SOLOMON BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody/Assessment Unit: Upper N. Fk. Solomon River
Water Quality Impairment: Sulfate

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Upper N. Fk. Solomon River

County: Decatur, Graham, Norton, Phillips, Sheridan and Thomas

HUC 8: 10260011

HUC 11 (HUC 14s)**:** **010** (010, 020, 030, 040, 050, 060 and 070)
020 (010, 020, 030, 040, 050, 060 and 070)
050 (010, 020, 030, 040, 050 and 060)

Drainage Area: 933 square miles

Main Stem Segment: WQLS: 5, 7, 9, 11 and 13 (N. Fk. Solomon R.) starting immediately upstream of Kirwin Reservoir in south-central Phillips County and traveling upstream to headwaters in west-central Thomas County (**Figure 1**).

Tributaries:
Ash Cr (24)
Wolf Cr (22)
Crooked Cr (6)
Beaver Cr (23)
Cactus Cr (28)
Scull Cr (21)
Big Timber Cr (8)
Sand Cr (26)
Otter Cr (10)
Game Cr (27)
E. Elk Cr (25)
Lost Cr (20)
Elk Cr (21)
Spring Cr (19)

Designated Uses: 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 (N. Fork Solomon River).

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)).

Upper N. Fk. Solomon River Watershed Sulfate TMDL HUC and Stream Segment Map

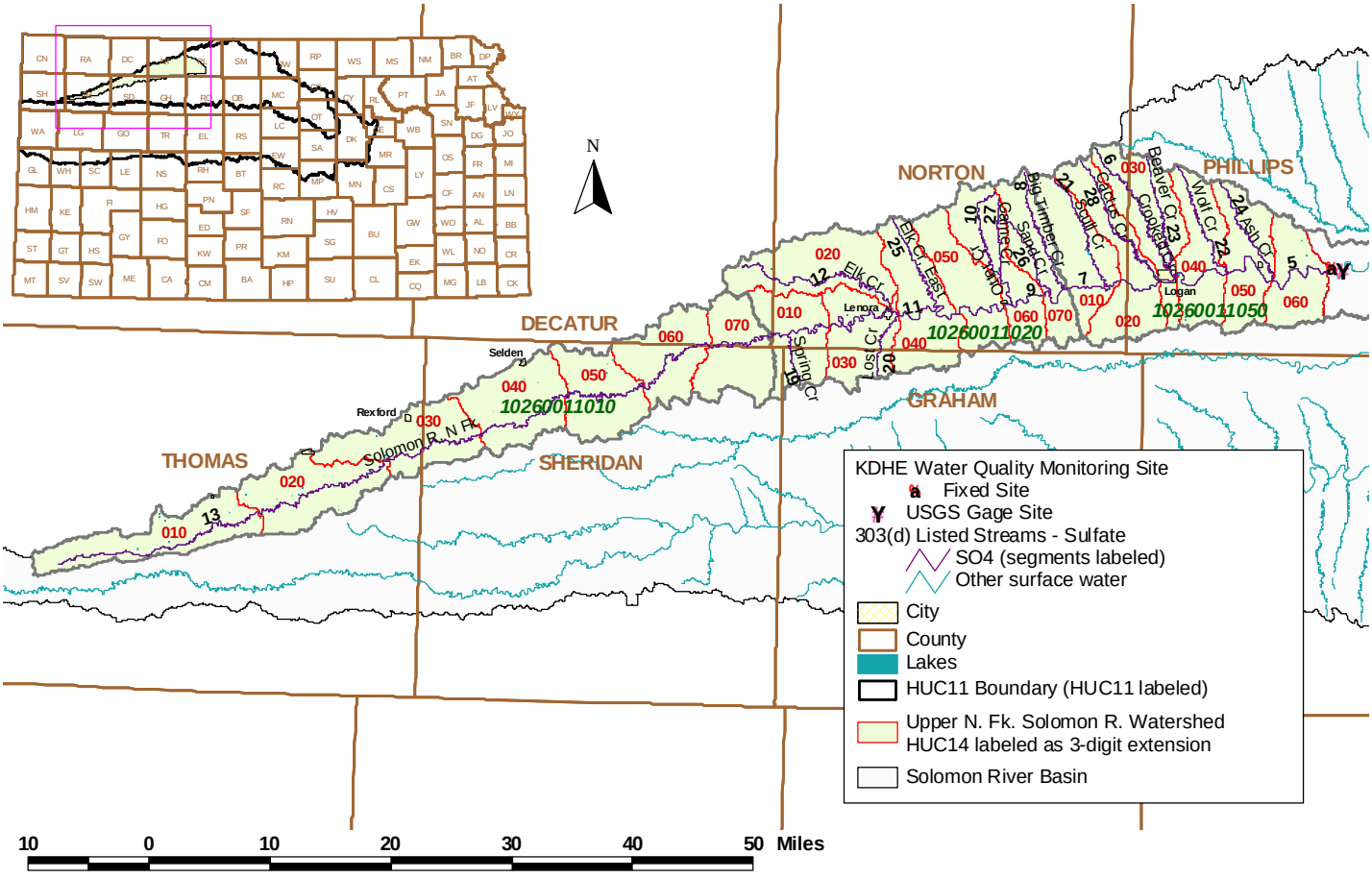

Figure 1

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

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

Monitoring Sites: Station 546 at Glade

Period of Record Used: 1990 –2001 for Station 546 (**Figure 2**)

Flow Record: North Fork Solomon River at Glade (USGS Station 06871000); 1970-2002.

