KANSAS/LOWER REPUBLICAN BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody/Assessment Unit: Shunganunga Creek
Water Quality Impairment: Dissolved Oxygen

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Middle Kansas **County:** Shawnee

HUC 8: 10270102

HUC 11 (HUC 14s)**:** **090** (010 and 020)

Drainage Area: 72.9 square miles

Main Stem Segment: WQLS: 39 and 40 (Shunganunga Creek) starting at the confluence with the Kansas River near the center of the east side of Shawnee County and traveling upstream to the headwaters in southwest Shawnee County (**Figure 1**).

Tributary Segments: Stinson Creek (394)
Deer Creek (41)
S. Br. Shunganunga Creek (106)

Designated Uses: Expected Aquatic Life Support, Primary Contact Recreation B (PCR C, Domestic Water Supply, Food Procurement, Groundwater Recharge, Industrial Water Supply, Irrigation Use, and Livestock Watering for Main Stem Segment and tributary S. Br Shunganunga Creek. Other tributary uses are the same, except recreation use for Stinson Creek is Secondary Contact b and Deer Creek is Primary Contact C.

Impaired Use: Expected Aquatic Life Support

Water Quality Standard: Dissolved Oxygen (DO): 5 mg/L (KAR 28-16-28e(c)(2)(A))

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Use under 2004 303(d): Not Supporting Aquatic Life

Monitoring Sites: Station 238 near Topeka

Period of Record Used: 1990 - 2004 for Station 238 (**Figure 2**); confirmed by 2004-2006 data

Flow Record: Bivariate Fit of Shunganunga Creek near Topeka (USGS Station 06889700; 1979-1981; 1993-1996) by Soldier Creek (USGS Station 0688950) used to estimate flow in Shunganunga Creek during sampling period (**Figure 3**) from Soldier Creek daily flows.

Long Term Flow Conditions: 10% Exceedance Flows = 27.6 cfs, 95% = 2.2 cfs

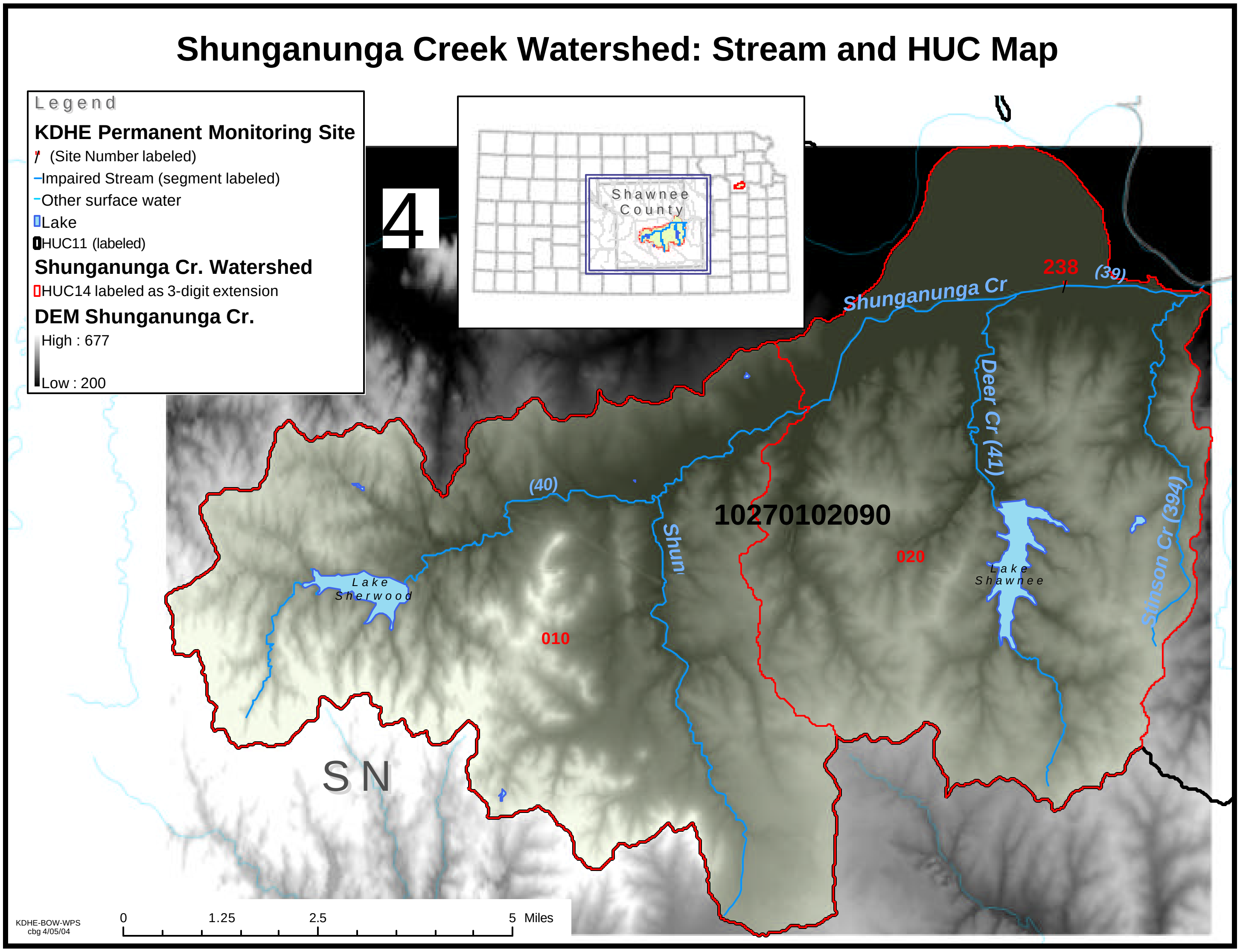


Figure 1

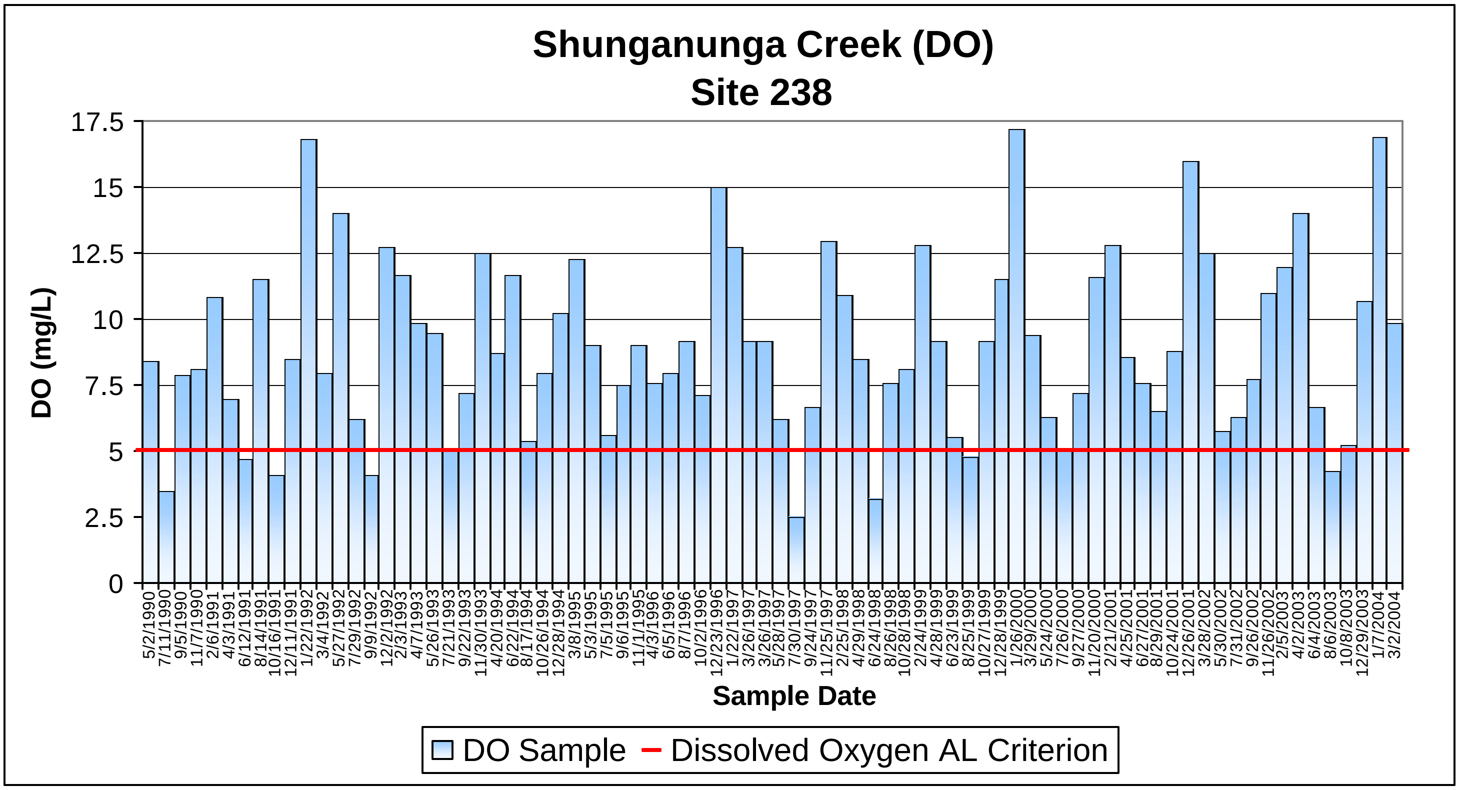
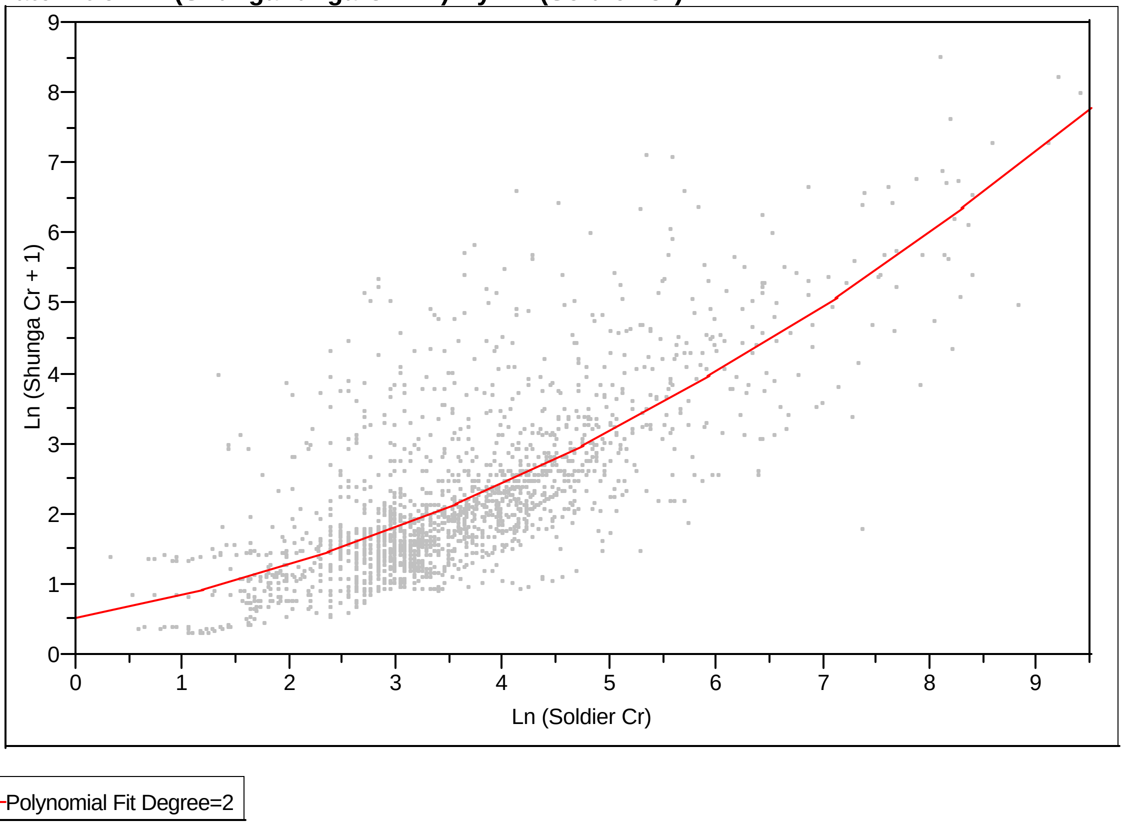


Figure 2

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 the 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 dissolved oxygen Aquatic Life criterion by multiplying the estimated flow values for Shunganunga Creek near Topeka along the curve by the applicable water quality criterion and converting the units to derive a load duration curve of pounds of DO per day. This load curve graphically displays the TMDL since any point along the curve represents water quality at the standard at that flow. Historic excursions from water quality standards (WQS) are seen as plotted points *below* the load curves. Water quality standards are met for those points plotting *above* the applicable load duration curves (**Figure 4**). In addition, a concentration duration curve was also created to visually aid in the identification of excursions from DO criterion (**Figure 5**).

