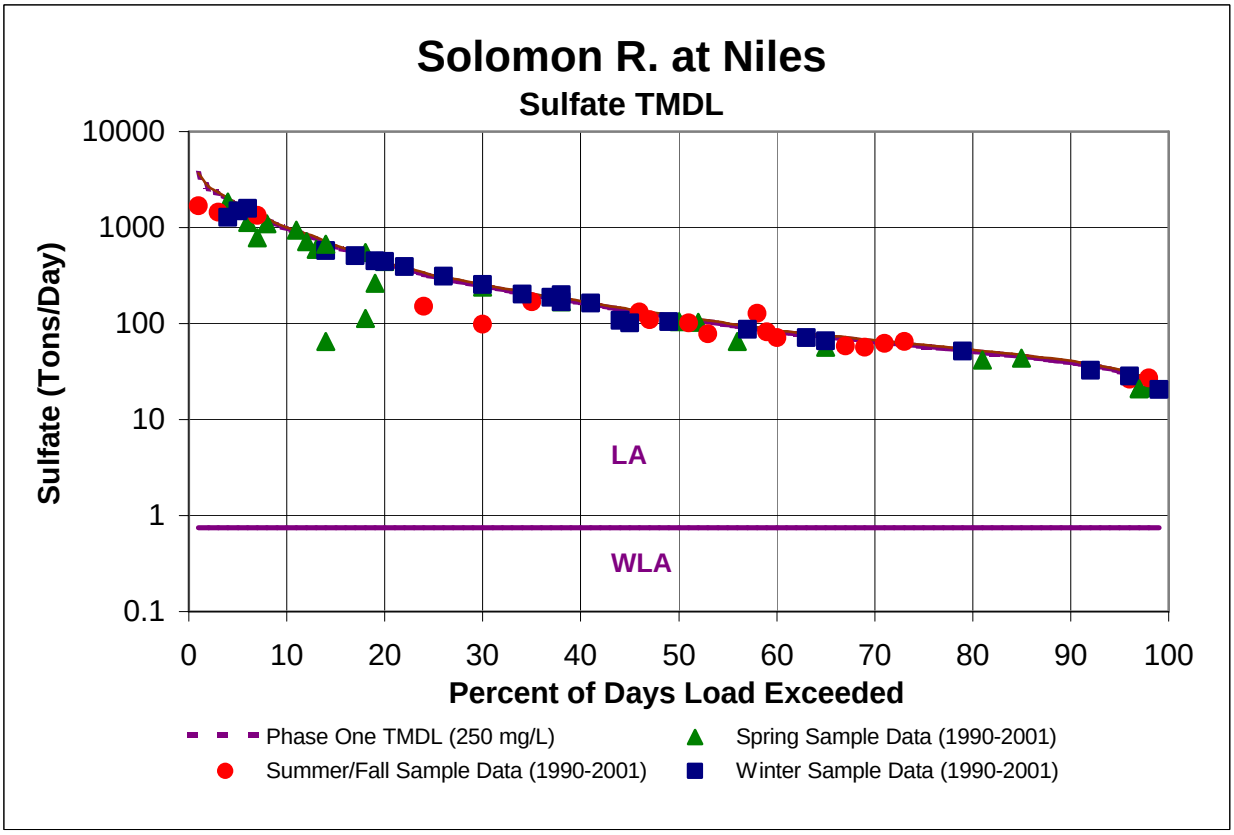

Figure 28

Defined Margin of Safety: The Margin of Safety provides some hedge against the uncertainty of loading and the sulfate endpoints for the Limestone Creek, Salt Creek and Solomon River systems. Since the greatest sulfate concentrations have occurred during low flow dominated conditions and the Phase One and Two targets are lower than these sulfate levels, the margin of safety is considered implicit in this TMDL. Furthermore, with the exception of the City of Beloit's diversion point on Segment 14 of the Solomon River, the lack of water diversion works along the river limits the applicability of the domestic water supply criterion. Holding the discharging facilities within the Lower Solomon Watershed to 250 mg/L explicitly maintains assurance that the low-flow endpoint will be attained.