Long Term Flow Conditions: Median Flow = 8 cfs

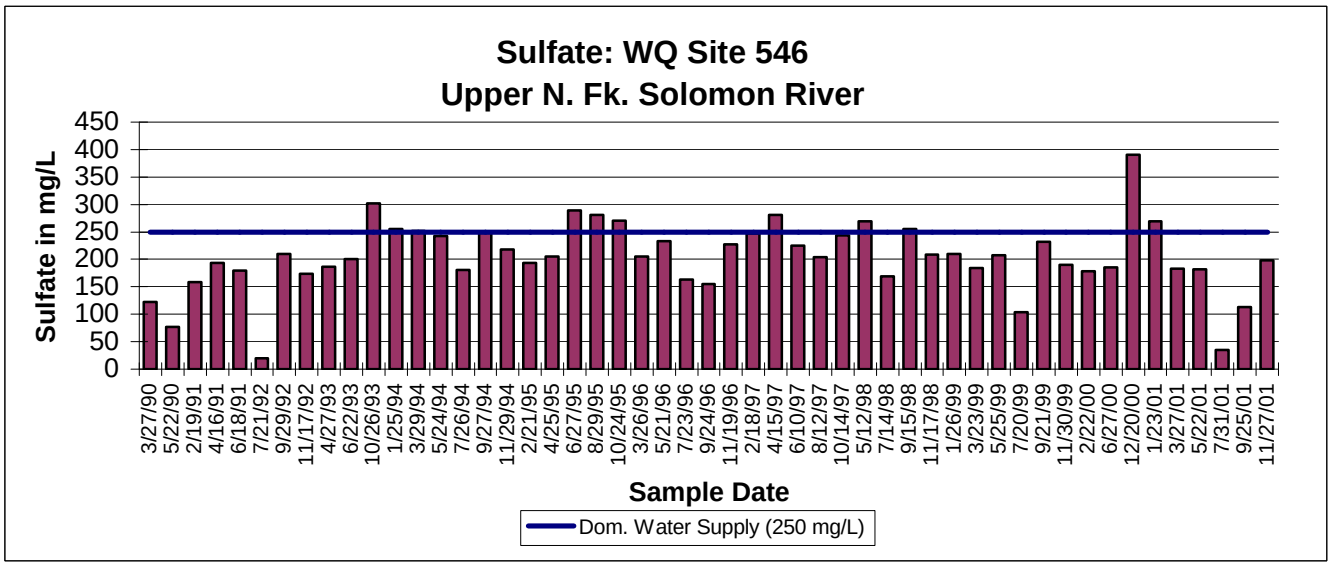

Figure 2

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 (**Figure 3**).

Excursions were seen in each of the three defined seasons and are outlined in **Table 1**. Fourteen percent of the Spring samples and 36% of Summer-Fall samples were over the secondary contact criterion. Twenty-one percent of the Winter samples were over the secondary criterion. Overall,

22% 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.**
N. Fk Solomon R. at Glade (546)	Spring	3	0	0	0	No Flow	No Flow	3/21 = 14%
	Summer/Fall	1	0	2	1	No Flow	No Flow	4/11 = 36%
	Winter	2	0	0	2	No Flow	No Flow	4/19 = 21%

Desired Endpoints of Water Quality (Implied Load Capacity) at Site 546 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. Still, the Upper North Fork Solomon River system is subject to loading of sulfate from shales in the underlying Cretaceous bedrock and its high gypsum and pyrite content. As such, the watershed's main stem and many of its tributaries often have elevated sulfate levels from this source.

Current 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. From current information, it appears that long-term increase in sulfate concentration with time is a result of increased water consumption in the Upper N. Fk. Solomon River watershed. Therefore, the Phase Two of this TMDL will also be based on the current standard applied to flows within the contributing portions of the Upper N. Fk. Solomon River watershed to Site 546.

Seasonal variation has been incorporated in this TMDL through the documentation of the seasonal consistency of sulfate level exceedances. 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 have been restored.

3. SOURCE INVENTORY AND ASSESSMENT

(Background and Historical Assessment based upon analysis provided by Don Whittemore, Kansas Geologic Survey)

The North Fork Solomon River near Glade (station 546) had an average sulfate concentration of 205 mg/L during March 1990 to March 2003 when the river had measurable flow. The sulfate concentration varied substantially over time, from a minimum of 20 mg/L in a high-flow event to 391 mg/L during a low-flow period. There were 3 samples collected from pools in the river channel when there was no measurable flow (2/19/91, 12/17/02, and 1/28/03). Although the lowest sulfate concentrations occurred during moderate to high stream flow, the relationship between flow and sulfate is not as pronounced as in most streams and rivers of Kansas with sulfate exceedances stemming from natural sources. In general, there is only a small trend of increasing sulfate concentration with decreasing flow in the river (**Figure 3,** solid line is best fit power curve).