Excursions were seen two of the three defined seasons and are outlined in **Table 1**. Fifteen percent of Spring samples and 19% of the Summer/Fall samples were below the aquatic life criterion. All of the Winter samples were compliant with the aquatic life criterion. Overall, 10% of the samples were under the criterion. This would represent a baseline condition of partial support of the impaired designated use. However, only one excursions has occurred since 2003.

Bivariate Fit of Ln (Shunganunga Cr + 1) By Ln (Soldier Cr)



Polynomial Fit Degree=2

Ln (Shunganunga Cr + 1) = 0.5401803 + 0.2659813 Ln (Soldier Cr) + 0.0523853 Ln (Soldier Cr)^2

Summary of Fit

RSquare	0.568683
RSquare Adj	0.56821
Root Mean Square Error	0.81534
Mean of Response	2.275033
Observations (or Sum Wgts)	1827

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	1598.7361	799.368	1202.456
Error	1824	1212.5576	0.665	Prob > F
C. Total	1826	2811.2938		0.0000

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.5401803	0.11854	4.56	<.0001
Ln (Soldier Cr)	0.2659813	0.057642	4.61	<.0001
Ln (Soldier Cr)^2	0.0523853	0.006586	7.95	<.0001

Figure 3

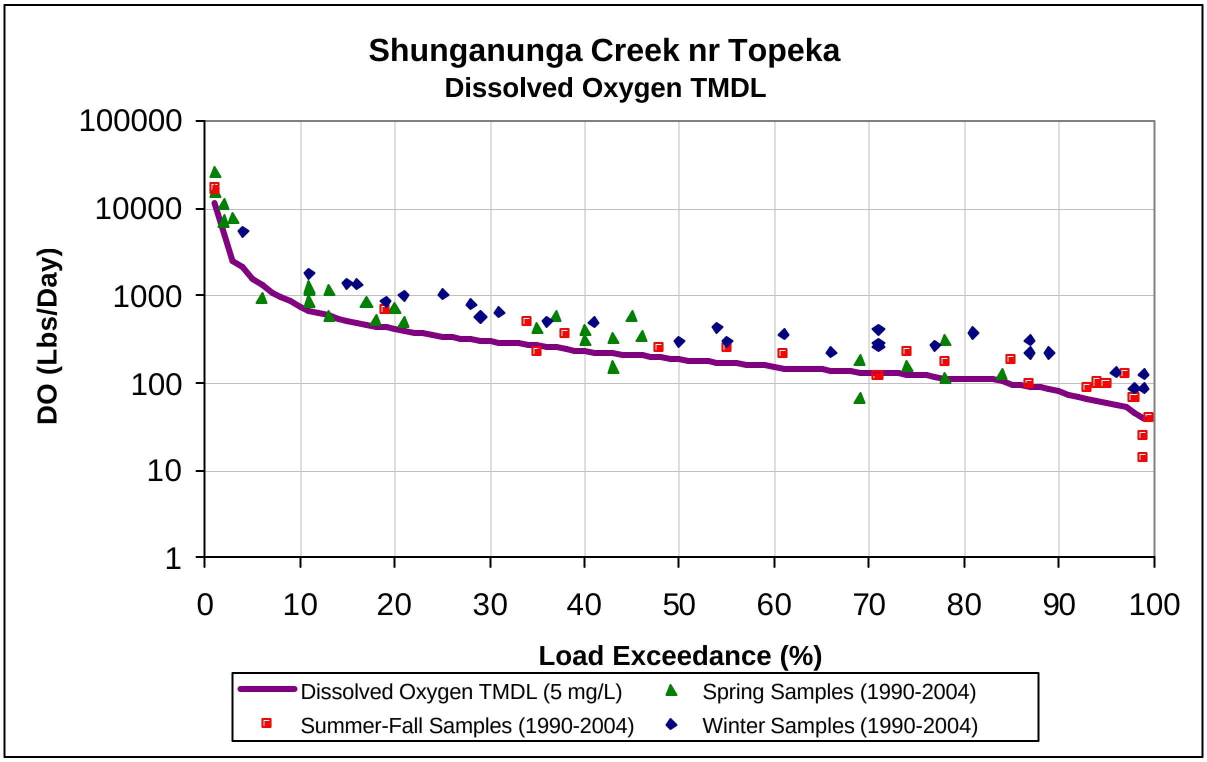


Figure 4

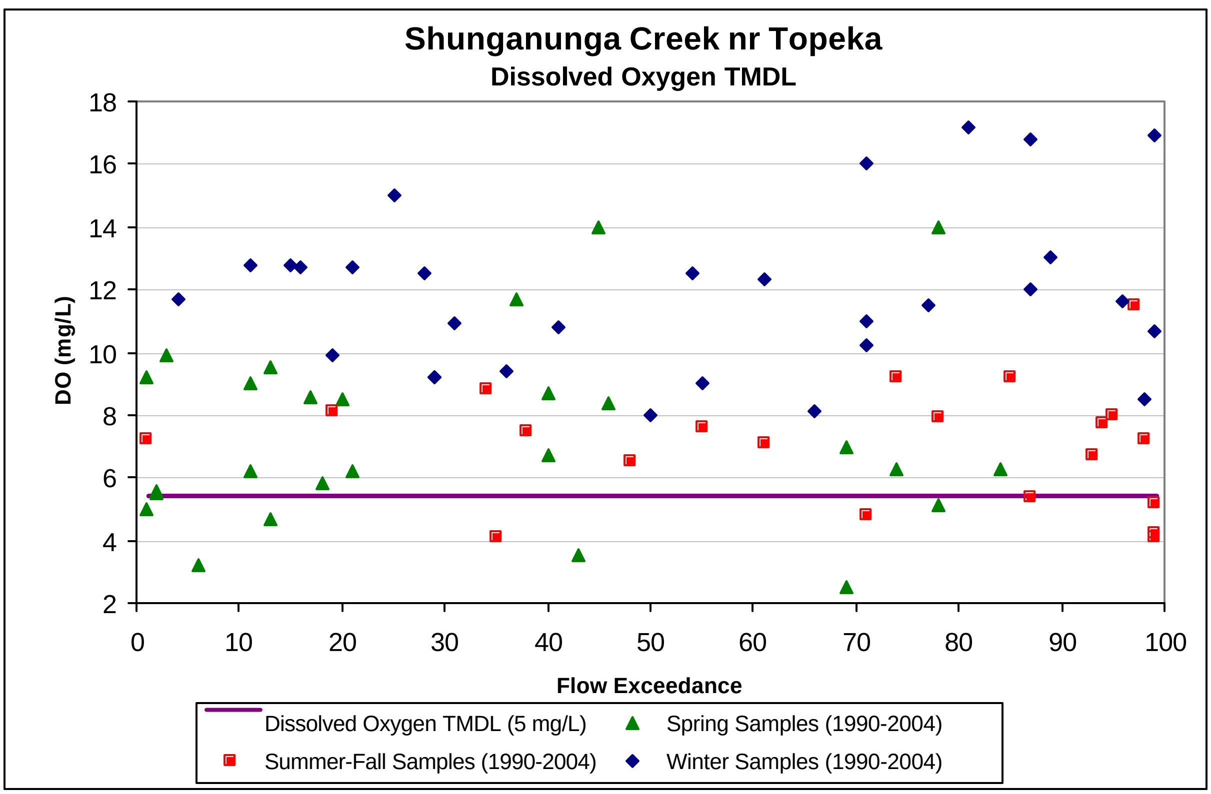


Figure 5

Table 1

NUMBER OF SAMPLES UNDER DISSOLVED OXYGEN STANDARD OF 5mg/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.**
Shunganunga Cr nr Topeka (238)	Spring	1	1	1	1	0	0	4/26 = 15%
	Summer/Fall	0	0	1	1	0	2	4/21 = 19%
	Winter	0	0	0	0	0	0	0/29 = 0%

DO exceedances have occurred across all flows conditions in the Shunganunga Creek watershed.

The data from Site 238 were initially divided into two groups for comparison purposes; those data associated with the DO excursions and those with DO compliant samples. The relationship of these DO groups was compared for ammonia (NH3), biochemical oxygen demand (BOD), fecal coliform bacteria (FCB), water temperature (Temp_C), total suspended solids (TSS), turbidity, nitrate, phosphorus, potassium, pH and estimated flow were used in making the comparisons. KDHE discontinued BOD sampling from its stream compliance water quality network at the end of 2001. Total Organic Carbon (TOC) will now be sampled in the place of BOD. Total Kjeldahl Nitrogen (TKN) samples were collected beginning in 2000. Because of insufficient sample numbers, both TOC and TKN could not be included in the group comparisons and the multiple regression model discussed later. **Table 2** outlines those water quality data used in the comparison.

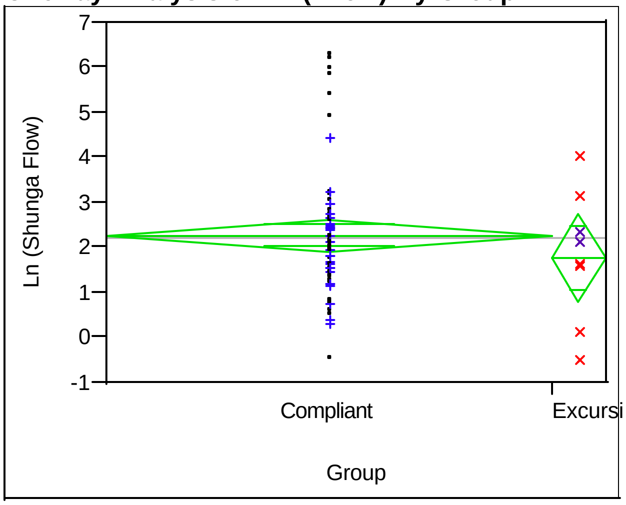
In the compliant-excursion DO group comparisons shown in Figures 6 through 16, winter data are shown as “+” markers, excursions are “x” markers and all other data are marked as dots. Parametric (t Test) statistical analyses were performed to determine if significant differences ($p>0.05$) existed between the means of these groups. The results indicate that there were significant differences in the compliant/excursion groups for some t Tests (equal variance). These results include Ln(FCB), pH, Temp_C, Ln(TSS) and the lognormal transformed turbidity Ln(Turb) (**Figures 9, 11, 13, 15 and 16, respectively**). Ammonia (**Figure 7**) showed a significant difference for the unequal variance t Test. A non-parametric (Wilcoxon/ Kuskal-Wallis Test) statistical analysis was performed for each of these parameters. The Temp_C, Ln(TSS) and Ln(Turb) test results were significant. The non-parametric analysis for Ln(FCB) (**Figure 9**) is a borderline, yet not significant, result from this comparison.

Samples collected from May 2004 to July 2006 tended to support these relationships. Of the 14 samples taken recently, only the most recent had a DO violation. This might be attributable to the low flows and high temperatures occurring during Summer 2006. Conditions in July 2006 had higher ammonia, lower pH, lower TSS and Turbidity. Total Organic Carbon is now collected in place of BOD and it was higher in July 2006 than over 2004-2006. Additionally, E coli bacteria are collected instead of Fecal Coliform Bacteria; those values were lower in July than over 2004-2006. The low TSS and bacteria numbers seem to reflect the lack of any runoff or sustained flows in July, which combined with the warm temperatures and any possible introduction of organic material (grass clippings, etc) could trigger a deficient DO condition.