State Water Plan Implementation Priority: Because the sulfate impairment in the Limestone Creek, Salt Creek (Minneapolis), Upper Solomon and Lower Solomon watersheds is due to geologic sources, this TMDL will be a Low Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Solomon Basin (HUC 8: 10260015) with a priority ranking of 23 (Medium Priority for restoration work).

Priority HUC 11s and Stream Segments: Because of the natural geologic contribution of this impairment, no priority subwatersheds or stream segments will be identified.

5. IMPLEMENTATION

Desired Implementation Activities

1. Monitor any anthropogenic contributions of sulfate loading to river.
2. Establish alternative background criterion.
3. Assess likelihood of river being used for domestic uses.

Implementation Programs Guidance

NPDES and State Permits - KDHE

a. NPDES and state permits for facilities for facilities in the watershed will be renewed after 2004 with sulfate monitoring and any appropriate permit limits which protects the domestic water supply criteria at any emerging/existing drinking water point of diversion on these streams.

Non-Point Source Pollution Technical Assistance - KDHE

a. Evaluate any potential anthropogenic activities that might contribute sulfate to the river as part of an overall Watershed Restoration and Protection Strategy.

Water Quality Standards and Assessment - KDHE

a. Establish background levels of sulfate for the river and tributaries.

Use Attainability Analysis - KDHE

a. Consult with Division of Water Resources on locating existing or future domestic points of diversion in the Solomon River system for drinking water purposes.

Timeframe for Implementation: Development of a background level-based water quality standard should be accomplished with the water quality standards revision.

Targeted Participants: Primary participants for implementation will be KDHE.

Milestone for 2008: The year 2008 marks the midpoint of the ten-year implementation window for the watershed. At that point in time, sampled data from Limestone Creek, Salt Creek (Minneapolis), Upper Solomon and Lower Solomon watersheds should indicate no evidence of increasing sulfate levels relative to the conditions seen in 1990-2003. Should the case of impairment remain, source assessment, allocation and implementation activities will ensue.

Delivery Agents: The primary delivery agents for program participation will be the Kansas Department of Health and Environment and the Kansas Department of Agriculture, Division of Water Resources.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution.

1. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.
2. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

3. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control nonpoint source pollution.

4. K.S.A. 82a-901, et seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

5. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan.*

6. The *Kansas Water Plan* and the Solomon Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

Funding: The State Water Plan Fund, annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL are a Low Priority consideration.

Effectiveness: Minimal control can be exerted on natural source contributions to loading.

6. MONITORING

KDHE will continue to collect bimonthly samples at Stations 667, 511, 512 and 266, including sulfate samples, in each of the three defined seasons. Based on that sampling, the priority status will be evaluated in 2008 including application of numeric criterion based on background concentrations. Should impaired status remain, the desired endpoints under this TMDL will be refined and direct more intensive sampling will need to be conducted under specified seasonal flow conditions over the period 2008-2012.

Monitoring of sulfate levels in effluent will be a condition of NPDES and state permits for facilities. This monitoring will continually assess the contributions of sulfate in the wastewater effluent released to the stream.

7. FEEDBACK

Public Meetings: Public meetings to discuss TMDLs in the Solomon Basin were held October 3, 2002, January 7 and March 3, 2003 in Stockton. An active Internet Web site was established at http://www.kdhe.state.ks.us/tmdl/ to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Solomon Basin.

Public Hearing: Public Hearings on the TMDLs of the Solomon Basin were held in Stockton on June 2, 2003.

Basin Advisory Committee: The Solomon Advisory Committee met to discuss the TMDLs in the basin on October 2, 2002, January 6 and March 3, 2003.

Milestone Evaluation: In 2008, evaluation will be made as to the degree of implementation that has occurred within the watershed and current condition of Limestone Creek, Salt Creek and the Solomon River. Subsequent decisions will be made regarding the implementation approach and follow up of additional implementation in the watershed.

Consideration for 303(d) Delisting: The stream will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2008-2012. Therefore, the decision for delisting will come about in the preparation of the 2012 303(d) list. Should modifications be made to the applicable water quality criteria during the ten-year implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality Management Plan and the Kansas Water Planning Process: Under the current version of the Continuing Planning Process, the next anticipated revision would come in 2005, which will emphasize implementation of TMDLs. At that time, incorporation of this TMDL will be made into both documents. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process for Fiscal Years 2008.