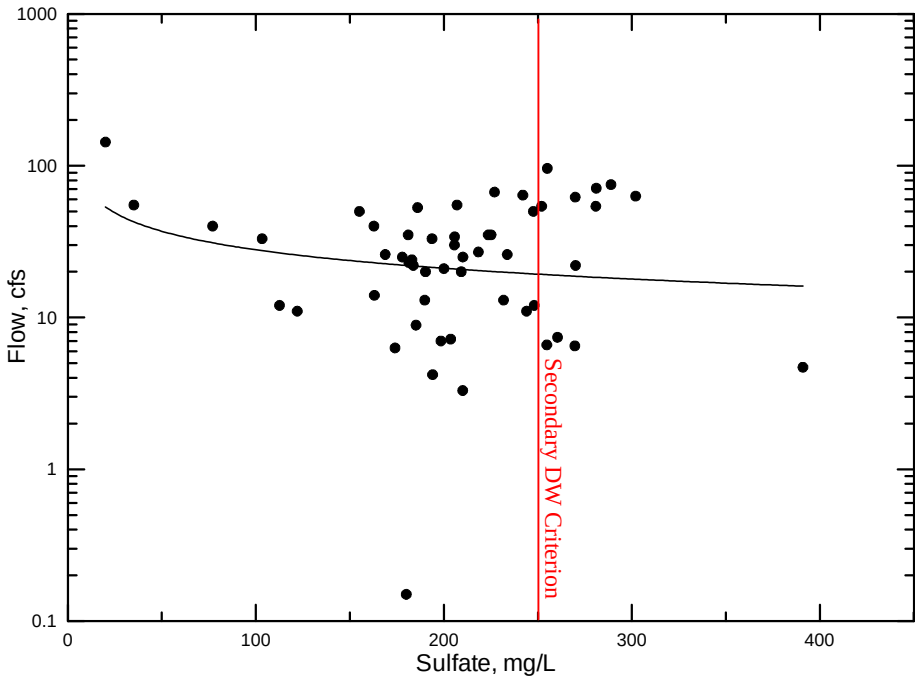

Figure 3

Background Source Conditions: The main natural source of sulfate in the North Fork Solomon River is from the weathering of Cretaceous bedrock that underlies the drainage basin. Dissolution of small amounts of gypsum (hydrous calcium sulfate) crystals and oxidation of the sulfide in pyrite (iron sulfide), primarily in certain shales of the Smoky Hill Member of the Niobrara Chalk, during the weathering of the bedrock increase the sulfate concentration of water moving through the subsurface. This ground water then discharges directly into streams or into the overlying Ogallala Formation and alluvial sediments before entering streams. Evapotranspiration consumption of ground water in the drainage basin and evaporation from the surface of streams has increased the sulfate concentration of the surface water through time.

Historical Assessment: The sulfate concentration in the upper North Fork Solomon River just upstream of Kirwin Lake has increased substantially from the period 1963-1975 (USGS data) to 1990-2003 (**Figure 4,** solid line is linear regression).

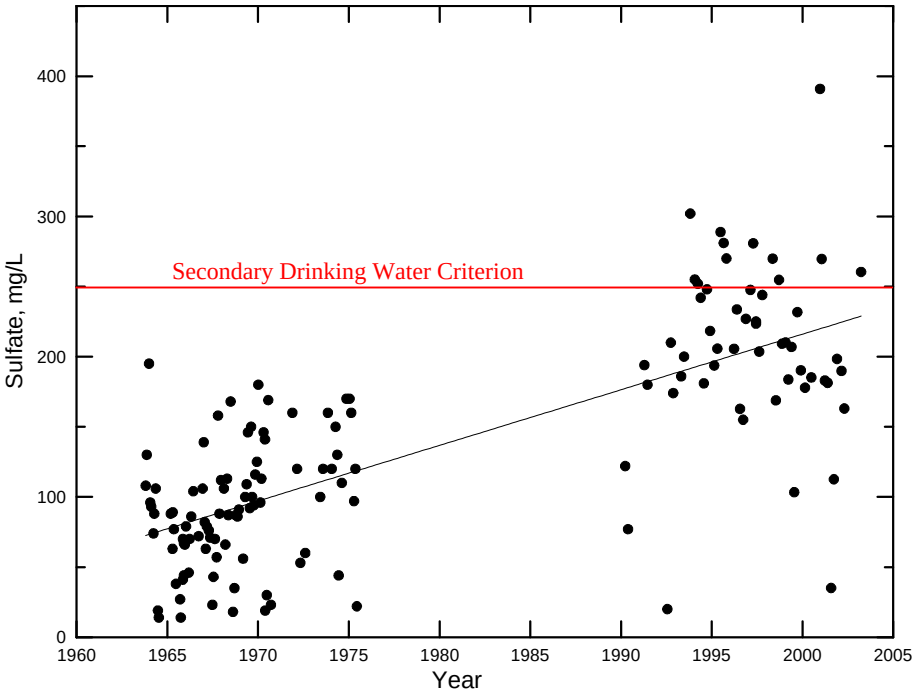

Figure 4

The average concentration was 92 mg/L during 1963-1975 and was 205 mg/L during 1990-2003. The inverse relationship between the flow of the river and the sulfate content at the water-quality monitoring site has changed from the early to the recent period such that flows in 1990-2002 have greater sulfate concentrations for similar flows for 1963-1975 (**Figure 5**, solid lines are best fit power curves).