Table 2

COL_DATE	Season	Group	DO	NH3	BOD	FCB	N	pH	K	TEMP_C	P	TSS	TURB	Flow
5/2/1990	SPR	Compliant	8.4	0.010	4.00	100	0.59	8.0	5.400	12	0.320	48	22.0	7.6
7/11/1990	**SPR**	**Exceed**	**3.5**	**0.130**	**2.40**	**200**		**8.0**	**5.880**	**27**	**0.190**	**46**	**32.3**	**8.0**
9/5/1990	S-F	Compliant	7.9	0.020	1.60	10	0.00	8.1	6.060	28	0.090	26	20.4	4.2
11/7/1990	WINT	Compliant	8.1	0.020	4.30	13000	1.18	7.6	5.360	4	0.470	76	58.4	5.1
2/6/1991	WINT	Compliant	10.8	1.200	3.90		1.09	7.4	5.850	0	0.520	20	23.0	8.3
4/3/1991	SPR	Compliant	7.0	0.270	2.20	540	0.97	7.7	5.520	12	0.360	39	27.5	4.9
6/12/1991	**SPR**	**Exceed**	**4.7**	**0.160**	**4.00**	**13000**	**1.20**	**7.6**	**6.620**	**22**	**0.370**	**228**	**237.0**	**22.6**
8/14/1991	S-F	Compliant	11.5	0.000	6.00	300	0.02	9.0	4.930	23	0.150	25	13.1	2.0
10/16/1991	**S-F**	**Exceed**	**4.1**	**0.000**	**5.30**	**5000**	**0.44**	**7.3**	**6.660**	**13**	**0.170**	**45**	**26.5**	**1.1**
1/22/1992	WINT	Compliant	16.8	0.120	5.40	100	1.39	8.4	6.320	3	1.000	12	10.3	3.4
3/4/1992	WINT	Compliant	8.0	0.200	4.60	100	0.95	8.0	5.340	13	0.550	38	17.5	6.9
7/29/1992	SPR	Compliant	6.2	0.070	3.50	1600	0.72	7.9	4.970	24	0.350	34	22.0	25.9
9/9/1992	**S-F**	**Exceed**	**4.1**	**0.180**	**3.40**	**100**	**0.02**	**8.0**	**7.620**	**12**	**0.200**	**41**	**26.8**	**10.1**
12/2/1992	WINT	Compliant	12.7	0.150	2.50	10	1.33	7.9	3.080	0	0.320	8	6.0	19.4
2/3/1993	WINT	Compliant	11.7	0.160	5.40	680	0.84	8.0	4.510	3	0.230	41	22.0	85.2
4/7/1993	SPR	Compliant	9.9	0.330	5.50	28000	0.88	7.5	4.010	7	0.190	30	17.5	143.3
5/26/1993	SPR	Compliant	9.5	0.090	2.90	500	0.47	7.9	3.410	17	0.140	24	11.0	22.2
7/21/1993	SPR	Compliant	5.0	0.100	4.90	9600	0.62	7.5	4.380	23	0.270	80	117.0	584.5
9/22/1993	S-F	Compliant	7.2	0.050	2.00	300	0.49	7.5	3.000	18	0.180	27	18.0	427.6
11/30/1993	WINT	Compliant	12.5	0.110	4.10	10	1.52	7.6	5.490	2	0.360	4	4.0	11.8
4/20/1994	SPR	Compliant	8.7	0.050	4.70	20	0.72	8.1	5.580	13	0.190	24	15.8	8.6
8/17/1994	S-F	Compliant	5.4	0.150	7.30	130	0.01	7.5	4.794	21	0.150	46	21.0	3.4
10/26/1994	S-F	Compliant	8.0	0.030	4.10	40	0.01	8.0	7.240	10	0.110	46	15.0	2.2
12/28/1994	WINT	Compliant	10.2	0.050	2.70	10	2.00	7.6	5.395	1	0.300	12	5.0	4.7
3/8/1995	WINT	Compliant	12.3	0.200	6.10	500	0.68	7.6	3.974	1	0.350	42	32.0	5.4
5/3/1995	SPR	Compliant	9.0	0.110	3.00	500	0.45	7.8	5.063	12	0.160	54	26.0	25.5
7/5/1995	SPR	Compliant	5.6	0.110	4.90	13800	0.46	7.6	2.980	19	0.260	120	23.0	375.9
9/6/1995	S-F	Compliant	7.5	0.088	4.30	100	0.45	7.7	4.090	24	0.122	33	18.0	9.1
11/1/1995	WINT	Compliant	9.0	0.112	3.00	10	0.11	7.8	6.696	8	0.143	26	6.0	6.1
4/3/1996	SPR	Compliant	7.6	0.173	4.40	37	0.76	6.9	5.485	9	0.450	62	32.0	8.0
6/5/1996	SPR	Compliant	8.0	0.122	4.70	4400	0.58	7.4	5.027	12	0.261	172	59.0	27.1
8/7/1996	S-F	Compliant	9.2	0.046	5.10	160	0.38	8.6	4.902	25	0.101	24	12.0	4.6
10/2/1996	S-F	Compliant	7.1	0.216	2.60	210	0.66	7.9	4.646	16	0.190	30	18.0	5.4
12/23/1996	WINT	Compliant	15.0	0.089	4.68	10	0.58	7.9	6.045	2	0.105	6	4.0	12.7
1/22/1997	WINT	Compliant	12.7	0.783	1.00	30	0.64	7.5	6.455	1	0.117	7	2.0	14.6
3/26/1997	WINT	Compliant	9.2	0.020	6.12	10	0.25	7.9	4.228	11	0.220	48	21.0	11.4
3/26/1997	WINT	Compliant	9.2	0.020	4.35	10	0.23	7.9	4.266	11	0.250	41	19.0	11.4
5/28/1997	SPR	Compliant	6.2	0.349	5.16	2400	0.91	7.3	4.158	15	0.262	132	88.0	14.5
7/30/1997	**SPR**	**Exceed**	**2.5**	**0.247**	**2.70**	**2700**	**0.50**	**7.1**	**4.973**	**25**	**0.258**	**132**	**123.0**	**4.9**
9/24/1997	S-F	Compliant	6.7	0.040	2.73	3200	0.64	7.6	3.440	18	0.210	84	46.0	2.4
11/25/1997	WINT	Compliant	13.0	0.021	2.04	40	0.27	7.9	7.932	5	0.573	14	11.0	3.2
2/25/1998	WINT	Compliant	10.9	0.076	2.07	10	0.13	7.8	4.511	10	0.256	39	17.0	10.8
4/29/1998	SPR	Compliant	8.5	0.351	3.39	2200	1.28	7.5	4.245	11	0.174	43	21.0	15.3
6/24/1998	**SPR**	**Exceed**	**3.2**	**0.199**	**2.07**	**3600**	**0.60**	**7.0**	**4.308**	**27**	**0.282**	**114**	**55.0**	**54.4**
8/26/1998	S-F	Compliant	7.6	0.044	1.65	490	0.08	8.0	6.266	28	0.142	43	16.0	6.1
10/28/1998	S-F	Compliant	8.1	0.020	1.00	220	0.25	7.8	5.209	18	0.203	30	11.0	15.8
2/24/1999	WINT	Compliant	12.8	0.151	3.75	150	0.45	7.5	4.436	2	0.196	15	8.0	19.6
4/28/1999	SPR	Compliant	9.2	0.040	3.42	4500	0.75	7.5	3.091	13	0.179	72	40.0	523.1
6/23/1999	SPR	Compliant	5.5	0.030	3.06	5900	0.61	7.5	3.076	23	0.340	76	47.0	240.9
8/25/1999	**S-F**	**Exceed**	**4.8**	**0.140**	**1.86**	**220**	**0.37**	**7.2**	**6.539**	**24**	**0.200**	**45**	**17.0**	**4.7**
10/27/1999	S-F	Compliant	9.2	0.087	1.62	40	0.18	7.5	8.068	12	0.273	30	12.0	3.6
12/28/1999	WINT	Compliant	11.5	0.421	2.01	10	0.92	7.2	5.795	3	0.332	14	8.1	4.4
3/29/2000	WINT	Compliant	9.4	0.020	2.49	20	0.11	8.1	3.868	12	0.200	46	17.0	9.8
5/24/2000	SPR	Compliant	6.3	0.110	3.03	150	0.40	7.8	7.296	24	0.250	41	17.0	4.6
7/26/2000	SPR	Compliant	5.1	0.020	3.21	210	0.01	7.5	6.339	23	0.160	50	23.0	4.2
9/27/2000	S-F	Compliant	7.2	0.030	1.86	1100	0.58	7.6	4.620	15	0.310	35	24.0	1.7
11/20/2000	WINT	Compliant	11.6	0.151	1.17	10	0.89	7.8	5.680	1	0.246	18	7.1	2.1
2/21/2001	WINT	Compliant	12.8	0.265	3.03	10	1.87	7.9	6.308	1	0.209	10	6.3	25.8
4/25/2001	SPR	Compliant	8.6	0.030	1.70	760	0.44	7.8	3.873	14	0.166	66	36.5	17.9
6/27/2001	SPR	Compliant	7.6	0.020	2.52	390	0.35	7.7	4.193	25	0.149	31	10.0	10.1
8/29/2001	S-F	Compliant	6.5	0.020	2.91	1400	0.38	7.6	4.630	25	0.221	62	32.0	7.3
10/24/2001	S-F	Compliant	8.8	0.020	1.00	70	0.34	7.7	4.449	16	0.202	20	4.2	10.3
12/26/2001	WINT	Compliant	16.0	0.020	2.43	10	0.11	8.3	5.934	2	0.430	10	6.4	4.7
3/28/2002	WINT	Compliant	12.5	0.100	No Data	10	0.10	8.2	5.460	9	0.444	34	16.0	6.3
5/30/2002	SPR	Compliant	5.8	0.200	No Data	900	0.42	7.7	4.009	22	0.252	61	32.0	16.5
7/31/2002	SPR	Compliant	6.3	0.100	No Data	10000	0.34	7.8	6.771	28	0.283	34	12.0	3.8
9/26/2002	S-F	Compliant	7.8	0.100	No Data	1050	0.21	7.9	4.725	19	0.295	66	29.5	2.4
11/26/2002	WINT	Compliant	11.0	0.100	No Data	10	0.10	7.8	9.173	3	0.461	11	4.9	4.7
2/5/2003	WINT	Compliant	12.0	0.100	No Data	50	1.42	7.5	12.152	3	0.676	22	5.9	3.4
4/2/2003	SPR	Compliant	14.0	0.100	No Data	10	0.10	8.0	7.361	17	0.167	48	19.0	4.2
6/4/2003	SPR	Compliant	6.7	0.100	No Data	8000	0.64	7.2	3.435	22	0.198	54	26.0	8.6
8/6/2003	**S-F**	**Exceed**	**4.3**	**0.100**	**No Data**	**No Data**	**0.10**	**7.9**	**6.032**	**27**	**0.176**	**56**	**22.4**	**0.6**
10/8/2003	S-F	Compliant	5.2	0.100	No Data	No Data	0.28	8.3	4.488	19	0.220	25	17.2	0.7
12/29/2003	WINT	Compliant	10.7	0.101	No Data	No Data	1.21	7.7	7.616	4	0.391	18	16.9	1.5
1/7/2004	WINT	Compliant	16.9	0.100	No Data	No Data	0.86	7.9	9.188	2	0.505	10	4.8	1.4
3/2/2004	WINT	Compliant	9.9	0.100	No Data	No Data	0.53	7.6	4.924	6	0.196	110	133.0	15.8

Oneway Analysis of Ln (Flow) By Group



Summary of Fit

Rsquare	0.011585
Adj Rsquare	-0.00177
Root Mean Square Error	1.414546
Mean of Response	2.221232
Observations (or Sum Wgts)	76

t Test

Assuming equal variances

	Difference	t Test	DF	Prob > |t|
Estimate	0.492405	0.931	74	0.3547
Std Error	0.528718			
Lower 95%	-0.56109			
Upper 95%	1.545899			

UnEqual Variances

	Difference	t Test	DF	Prob > |t|
Estimate	0.4924	0.896	8.56685	0.3945
Std Error	0.5493			
Lower 95%	-0.7129			
Upper 95%	1.6977			

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	1	1.73552	1.73552	0.8674	0.3547
Error	74	148.06949	2.00094		
C. Total	75	149.80502			

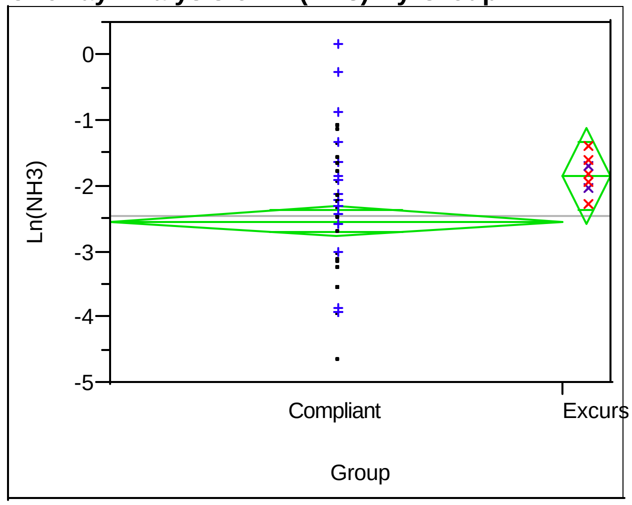
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Compliant	68	2.27306	0.17154	1.9313	2.6149
Excursion	8	1.78066	0.50012	0.7842	2.7772

Std Error uses a pooled estimate of error variance

Figure 6

Oneway Analysis of Ln(NH3) By Group



Summary of Fit

Rsquare	0.043315
Adj Rsquare	0.030027
Root Mean Square Error	0.958851
Mean of Response	-2.46106
Observations (or Sum Wgts)	74

t Test

Assuming equal variances

	Difference	t Test	DF	Prob > |t|
Estimate	-0.68767	-1.806	72	0.0752
Std Error	0.38087			
Lower 95%	-1.44693			
Upper 95%	0.07159			