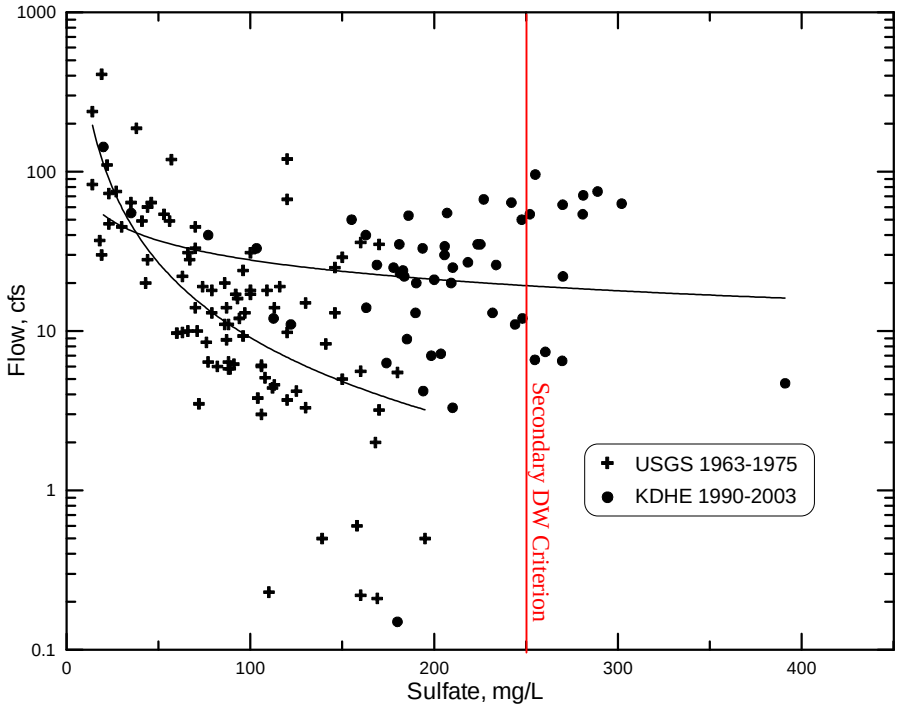

Figure 5

The record of mean annual flows from USGS gage station 06871000 on the North Fork Solomon River indicates that there has been a general decrease in the stream flow from 1953 to 2002. However, there is no significant difference between the mean daily flow values for the dates of water-sample collection from the river for 1963-1975 and 1990-2002. Thus, the substantial increase in the sulfate concentration of the river from the early to the recent period cannot be explained by decreasing flows. The increase in sulfate concentration with no significant change in flow between the sampling periods has caused a notable increase in the sulfate loads during the recent period (**Figure 6**, solid line is linear regression for all data shown).

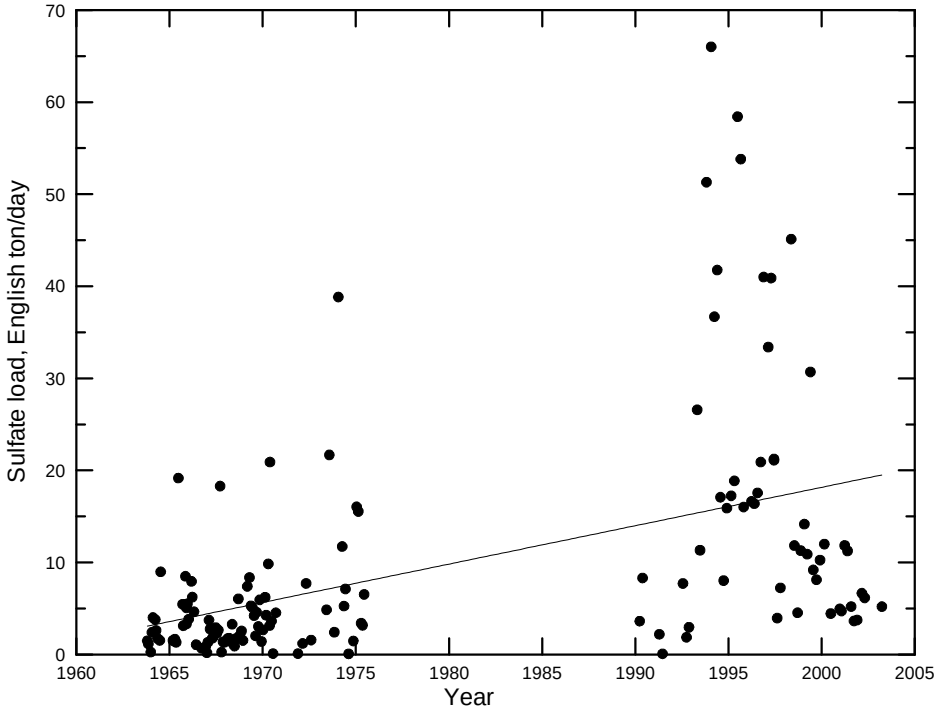

Figure 6

The specific conductance and total dissolved solids concentrations of the upper North Fork Solomon River also increased during the period of 1963-1975 to 1990-2003. There are no known, substantial external sources of sulfate or other major dissolved constituents from anthropogenic activities to the system between these periods that could account for the appreciable concentration/load increases. The most probable explanation for the sulfate increase in the river is related to water use and consumptive use of water in the watershed. Evaporation and plant transpiration consume water and leave dissolved constituents in the residual water, thereby increasing the constituent concentrations.

The uppermost part of the watershed of the upper North Fork Solomon River in Thomas and Sheridan counties is underlain by the Ogallala-High Plains aquifer. There are many irrigation wells in the aquifer in these two counties. There are also a large number irrigation wells in the alluvial aquifer along the river in the southeast corner of Decatur County and in southern Norton and Phillips counties upstream of water quality monitoring Site 546 (**Figure 7**). Water Use reports for 2001 indicate that of the 44,712 acre-feet of water used in the watershed, 43,491 acre-feet were for irrigation use from groundwater sources. The total number of reported acres irrigated was 36,681.

The dissolved salts in the groundwater used for irrigation are gradually concentrated in the soil of the irrigated area. Most of the irrigation water applied to crops is consumed by evapo-transpiration, leaving the dissolved salts in the soil. Although some of the salts are leached below the root zone, much of the salt remains within the root zone of the soil. Heavy rainfall first must saturate shallow soil before substantial runoff occurs. The rainwater infiltrating the shallow soil readily dissolves soluble salts. Water in the saturated soil moves laterally down slope in the soil if the rainfall rate is great enough. The saturated soil water then leaves irrigated fields in small surface drainages to form runoff to the river tributaries. The buildup of substantial amounts of salts in irrigated soils generally requires several years. Thus, there is a lag time between the transport of dissolved salts in the groundwater used for irrigation to the soil and the appearance of substantial amounts of the salts in the river water. Irrigation in western Kansas had increased appreciably from the 1950s to the 1980s. The increase of sulfate in the river water fits the timing of the increase in irrigation and the lag time for buildup and transport of the additional dissolved salts to the river.

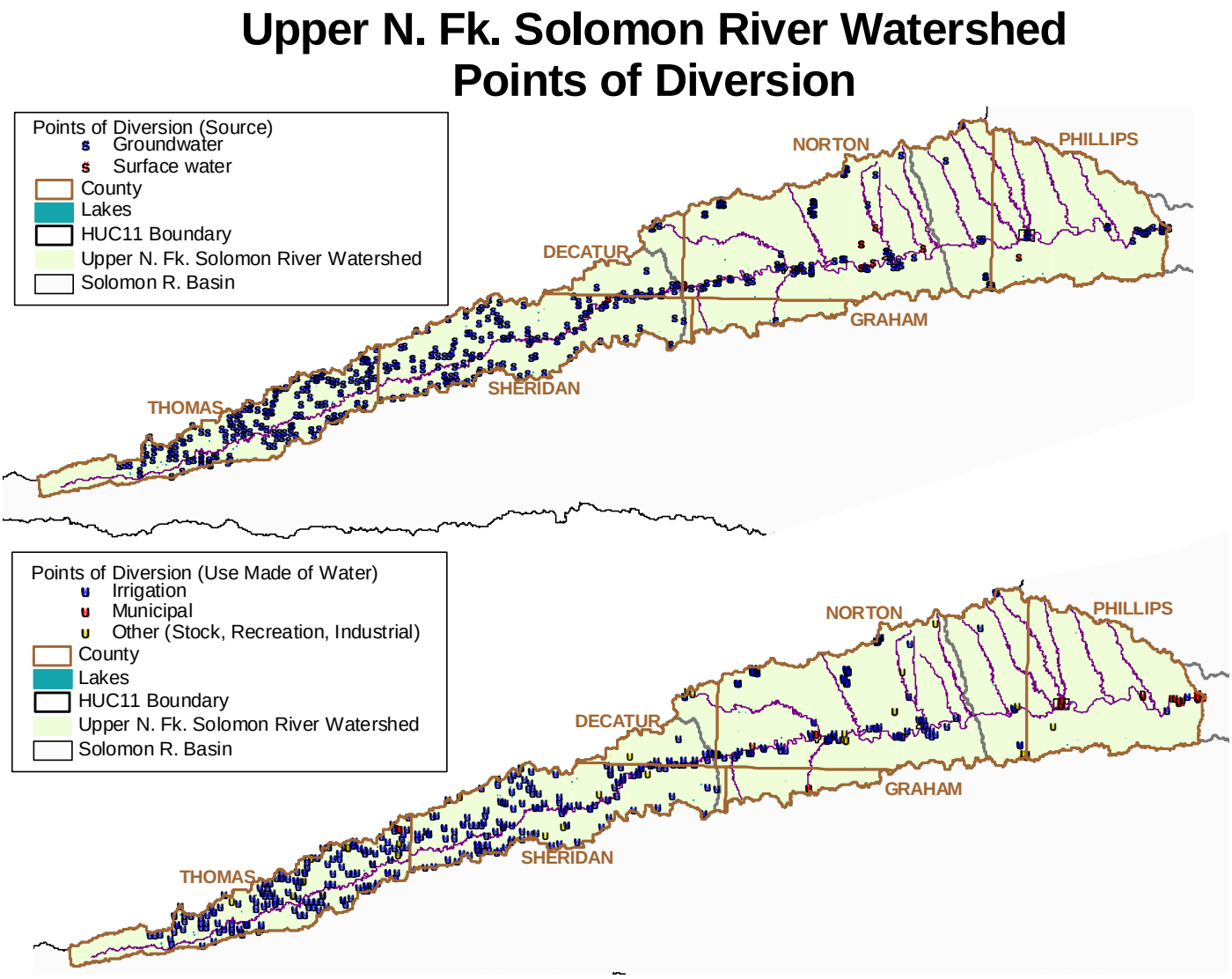

Figure 7

The sulfate/chloride ratio has not changed significantly from the period 1963-1975 to 1990-2003. However, there is a pattern of increasing and then decreasing ratios for samples collected from 1990 to 2003. The pattern for the recent period appears similar to that for the annual flow of the North Fork Solomon River at site 546 (**Figure 8**).