UnEqual Variances

	Difference	t Test	DF	Prob > |t|
Estimate	-0.6877	-4.146	25.1856	0.0003
Std Error	0.1659			
Lower 95%	-1.4718			
Upper 95%	0.0965			

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	1	2.997095	2.99710	3.2599	0.0752
Error	72	66.196489	0.91940		
C. Total	73	69.193585			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Compliant	67	-2.5261	0.11714	-2.760	-2.293
Excursion	7	-1.8384	0.36241	-2.561	-1.116

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Compliant	67	2391	35.6866	-2.244
Excursion	7	384	54.8571	2.244

2-Sample Test, Normal Approximation

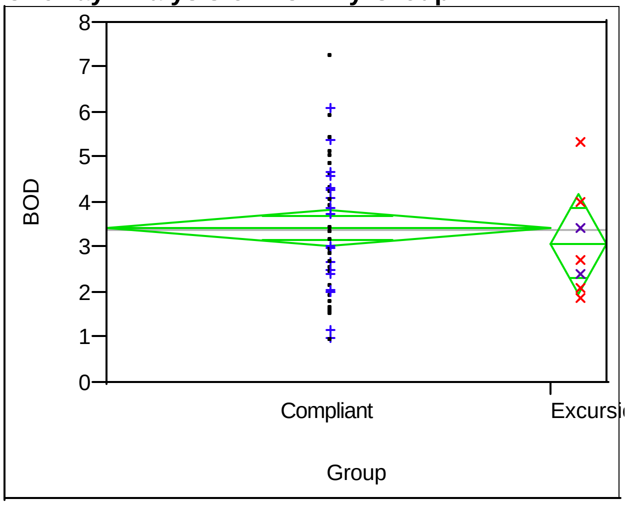
S	Z	Prob>|Z|
384	2.24386	0.0248

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
5.0766	1	0.0243

Figure 7

Oneway Analysis of BOD By Group



Summary of Fit

Rsquare	0.005532
Adj Rsquare	-0.01077
Root Mean Square Error	1.472366
Mean of Response	3.409921
Observations (or Sum Wgts)	63

t Test

Assuming equal variances

	Difference	t Test	DF	Prob > |t|
Estimate	0.343839	0.583	61	0.5624
Std Error	0.590259			
Lower 95%	-0.83646			
Upper 95%	1.524136			

UnEqual Variances

	Difference	t Test	DF	Prob > |t|
Estimate	0.3438	0.682	8.42149	0.5134
Std Error	0.5040			
Lower 95%	-1.0055			
Upper 95%	1.6932			

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	1	0.73563	0.73563	0.3393	0.5624
Error	61	132.23950	2.16786		
C. Total	62	132.97512			

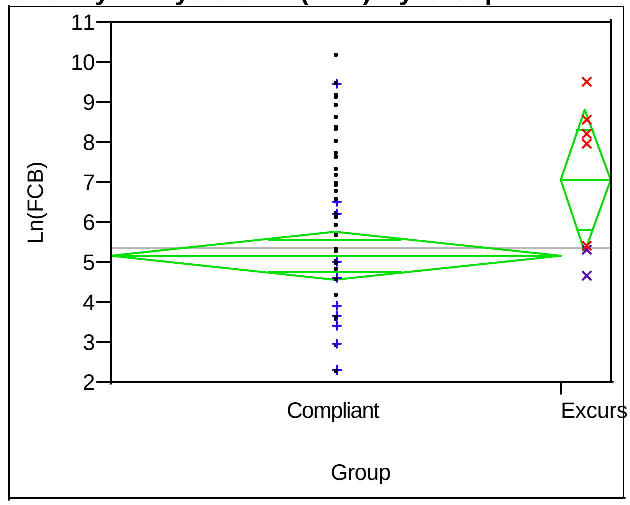
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Compliant	56	3.44812	0.19675	3.0547	3.8416
Excursion	7	3.10429	0.55650	1.9915	4.2171

Std Error uses a pooled estimate of error variance

Figure 8

Oneway Analysis of Ln(FCB) By Group



Summary of Fit

Rsquare	0.056069
Adj Rsquare	0.042187
Root Mean Square Error	2.342303
Mean of Response	5.365866
Observations (or Sum Wgts)	70

t Test

Assuming equal variances

	Difference	t Test	DF	Prob > |t|
Estimate	-1.8755	-2.010	68	0.0484
Std Error	0.9332			
Lower 95%	-3.7377			
Upper 95%	-0.0133			

UnEqual Variances

	Difference	t Test	DF	Prob > |t|
Estimate	-1.8755	-2.402	8.23164	0.0422
Std Error	0.7809			
Lower 95%	-4.0170			
Upper 95%	0.2660			

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	1	22.16024	22.1602	4.0391	0.0484
Error	68	373.07413	5.4864		
C. Total	69	395.23438			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Compliant	63	5.17832	0.29510	4.5894	5.7672
Excursion	7	7.05382	0.88531	5.2872	8.8204

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Compliant	63	2138	33.9365	-1.931
Excursion	7	347	49.5714	1.931

2-Sample Test, Normal Approximation

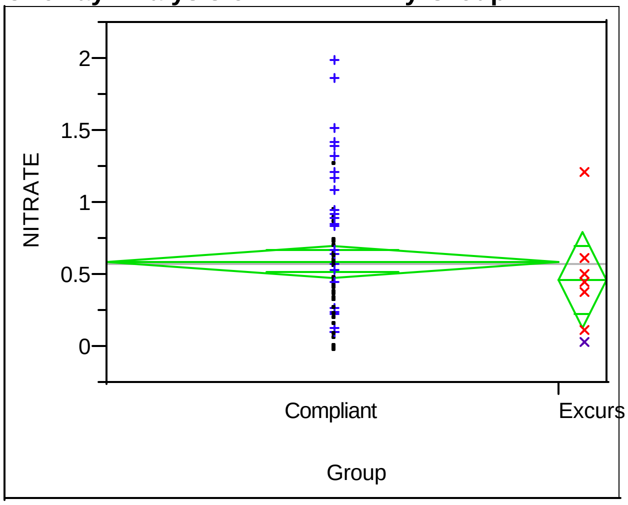
S	Z	Prob>|Z|
347	1.93063	0.0535

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
3.7654	1	0.0523

Figure 9

Oneway Analysis of NITRATE By Group



Summary of Fit

Rsquare	0.007283
Adj Rsquare	-0.00632
Root Mean Square Error	0.44616
Mean of Response	0.578933
Observations (or Sum Wgts)	75

t Test

Assuming equal variances

	Difference	t Test	DF	Prob > |t|
Estimate	0.129601	0.732	73	0.4666
Std Error	0.177100			
Lower 95%	-0.22336			
Upper 95%	0.482560			

UnEqual Variances

	Difference	t Test	DF	Prob > |t|
Estimate	0.12960	0.829	7.7778	0.4317
Std Error	0.15631			
Lower 95%	-0.28083			
Upper 95%	0.54003			

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	1	0.106601	0.106601	0.5355	0.4666
Error	73	14.531314	0.199059		
C. Total	74	14.637915			

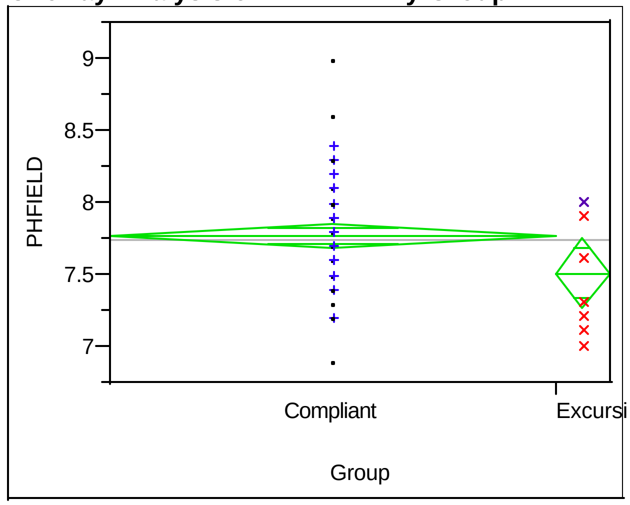
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Compliant	68	0.591029	0.0541	0.48320	0.69886
Excursion	7	0.461429	0.1686	0.12534	0.79751

Std Error uses a pooled estimate of error variance

Figure 10

Oneway Analysis of PHFIELD By Group



Summary of Fit

Rsquare	0.052219
Adj Rsquare	0.039411
Root Mean Square Error	0.33807
Mean of Response	7.740789
Observations (or Sum Wgts)	76

t Test

Assuming equal variances

	Difference	t Test	DF	Prob > |t|
Estimate	0.255147	2.019	74	0.0471
Std Error	0.126361			
Lower 95%	0.003367			
Upper 95%	0.506928			

UnEqual Variances

	Difference	t Test	DF	Prob > |t|
Estimate	0.25515	1.676	8.06542	0.1320
Std Error	0.15224			
Lower 95%	-0.03583			
Upper 95%	0.54613			

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	1	0.4659791	0.465979	4.0771	0.0471
Error	74	8.4575735	0.114292		
C. Total	75	8.9235526			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Compliant	68	7.76765	0.04100	7.6860	7.8493
Excursion	8	7.51250	0.11953	7.2743	7.7507

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Compliant	68	2700.5	39.7132	1.397
Excursion	8	225.5	28.1875	-1.397

2-Sample Test, Normal Approximation

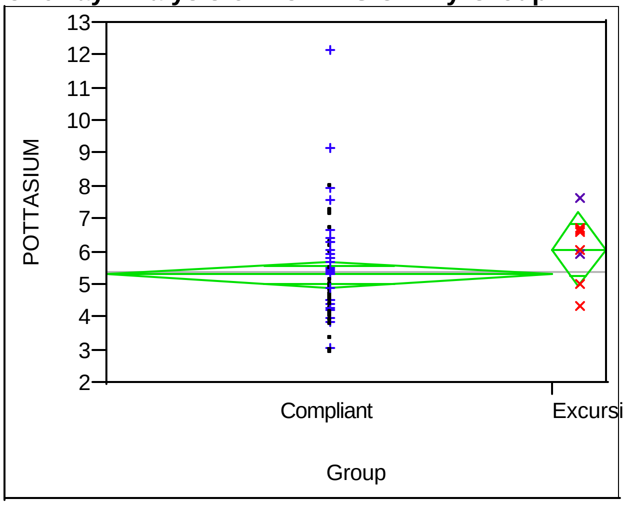
S	Z	Prob>|Z|
225.5	-1.39736	0.1623

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
1.9765	1	0.1598

Figure 11

Oneway Analysis of POTTASIUM By Group



Oneway Anova

Summary of Fit

Rsquare	0.021918
Adj Rsquare	0.008701
Root Mean Square Error	1.593414
Mean of Response	5.392717
Observations (or Sum Wgts)	76

t Test

Assuming equal variances

	Difference	t Test	DF	Prob > |t|
Estimate	-0.76695	-1.288	74	0.2018
Std Error	0.59557			
Lower 95%	-1.95366			
Upper 95%	0.41976			

UnEqual Variances

	Difference	t Test	DF	Prob > |t|
Estimate	-0.7670	-1.830	11.5619	0.0931
Std Error	0.4191			
Lower 95%	-2.0701			
Upper 95%	0.5362			

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	1	4.21039	4.21039	1.6583	0.2018
Error	74	187.88355	2.53897		
C. Total	75	192.09394			

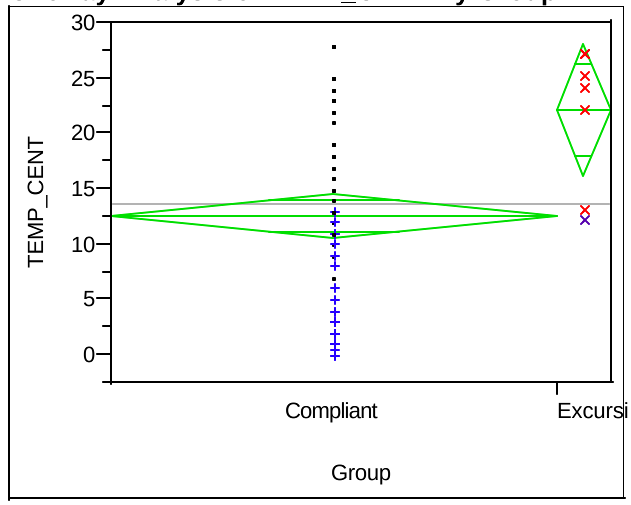
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Compliant	68	5.31199	0.19323	4.9270	5.6970
Excursion	8	6.07894	0.56336	4.9564	7.2015

Std Error uses a pooled estimate of error variance

Figure 12

Oneway Analysis of TEMP_CENT By Group



Oneway Anova

Summary of Fit

Rsquare	0.112234
Adj Rsquare	0.100237
Root Mean Square Error	8.36121
Mean of Response	13.57237
Observations (or Sum Wgts)	76

t Test

Assuming equal variances

	Difference	t Test	DF	Prob > |t|
Estimate	-9.5588	-3.059	74	0.0031
Std Error	3.1252			
Lower 95%	-15.7859			
Upper 95%	-3.3317			

UnEqual Variances

	Difference	t Test	DF	Prob > |t|
Estimate	-9.559	-3.943	10.4359	0.0025
Std Error	2.424			
Lower 95%	-16.483			
Upper 95%	-2.635			

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	1	654.0248	654.025	9.3553	0.0031
Error	74	5173.3272	69.910		
C. Total	75	5827.3520			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Compliant	68	12.5662	1.0139	10.546	14.587
Excursion	8	22.1250	2.9561	16.235	28.015

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Compliant	68	2446.5	35.9779	-2.898
Excursion	8	479.5	59.9375	2.898

2-Sample Test, Normal Approximation

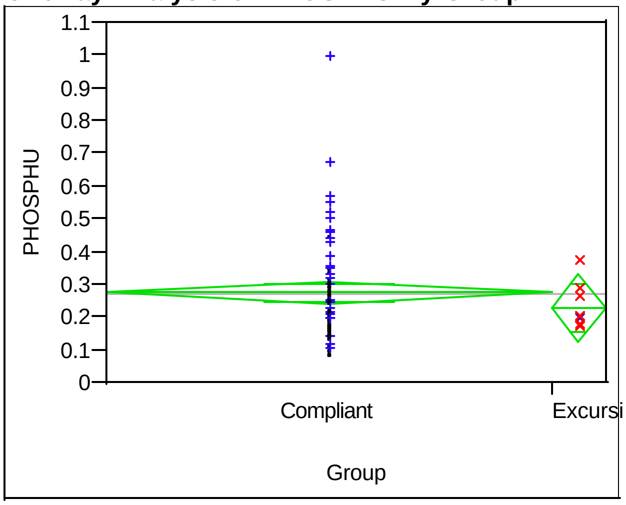
S	Z	Prob>|Z|
479.5	2.89780	0.0038

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
8.4464	1	0.0037

Figure 13

Oneway Analysis of PHOSPHU By Group



Oneway Anova

Summary of Fit

Rsquare	0.008793
Adj Rsquare	-0.0046
Root Mean Square Error	0.148545
Mean of Response	0.271
Observations (or Sum Wgts)	76

t Test

Assuming equal variances

	Difference	t Test	DF	Prob > |t|
Estimate	0.044985	0.810	74	0.4204
Std Error	0.055522			
Lower 95%	-0.06565			
Upper 95%	0.155616			

UnEqual Variances

	Difference	t Test	DF	Prob > |t|
Estimate	0.04499	1.467	17.1907	0.1605
Std Error	0.03067			
Lower 95%	-0.07206			
Upper 95%	0.16203			

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	1	0.0144853	0.014485	0.6565	0.4204
Error	74	1.6328647	0.022066		
C. Total	75	1.6473500			

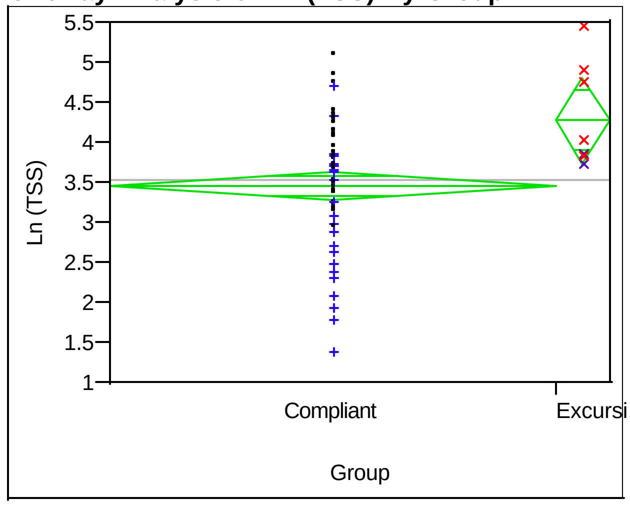
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Compliant	68	0.275735	0.01801	0.23984	0.31163
Excursion	8	0.230750	0.05252	0.12610	0.33540

Std Error uses a pooled estimate of error variance

Figure 14

Oneway Analysis of Ln (TSS) By Group



Oneway Anova

Summary of Fit

Rsquare	0.10342
Adj Rsquare	0.091304
Root Mean Square Error	0.750385
Mean of Response	3.544354
Observations (or Sum Wgts)	76

t Test

Assuming equal variances

	Difference	t Test	DF	Prob > |t|
Estimate	-0.81944	-2.922	74	0.0046
Std Error	0.28047			
Lower 95%	-1.37829			
Upper 95%	-0.26058			

UnEqual Variances

	Difference	t Test	DF	Prob > |t|
Estimate	-0.8194	-3.320	9.42957	0.0084
Std Error	0.2468			
Lower 95%	-1.4495			
Upper 95%	-0.1893			

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	1	4.806345	4.80635	8.5359	0.0046
Error	74	41.667704	0.56308		
C. Total	75	46.474049			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Compliant	68	3.45810	0.09100	3.2768	3.6394
Excursion	8	4.27753	0.26530	3.7489	4.8062

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Compliant	68	2459.5	36.1691	-2.675
Excursion	8	466.5	58.3125	2.675

2-Sample Test, Normal Approximation

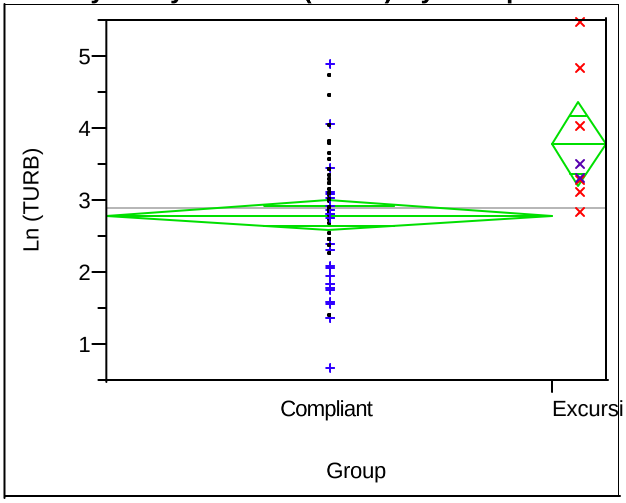
S	Z	Prob>|Z|
466.5	2.67535	0.0075

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
7.2029	1	0.0073

Figure 15

Oneway Analysis of Ln (TURB) By Group



Summary of Fit

Rsquare	0.120889
Adj Rsquare	0.109009
Root Mean Square Error	0.823755
Mean of Response	2.905012
Observations (or Sum Wgts)	76

t Test

Assuming equal variances

	Difference	t Test	DF	Prob > |t|
Estimate	-0.98218	-3.190	74	0.0021
Std Error	0.30790			
Lower 95%	-1.59568			
Upper 95%	-0.36869			

UnEqual Variances

	Difference	t Test	DF	Prob > |t|
Estimate	-0.9822	-2.895	8.34455	0.0192
Std Error	0.3393			
Lower 95%	-1.6871			
Upper 95%	-0.2772			

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	1	6.905111	6.90511	10.1759	0.0021
Error	74	50.214348	0.67857		
C. Total	75	57.119459			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Compliant	68	2.80162	0.09989	2.6026	3.0007
Excursion	8	3.78381	0.29124	3.2035	4.3641

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
Compliant	68	2449.5	36.0221	-2.844
Excursion	8	476.5	59.5625	2.844

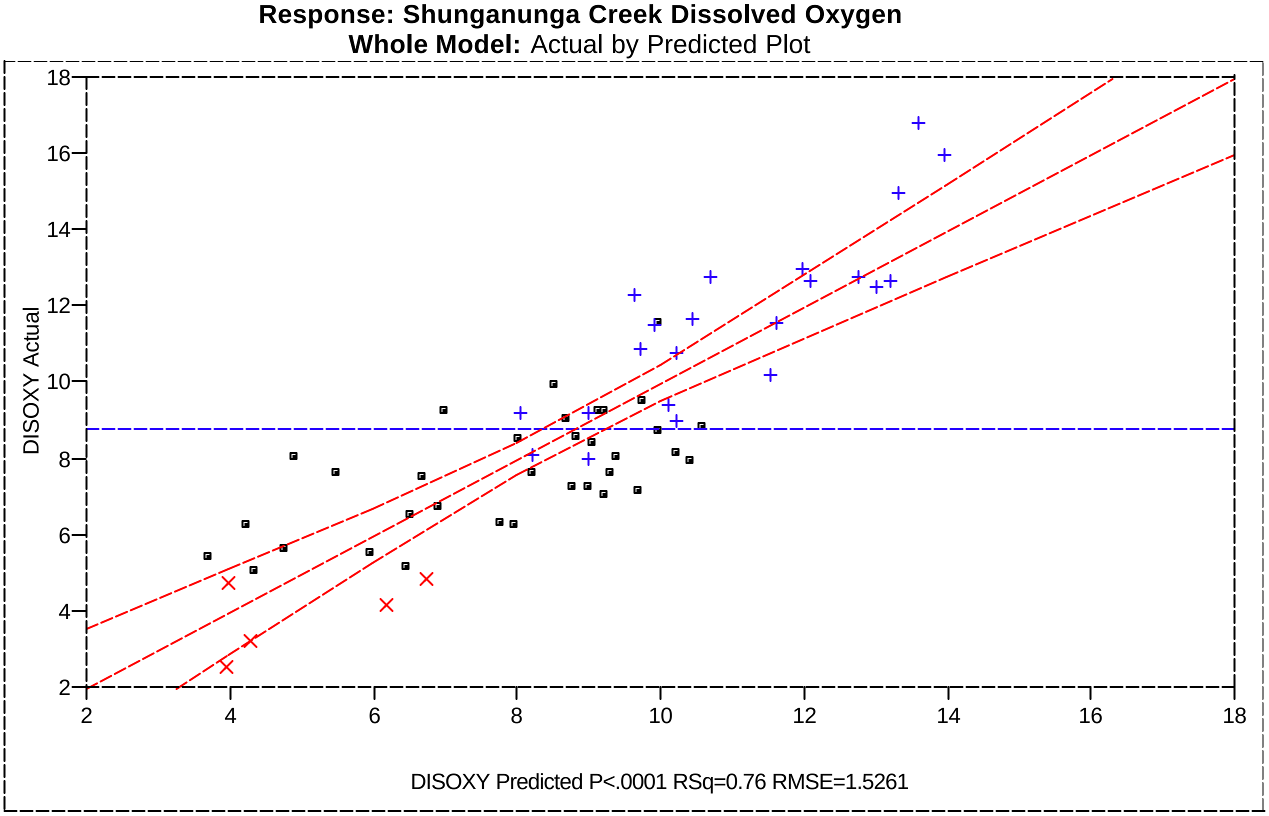
2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
476.5	2.84448	0.0044

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
8.1393	1	0.0043

Figure 16



Summary of Fit

RSquare	0.755023
RSquare Adj	0.74213
Root Mean Square Error	1.526124
Mean of Response	8.77459
Observations (or Sum Wgts)	61

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	409.15699	136.386	58.5584
Error	57	132.75613	2.329	Prob > F
C. Total	60	541.91311		<.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-8.804593	5.384572	-1.64	0.1075
pH	3.1842842	0.631826	5.04	<.0001
Ln (TSS)	-1.518216	0.320627	-4.74	<.0001
BOD_TEMP	-0.036308	0.006937	-5.23	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
pH	1	1	59.157356	25.3997	<.0001
Ln (TSS)	1	1	52.221303	22.4217	<.0001
BOD_TEMP	1	1	63.809540	27.3972	<.0001

Figure 17

A multiple regression was built to predict DO from the available sample data in Table 2. Parameter pairs were also crossed and their value to the regression was explored. The results of this regression model are shown in **Figure 17** below. This model indicates the best predictors of DO from the parameters in Table 2 were pH, TSS and the cross of BOD and temperature. Multivariate outlier analysis (Jackknife distances) indicates five outliers in the data. These outliers have been removed from the Figure 17 model. Sample dates removed from the analysis were 7/11/90, 12/11/91, 5/27/92, 9/9/92 and 6/22/94 (Table 2). All probable outliers in the data were collected early during the sampling period, which most likely indicates some kind difference or change in the watershed from the norm for the model.