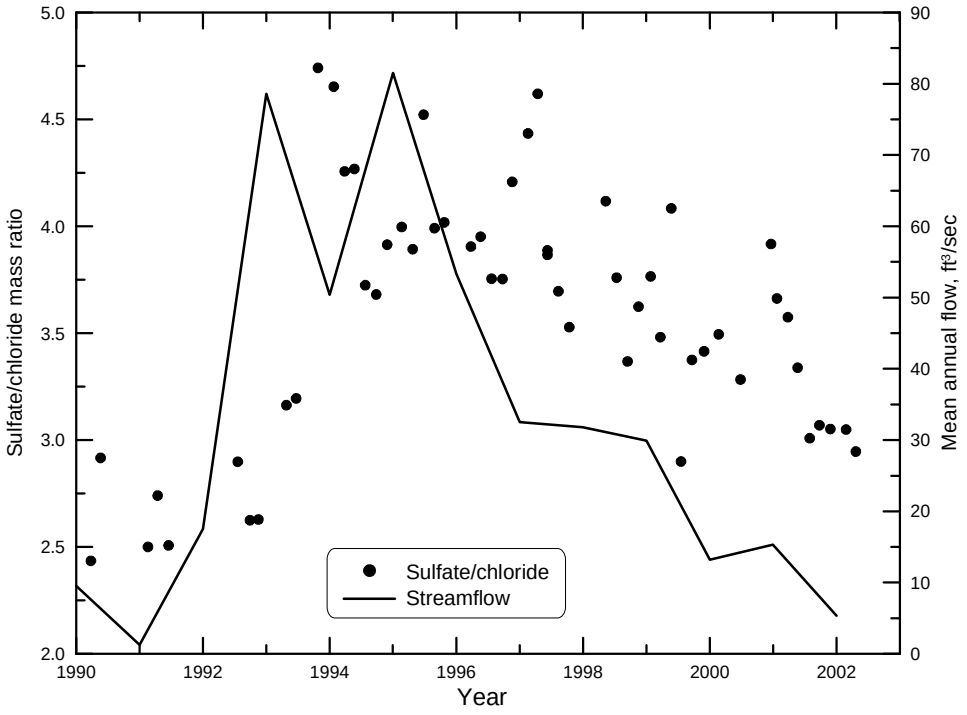

Figure 8

The sulfate/chloride ratio rose during the beginning of the wet period in 1993, remained at higher values during the wet period that extended to 1996, and decreased during the decline in annual flows from 1996 to 2002. This pattern fits the previous explanation for the long-term sulfate increase in the river; the accumulation of soil salts in irrigated fields and transport to streams during heavy rains. The sulfate/chloride ratio can be greater in surface soils than at greater depths below irrigated fields because sulfate minerals precipitate before chloride minerals as water is lost, due to the smaller solubility of the sulfate minerals in water. Thus, dissolved chloride in soil moisture can migrate preferentially to deeper depths in the soil in comparison with sulfate. Runoff from heavy rains that have dissolved and mobilized near-surface soil salts can therefore have a somewhat greater sulfate/chloride ratio than the water that infiltrates to the water table and later discharges to streams.

Consumption of water by phreatophytes (high water-use trees) in the valley of the upper North Fork Solomon River can increase the dissolved solids concentration of groundwater in the alluvial aquifer. The Kansas Geological Survey (KGS) conducted a study for the Division of Water Resources (DWR), Kansas Department of Agriculture, to assist the DWR Subbasin

Program in understanding stream-aquifer relationships in the Solomon river basin (Butler et al., 2002[1]). Part of the study included installation of observation wells across the alluvial aquifer of the upper South Fork Solomon River near KDHE monitoring Site 547. The highest dissolved solids observed in the aquifer were associated with the riparian portion of the valley. Water levels in the observation well in the riparian zone exhibit a diurnal variation that is similar to that observed in an ongoing study by the KGS in the middle Arkansas River basin in Kansas to quantify groundwater consumption by phreatophytes. Phreatophyte concentration of dissolved solids partly explains the generally higher concentration of dissolved solids in the alluvial aquifer than in the High Plains aquifer. If the phreatophyte covered area has increased from the middle to the later part of the 20th century in the upper North Fork Solomon River, phreatophyte impacts on water loss and dissolved solids concentration could be partially responsible for the increase in sulfate concentration in the river.

Oil-field Brine: Oil-field brine in Kansas that was disposed at or near the land surface in the past generally has a sulfate concentration that is relatively low in comparison with the high chloride content of such brine. Thus, oil-brine contamination in the drainage basin is not expected to be a significant source of sulfate in the river water.

NPDES: There is one NPDES municipal permitted wastewater discharger (the city of Logan) located within the watershed that would contribute a sulfate load to Site 546 (**Figure 9**). This system is outlined below is **Table 2**. The dissolved sulfate found in municipal wastewater is expected to be of natural origin derived from the source water.

In 2000 the city of Logan relocated their municipal water supply well field to an area southwest of town near the North Fork Solomon River watershed boundary. In doing so, they changed their source of supply from the main stem alluvium to the Ogallala Aquifer and drastically reduced the sulfate concentration in their drinking water. Drinking water monitoring records indicate that the average sulfate concentration for point of entry samples prior to the well field relocation was 400 mg/L, while samples after the relocation averaged 6.5 mg/L. With this change in source of supply, any municipal point source sulfate load would be negligible in the context of the natural sulfate loads that occur within the watershed.

The cities of Rexford, Selden and Lenora each have a non-discharging lagoon that may contribute a sulfate load to North Fork Solomon River (Segment 13) 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 would constitute an impairment to the designated uses of the river. 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

[1] Butler, J.J., Jr., Whittemore, D.O., Healey, J.M., and Schulmeister, M.K., 2002, Stream-aquifer investigations on the Solomon River: Construction, geochemical sampling, and slug testing of groundwater observation wells in Rooks county, Kansas and geological logging of existing wells in Rooks, Smith and Osborne counties, Kansas: Kansas Geological Survey Open-File Report 2002-60, 41 p., for Kansas Department of Agriculture.

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.

Table 2

Discharging Facility	NPDES Permit	Stream Reach	Segment	Design Flow	Type
Logan WTF	M-S025-OO01	Crooked Cr	6	0.1 mgd	Mechanical

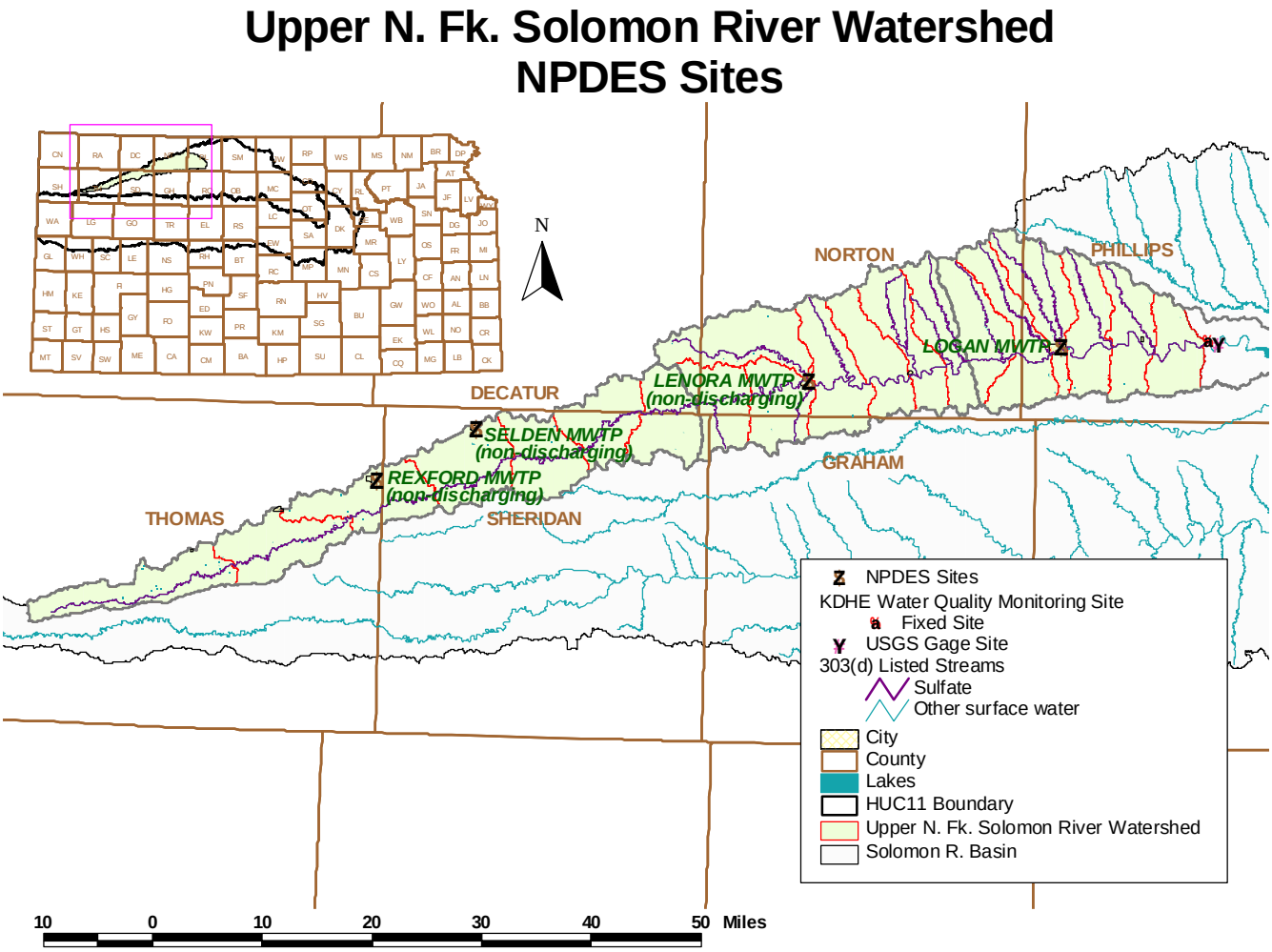

Figure 9

4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

Although the source of the dissolved sulfate in the river water is natural, land and water use changes appear to have caused a long-term increase in the sulfate concentration by increasing evapotranspiration consumption of water, resulting in the same residual dissolved solids in a smaller water volume. However, it also appears climatic variations have a greater effect on the short-term sulfate concentration of the river water than the land and water use changes.

There is no evidence of significant anthropogenic sources that directly contribute to the elevated sulfate conditions in the upper N. Fk. Solomon River watershed.

Point Sources: The following Wasteload Allocations shall only apply upon initiation of the use of these surface waters for potable supply through a constructed point of diversion.