The model in Figure 17 suggests that when water temperatures, BOD and TSS are high and when pH is low in Shunganunga Creek DO excursions can result. In addition to the seasonal impact of higher water temperatures, the importance of pH in the model is probably an indication of the biological activity in the creek and its resulting impact on DO. The BOD and TSS value to the model is likely an indication of an excessive organic/oxygen demanding substance load in the stream.

The model in Figure 17 was used to set the BOD targets for the watershed. Figure 18 illustrates how this was accomplished. Using the highest sampled temperature, average pH, and the same TSS range as that of the DO excursion data with a DO target of 5.0 mg/L the model prediction equation, **DO = -8.8 + 3.18 pH – 1.52 Ln(TSS) – 0.036 BOD*Temp_C**, was solved for BOD resulting in a range of BOD targets by Ln(TSS). Using the same prediction equation where DO is 5.5, to incorporate a margin of safety (MOS) in the prediction, a Temp_C of 27, a median pH of 7.25 and the average of the Ln(TSS) for the DO excursion data yields a target BOD of 2.1 mg/L under these conservative stream conditions. Since DO excursions have occurred only under warmer stream temperature condition in the Shunganunga Creek watershed this BOD target will only apply for the Spring and Summer-Fall seasons. The Winter BOD target was found by using the minimum pH value for the Winter seasons samples, and the maximum temperature and Ln(TSS) values for that season. DO was again set at 5.5 mg/L (for an explicit 10% MOS) and the result yielded a Winter BOD target of 4.8 mg/L.

Desired Endpoints of Water Quality (Implied Load Capacity) at Site 238 over 2010 – 2014

The ultimate endpoint for this TMDL will be to achieve the Kansas Water Quality Standard of 5 mg/l to fully support Aquatic Life. Seasonal variation is accounted for by this TMDL, since the TMDL endpoint is sensitive to stream temperature, with the highest temperatures usually occurring in the Spring and Summer-Fall seasons.

This endpoint will be reached as a result of expected, though unspecified, improvements in tributary buffer strip conditions, which will filter organic laden sediment before reaching the stream, and stream morphology assessments, which will be used to determine if enhancement to re-aeration of flow within the stream is needed. Improvements to buffer strip conditions will result from implementation of corrective actions and Best Management Practices, as directed by this TMDL. Achievement of this endpoint will provide full support of the aquatic life function of the creek and attain the dissolved oxygen water quality standard.

DO = -8.804593 + 3.1842842pH - 1.518216Ln(TSS) - 0.036308 BOD*Temp_C

Parameter	Coef
Int	-8.804593
pH	3.1842842
Ln(TSS)	-1.518216
BOD*Temp_C	-0.036308

BOD where DO = 5, pH = 7.35 (Avg pH of excursions),
TEMP_C = 27 (Max Temp of excursions) and LN(TSS) = 3.8 to 4.9

DO	pH	LN(TSS)	TEMP_C	BOD
5	7.35	3.8	27	3.9
5	7.35	4	27	3.6
5	7.35	4.2	27	3.3
5	7.35	4.4	27	3.0
5	7.35	4.6	27	2.7
5	7.35	4.8	27	2.4

BOD where DO = 5.5 (10% MOS), pH = 7.25 (Median of pH excursions),
TEMP_C = 27 (Max Temp of excursions) and LN(TSS) = 3.8 to 4.9

DO	pH	LN(TSS)	TEMP_C	BOD
5.5	**7.25**	**4.45**	**27**	**2.1**

BOD where DO = 5.5 (10% MOS), pH = 7.2 (Min. pH of Winter samples),
TEMP_C = 13 (Max. Temp of Winter samples) and LN(TSS) = 4.2 (Max. of Winter Samples)

DO	pH	LN(TSS)	TEMP_C	BOD
5.5	**7.2**	**4.2**	**13**	**4.8**

Excursion TSS	LN(TSS)
46	3.828641396
228	5.429345629
132	4.882801923
114	4.736198448
45	3.80666249
55.5	4.016383021
Avg	4.450005484
Geo Mean	85.62741362

Excursion	pH
	7.6
	7.3
	7.1
	7
	7.2
	7.9
Avg	7.35
Median	7.25

Excursion	TempC
	27
	24
	27
	25
	22
	13
Avg	23

Figure 18

This TMDL will be staged. Although BOD samples are no longer collected from the KDHE stream compliance network, the targets at Site 238 on Shunganunga Creek in Stage I will be framed around BOD reductions. Once sufficient TOC samples are collected for intra-watershed comparison purposes at Site 238, the BOD targets for this TMDL will be revised to TOC targets for Stage II. Therefore, to prevent further organic loading that might offset the benefits of future watershed and stream corridor improvements, the BOD targets will be to reduce in stream BOD at sampling site 238 under higher stream temperature conditions. This target was calculated from the multiple regression equation using BOD, temperature, pH and TSS as predictors for DO and incorporates an explicit margin of safety (MOS) in the target.

3. SOURCE INVENTORY AND ASSESSMENT

NPDES: There are two active NPDES municipal permitted wastewater dischargers within the watershed (**Figure 19**), both of which could contribute an organic/nutrient substance load to monitoring Site 238 in the Shunganunga Creek watershed. Both systems are outlined in **Table 3** below. Expansion and extension of Topeka's wastewater system has caused historic dischargers such as Shawnee County MSD's #8 and #33 and Frito-Lay, to hook into the city's sewer system and discontinue their discharges. Some of these facilities may have been the cause of dissolved oxygen problems in the past. Only one problem has arisen at Site 238 since 2004 and it can be linked to the extreme dry, hot conditions during 2006.

The East Side Baptist Church facility shown in Figure 19 has a non-discharging one cell lagoon systems that may contribute an oxygen demanding substance load to Stinson Creek en route to Shunganunga Creek below the monitoring station and only discharges under extreme precipitation events (stream flows associated with such events are typically exceeded only 1 - 5 % of the time). 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 reported to KDHE.

The Sherwood improvement district relies on a mechanical system (activated sludge) for the treatment of their wastewater. Monthly effluent monitoring reports since 1999 indicate the plant has always been well below their BOD permit limits. The maximum BOD from their reports was 10mg/L and the average BOD for the same period was 3.9 mg/L. The plant was upgraded and placed online in July 2003. Recent data indicate the plant discharges about 1 MGD and under 2 mg/l BOD. The information in Table 3 and Streeter-Phelps model presented shown in **Figure 20** reflect the upgrade. Due to the plant remaining well below BOD permit limits that already protect DO criteria in Shunganunga Creek; this system cannot be considered a cause of the DO problem in the watershed.

The Shawnee Hills Mobile Home WWTP uses an aerated three cell lagoon system for the treatment of their wastewater. Monthly effluent monitoring reports since 1999 indicate the plant is usually below their BOD limits. However, recently, the plant discharges BOD of 29-32 mg/l and during this time period the facility exceeded their BOD limit about 25% of the time. Despite this, Streeter-Phelps analysis (**Figure 20**) indicates that the current permit limit maintains DO levels above 5.0 mg/L in Shunganunga Creek. Appendix A displays the stream segment profile of DO from the confluence of the two wastewater discharges to Site 238.

Table 3. Summary of Shunganunga Creek Watershed NPDES Facilities

Discharging Facility	NPDES Permit # / Federal Permit #	Stream Reach	Segment	Design Flow	Type	Permit Expires
Shawnee Hills Mobile Homes WWTP	C-KS72-OO11 KS0119903	S. Br. Shunganunga Cr	106	0.0153 mgd	Divided Aerated Lagoon	May 31, 2009
Sherwood Improvement District	M-KS72-OO27 KS0117731	Shunganunga Cr	40	2.4 mgd	Trickling Filter	August 31, 2010

Livestock Waste Management Systems: A single operation is certified within the watershed. This facility (small dairy) is located between Stinson and Tecumseh Creeks near the edge of the watershed (**Figure 19**). The facility is not of sufficient size to warrant NPDES permitting. Permitted livestock facilities have waste management systems designed to minimize runoff entering their operations or detaining runoff emanating from their areas. Such systems are designed to retain the 25 year, 24 hour rainfall/runoff event, as well as an anticipated two weeks of normal wastewater from their operations. Such rainfall events typically coincide with stream flows that are exceeded less than 1 - 5 percent of the time. Therefore, events of this type, infrequent and of short duration, are not likely to cause chronic impairment of the designated uses of the waters in this watershed. Requirements for maintaining the water level of the waste lagoons a certain distance below the lagoon berms ensures retention of the runoff from these intense, local storm events. In Shawnee County, such an event would generate 6.1 inches of rain, yielding 4.9 to 5.7 inches of runoff in a day. The watershed's total potential animal units is 220. The actual number of animal units on site is variable, but typically less than potential numbers. Any discharge from the facility would travel down Stinson Creek before entering Shunganunga Creek immediately before entering the Kansas River, all below Site 238.

Land Use: Most of the watershed is urban land and grassland (47.5 and 28.5% of the area, respectively) and cropland (17.5%). Much of the urban land is located along the main stem for most of the watershed (**Figure 21**). According to the NRCS Riparian Inventory, there are approximately 5,350 acres of riparian area in the watershed, most of which is categorized as forest land (34%), crop/tree mix (18%), cropland (13%), pasture/tree mix (8%), pasture land (6%) and shrub/scrub land (4%) (**Figure 21**). Summing those riparian categories with a tree/shrub component shows that two-thirds of the riparian area in the water can contribute leaf material to the organic matter load in the late Summer/Fall, which can lead to DO excursions driven by the decomposition of leaves in the stream under these conditions. However, the more pervasive threat will be urban stormwater. Topeka has several programs in place that should on contribute to restoring the water quality standards to Shunganunga Creek. Chief among them is a buffer ordinance that uses stream buffers as a best management practice with minimum requirements in their design and designated setback widths as a function of stream size along with allowable uses in buffer areas. In conjunction with the buffer ordinance, Topeka has implemented a retrofit program to increase infiltration and meander capacity within buffer zones. Topeka also employs a series of best management practices under its Stormwater Management Plan to improve the quality of runoff entering Shunganunga Creek.

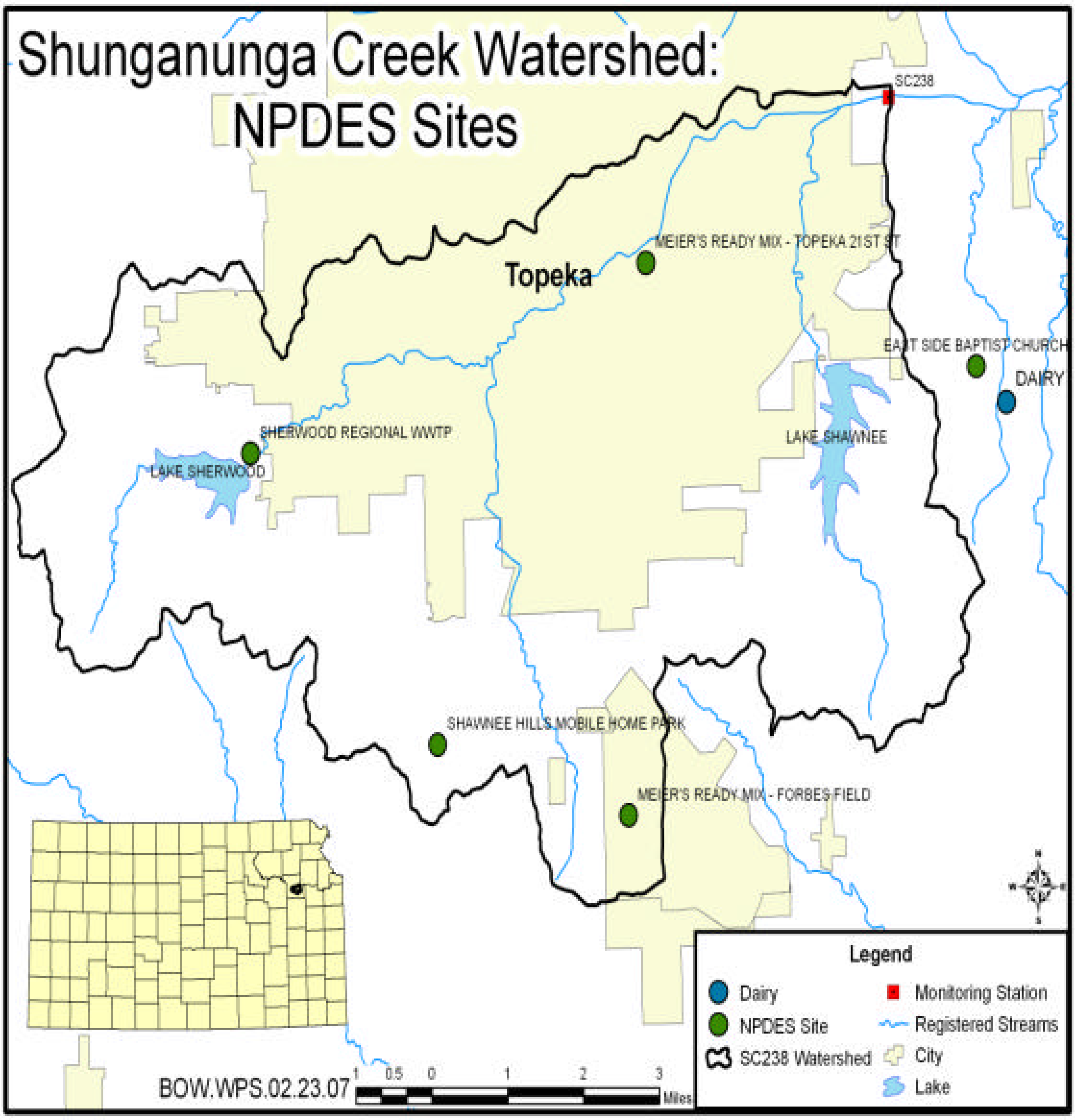


Figure 19

Streeter-Phelps DO Sag Model - Shunganunga_Sherwood_ShawneeCoMHP
Single Reach - Single Load

1 cfs = .0283 m^3/s
0.25 mph =0 .11176 m/s

		Elev (ft)	Dist (km) to Site 238	Min DO	Crit Dist DO
0.1050722	Design Flow (Sherwood)	980	19.15	6.69	0.01
0.0006698	Design Flow (SH Co MHP)	1065	18.50	6.55	0.01
0.1057421	Comb. Design Flows at Confluen	900	11.26	5.91	9.43

Elevation Correction (DO)

Elevation	**900**	ft
Correctn Factor (DO_{sat})	0.9712	mg/L

Unless modified by upstream pt. source, upstream BOD set as target for basin
Upstream DO (where appropriate) elevation corrected and set at 90% sat.

Velocity	0.11176		
BOD coef	0.23	Theta	1.056
O2 coef	(see Calc K_r)	Theta	1.024

Distance (km)
Flow (m^3/s)
Concentration (mg/L)
Temp (C)
Vel (m/s)

		Flow	BOD	DO	T	Dist (km)	Slope (ft.mi)	Calc K_r	
1	**Sherwood Imp Dist**	0.1050722	20	6.69	25	7.88	16.33	4.44	
	Upstream	0	0	0	0	-----			
	Result at Dist (S. Br Shunga' Cr.)	0.10507224	15.63	6.94	25				Elev = 900 ft
2	**SH Co. MHP**	0.0006698	30	6.55	25	7.24	36.67	10.84	
	Upstream	0	0	0	0	-----			
	Result at Dist (Shunga' Cr.)	0.000669836	23.92	6.82	25				Elev = 900 ft
3	S. Br. Shunga' (SH Co. MHP Result)	0.0006698	23.92	6.82	25	11.26	5.57	1.48	
	Upstream (Sherwood Result)	0.10507224	15.63	6.94	25	-----			
	Result at Dist (Site 238)	0.105742076	11.03	5.93	25				Elev = 861 ft

Kr Values (Foree 1977) using	0.42 (0.63 + 0.4S^1.15)
for q < 0.05 where q = cfs/mi^2 and	S (ft/mile)

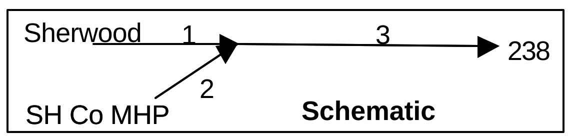


Figure 20

On-Site Waste Systems: The watershed's population density is high (845 persons/sq mi) when compared to densities elsewhere in the Kansas/Lower Republican Basin. The rural population projection for Shawnee County through 2020 shows a marked increase of about 40%. Based on 1990 census data about 13.5% of households in Shawnee County are on septic systems. Failing on-site waste systems can contribute oxygen demanding substance loadings and their impact on the impaired segment may be of importance, given the lack of other sources in the watershed. Topeka has enacted a septic tank elimination program to have dwellings and buildings connect to the public sanitary sewer. As of 2005, 155 houses were identified that Topeka was addressing to connect to its wastewater system.

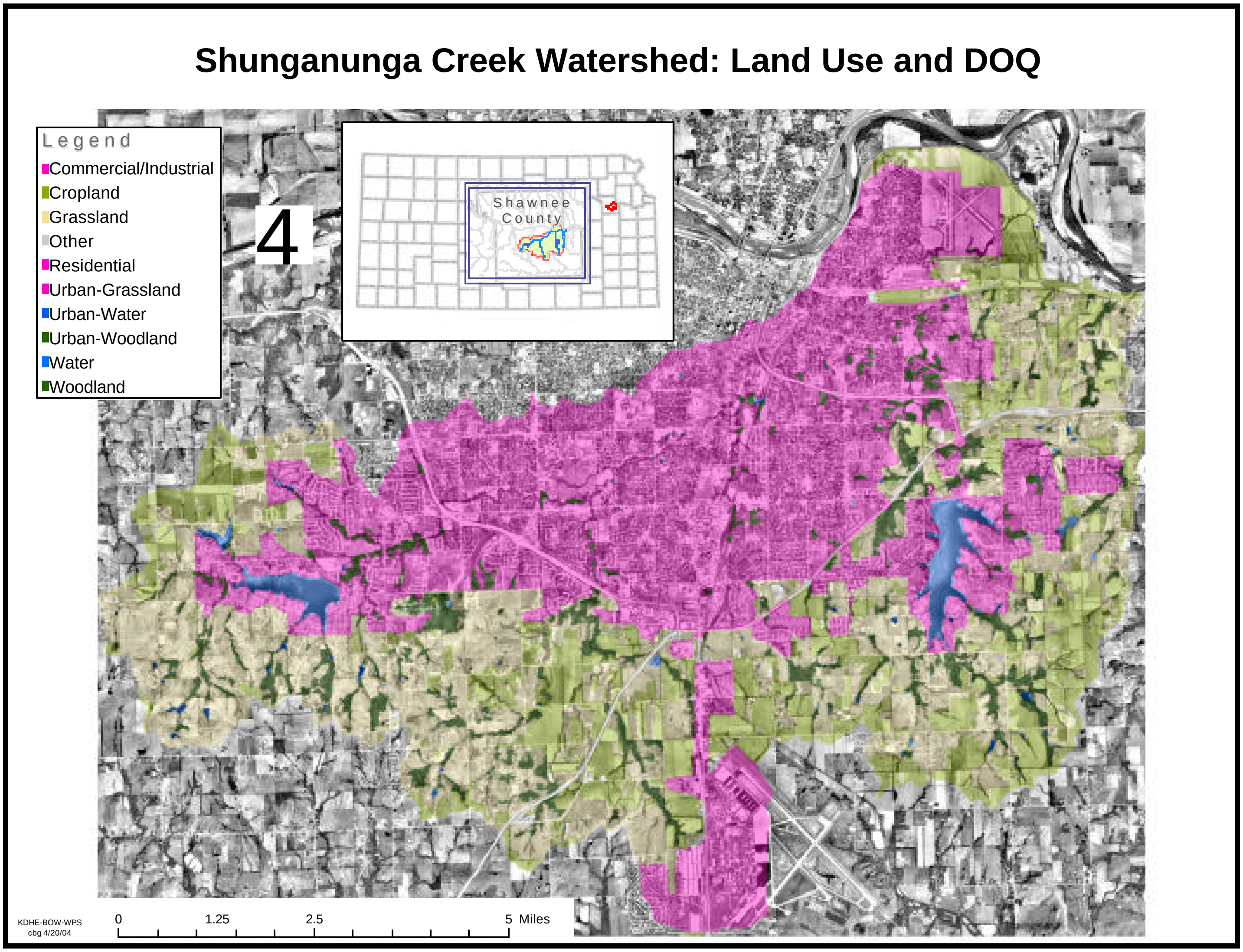


Figure 21

Background Levels: Some organic enrichment may be associated with environmental background levels, including contributions from wildlife and stream side vegetation. It is likely that the density of animals such as deer is fairly dispersed across the rural portion of the watershed and that the loading of oxygen demanding material is greater along the streams in this area. In the case of wildlife, this loading should result in minimal loading to the streams below the levels necessary to violate the water quality standards. In the case of streamside vegetation, the loading should also be greatest along stream segments of the watershed outside the urban areas with its larger proportion of woodland near the stream.

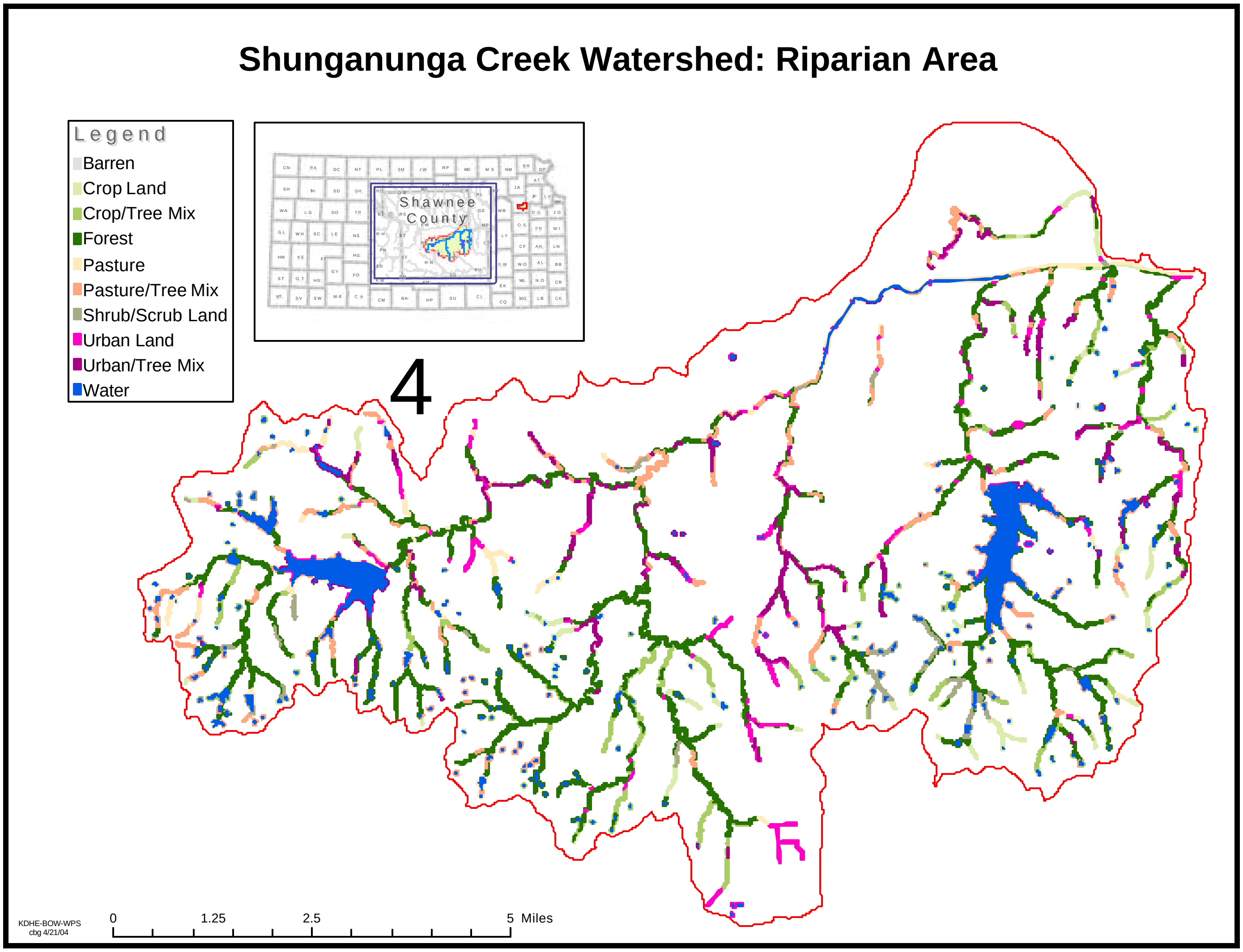


Figure 22

4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

This is a staged TMDL. Additional monitoring over time will be needed to ascertain the relationship of organic loadings to DO during the critical seasons of concern.

BOD is a measure of the amount of oxygen required to stabilize organic matter in a stream. As such, BOD is presently used as a benchmark measure to anticipate DO levels while it measures the total concentration of DO that will be demanded as organic matter degrades in a stream. In Phase one, any allocation of wasteloads and loads will be made in terms of BOD. The target BOD levels were established by the multiple regression model from Figure 18 and are based upon the relationship between DO and BOD, stream temperature, pH and total suspended solids. Using the regression equation, a target DO level was set (which includes an explicit margin of safety), conservative values were assigned to pH, TSS and temperature and the resulting BOD level was used to establish the BOD target curve for the Shunganunga Creek watershed (**Figure 23**). Future growth in wasteloads should be offset by reductions in the loads contributed by nonpoint sources. This offset along with appropriate limitations is expected to eliminate the impairment. This TMDL represents the "Best Professional Judgment" as to the expected relationship between physical factors, organic matter and DO in the watershed.