A Phase One Wasteload Allocation of 84 lbs (0.042 tons) sulfate per day will be established by this TMDL at 100 mg/L sulfate and the design flow (0.155 cfs) of the point source (**Figure 10**). Use of the 100 mg/L sulfate target is based upon the low sulfate levels in the city's source water, yet accommodates any future growth of the city. Establishment of the WLA at 100 mg/L sulfate rather than at the 250 mg/L secondary drinking water criterion or any elevated background criterion prevents excessive loading in the future of sulfate by point sources in the watershed.

The non-discharging facilities located within the watershed will have a Phase One Wasteload Allocation of zero.

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

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 10.** From this, the load allocation is 5.4 tons sulfate per day at median flow (8 cfs).

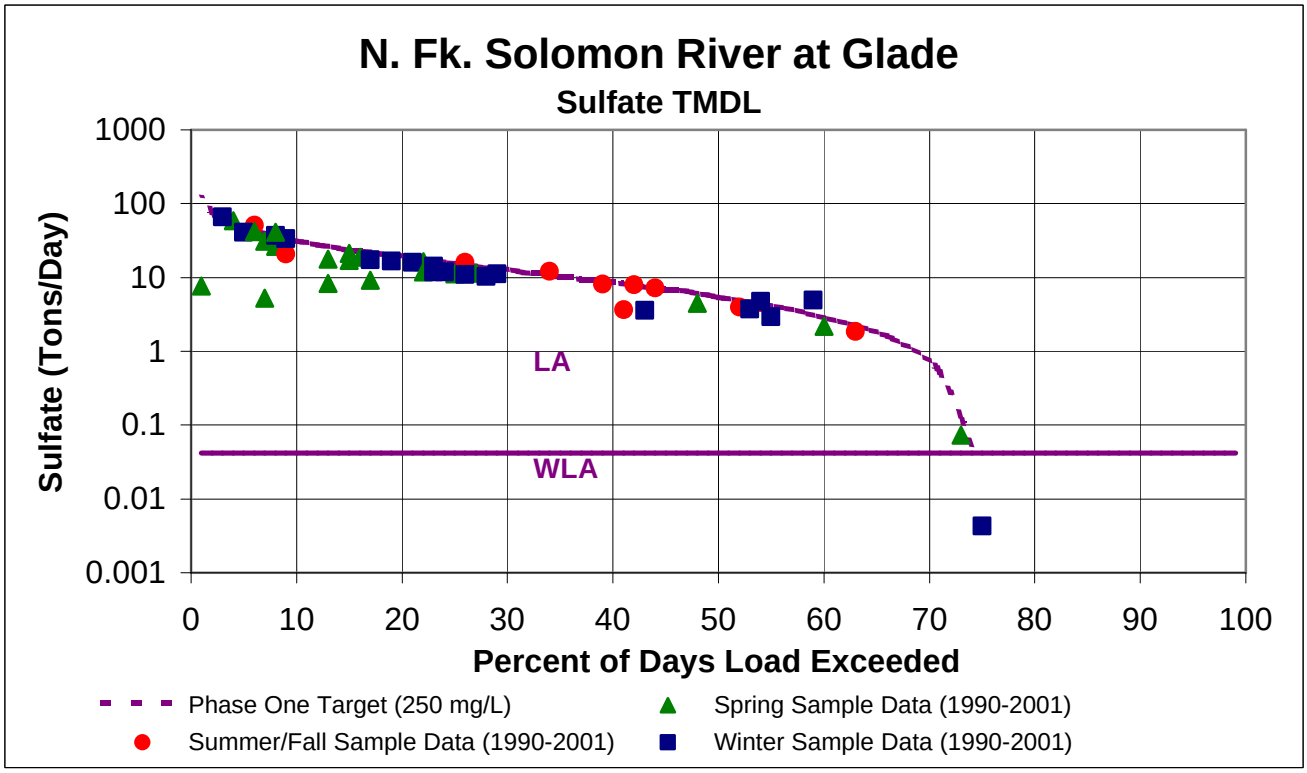

Figure 10

Defined Margin of Safety: The Margin of Safety provides some hedge against the uncertainty of loading and the sulfate endpoints for the upper N. Fk Solomon River system. Since the maximum sulfate concentration has occurred at winter base flows and the current Phase One target is lower than this critical winter sulfate level, the margin of safety is considered implicit in this TMDL. Furthermore, the lack of surface water diversion works along the river limit the applicability of the domestic water supply criterion. Explicitly maintaining a WLA based upon a 100 mg/L sulfate target despite any future elevated background determination ensures WLA will not cause sulfate concentrations to exceed 250 mg/L.

State Water Plan Implementation Priority: Because the sulfate impairment in the upper N. Fk. Solomon River watershed is due to geologic sources, this TMDL will be a Low Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Upper North Fork Solomon Basin (HUC 8: 10260011) and is classified as a Category II watershed under the unified assessment.

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.
4. Minimize irrigation return flows

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 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 on the N. Fk. Solomon River for drinking water purposes.

Water Right Management – KDA/DWR

a. Encourage proper use of tailwater control practices to minimize irrigation return flows.

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 the upper N. Fk. Solomon River watershed 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.

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 soucre contributions to loading.

6. MONITORING

KDHE will continue to collect bimonthly samples at Station 546, 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 to confirm the degree of impairment that has occurred within the watershed of Upper North Fork 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 intervening 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 (CPP), the next anticipated revision will come with the adoption of the new EPA Watershed Rule which will emphasize implementation of TMDLs. At that time, incorporation of this TMDL will be made into the CPP. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process after Fiscal Year 2008.