Point Sources: Point sources are responsible for maintaining their systems in proper working condition and appropriate capacity to handle anticipated wasteloads of their respective populations. The State and NPDES permits will continue to be issued on 5 year intervals, with inspection and monitoring requirements and conditional limits on the quality of effluent released from these facilities. Ongoing inspections and monitoring of the systems will be made to ensure that minimal contributions have been made by this source.

Based upon the preceding assessment, only the discharging point sources (Sherwood Regional WWTP and Shawnee County MHP) contributing a BOD load in the Shunganunga Creek watershed upstream of site 238 will be considered in this Wasteload Allocation.

The Shawnee Co. MHP BOD permit limit is 30 mg/L. Sherwood Regional WWTP BOD limit varies by month based upon expected ambient stream temperatures and ranges from 20 mg/L during July and August to 30 mg/L for October through April. Streeter-Phelps analysis performed for the warmest stream temperature conditions for both point sources indicate the present BOD permit limit for these point sources maintain DO levels above 5 mg/L in the stream when there is no flow upstream of either discharge point (see Streeter-Phelps analysis, Figure 20).

The sum of the design flows of the point sources (3.74 cfs) redefines the lowest flow seen at site 238 (85 - 99% exceedance), and the WLA (combined) equals the TMDL curve across this flow condition (**Figure 23**). A horizontal dashed line below the TMDL curve notes the demarcation between the WLAs and LAs in Figure 23. The color of this line matches the "cool" or "warm" season TMDL curves established by the different BOD targets from the multiple regression model in Figure 18.

Using this, the "warm" season WLA for Shawnee County MHP is 3.8 lbs/day BOD, which translates to an in-stream WLA of 0.27 lbs/day BOD at Site 238 for the "warm" season BOD target of 2.1 mg/L. For the Sherwood facility, using the warmest stream temperatures as a conservative condition, the WLA is 400.6 lbs/day, which translates to an in stream WLA of 42.1 lbs/day at Site 238.

No DO excursions exist for those samples collected during the defined Winter season. Because of this, the BOD target for these cooler stream temperature conditions differs from that of the warm stream temperature BOD target. This "cool" season BOD target is 4.8 mg/L and is also shown in **Figure 23**. The WLA for Shawnee County MHP remains at 3.8 lbs/day BOD but the WLA at Site 238 on Shunganunga Creek now translates to an in-stream value of 0.62 lb/day BOD at the “cool” season target. The Sherwood facility’s WLA is 1,051.6 lbs/day BOD based on their higher BOD permit limit of 30 mg/L during the Winter season. This translates into an in-stream WLA of 96.1 lbs/day BOD at Site 238.

Should future point sources be proposed in the watershed and discharge into the impaired segment, the current Wasteload Allocation will be revised by adjusting current load allocations to account for the presence and impact of these new point source dischargers (**Figure 23**). Appendix B lists the permitted facilities in the Shunganunga watershed, including CAFOs and non-discharging facilities. Those facilities have a Wasteload Allocation of zero.

Non-Point Sources: Based on the prior assessment of sources, the distribution of excursions from water quality standards at site 238 and the relationship of those excursions to temperature conditions and seasons, non-point sources are seen as a contributing factor to the DO excursions in the watershed.

The Load Allocation assigns responsibility for meeting the seasonal in stream BOD target levels (warm season BOD target = 2.1 mg/L; cool season = 4.8 ng/L) at site 238 for flows greater than 3.74 cfs (0-85% exceedance). The LA equals zero for flows from 0 – 3.74 cfs (85 - 99 % exceedance), since the flow at this condition is entirely effluent created, and then increases above the WLA/LA demarcation line to the TMDL curve with increasing flows above 3.74 cfs (**Figure 23**).

Activities to reduce organic substance loading should be directed toward the urban stormwater management and any smaller, unpermitted livestock operations still remaining within the watershed. Sediment control practices such as buffer strips and grassed waterways should help reduce the urban and rural non-point source BOD load under higher flows as well as reduce the oxygen demand exerted by the organic matter transported to the stream that may occur during higher stream temperature conditions.

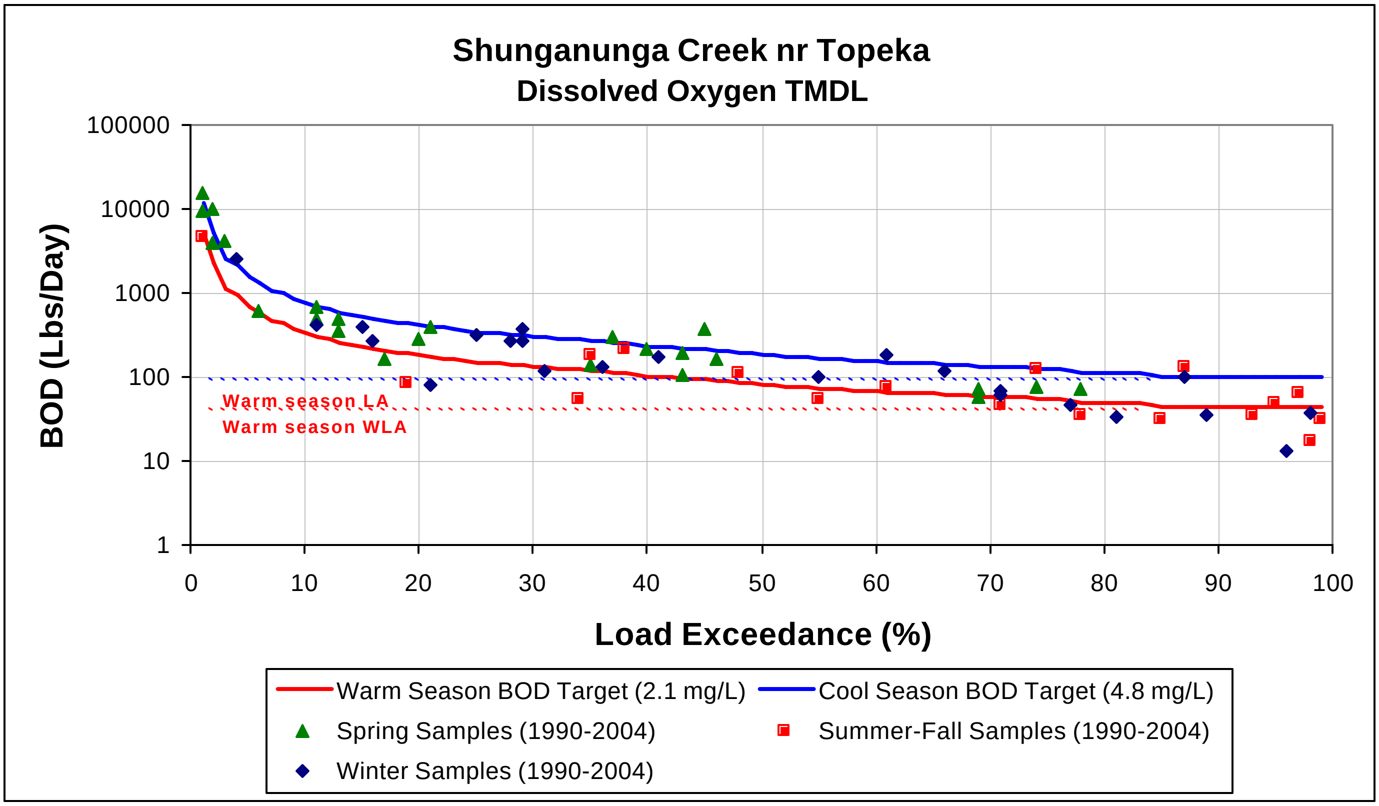


Figure 23

Defined Margin of Safety: The Margin of Safety is explicit and based on a target DO of 5.5 mg/L at Site 238, rather than the 5.0mg/L criterion.

State Water Plan Implementation Priority: Because this watershed has indicated some problem with dissolved oxygen, which has short term and immediate consequences for aquatic life, this TMDL will be a High Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Lower Kansas Basin (HUC 8: 10270104) with a priority ranking of 1 (Highest Priority for restoration work).

Priority HUC 11s and Stream Segments: Priority focus of implementation will concentrate on installing best management practices adjacent to main stem segments and flow contributing tributaries in the watershed.

5. IMPLEMENTATION

Desired Implementation Activities

1. Maintain necessary state and federal permits and inspect permitted facilities for permit compliance.
2. Install necessary stormwater management practices in urban areas of the watershed.
3. Where needed, create/restore riparian vegetation along target stream segments.

4. Install grass buffer strips where needed along streams.
5. Insure that labeled application rates of chemical fertilizers are being followed.
6. Insure proper on-site waste system operations in proximity to targeted streams.

Implementation Programs Guidance

NPDES and State Permits - KDHE

a. Municipal permits for facilities in the watershed will be renewed in 2010 maintaining existing operations of the wastewater treatment systems.
b. Livestock facilities will be inspected for integrity of applied pollution prevention technologies.
c. Manure management plans will be implemented.

Stormwater Management - KDHE

a. Review and support urban stormwater management permits and plans, including data collection efforts to spatially isolate runoff contributions of oxygen demanding substance loadings to stream.
b. Assist Topeka and Shawnee County with evaluation of Best Management Practices that will lead to reduction in organic substance/nutrient loading from urban settings during runoff.

Non-Point Source Pollution Technical Assistance - KDHE

a. Support Section 319 demonstration projects for pollution reduction from livestock operations in watershed.
b. Provide technical assistance on practices geared to small livestock operations which minimize impact to stream resources.
c. Guide federal programs such as the Environmental Quality Improvement Program, which are dedicated to priority subbasins through the Unified Watershed Assessment, to priority stream segments identified by this TMDL.
d. Assist evaluation of stormwater quality from urbanized areas of watershed.
e. Coordinate implementation of the TMDL as part of a Middle Kansas Subbasin Watershed Restoration and Protection Strategy (WRAPS).

Water Resource Cost Share & Non-Point Source Pollution Control Programs - SCC

a. Provide alternative water supplies to small livestock operations.
b. Develop improved grazing management plans.
c. Reduce grazing density on overstocked pasturelands.
d. Install livestock waste management systems for manure storage.
e. Implement manure management plans.
f. Install replacement on-site waste systems close to streams.
g. Coordinate with USDA/NRCS Environmental Quality Improvement Program in providing educational, technical and financial assistance to agricultural producers.

Riparian Protection Program - SCC

a. Develop riparian restoration projects along targeted stream segments, especially those areas with baseflow.
b. Design winter feeding areas away from streams.
c. Coordinate with Topeka Public Works Department to evaluate riparian conditions and implement the city buffer ordinance.

Buffer Initiative Program - SCC

a. Install grass buffer strips near streams.
b. Leverage Conservation Reserve Enhancement Program to hold riparian land out of production.
c. Coordinate with Topeka to supplement installation of buffers through the city ordinance.

Extension Outreach and Technical Assistance - Kansas State University

a. Educate livestock producers on riparian and waste management techniques.
b. Educate chemical fertilizer users on proper application rates and timing.
c. Provide technical assistance on livestock waste management design.
d. Continue Section 319 demonstration projects on livestock management.

Agricultural Outreach - KDA

a. Provide information on livestock management to commodity advocacy groups.
b. Support Kansas State outreach efforts.

Local Environmental Protection Program - KDHE

a. Inspect and repair on-site waste systems within 500 feet of priority stream segments in unincorporated areas of Shawnee County.

Timeframe for Implementation: Pollution reduction practices and buffer strips should be installed on main stem and directly contributing tributaries over the years 2007-2015.

Targeted Participants: Primary participants for implementation will be the landowners immediately adjacent to the priority stream segments and Public Works Departments. Implemented activities should be targeted to those stream segments with greatest potential to impact DO conditions. Nominally, this would be most likely be:

1. Areas of denuded riparian vegetation along Shunganunga Creek and its contributing tributaries.
2. Unbuffered cropland adjacent to stream
3. Sites where drainage runs through or adjacent to livestock areas
4. Sites where livestock have full access to stream and stream is primary water supply
5. Poor riparian sites

6. Failing on-site waste systems
7. Uncontrolled entry points for urban runoff
8. Coincidental areas of impervious surfaces and incidental fecal waste dropping
9. Failing sewer lines

Some inventory of local needs should be conducted in 2007-2008 to identify such activities. Such an inventory would be done by local program managers with appropriate assistance by commodity representatives and state program staff in order to direct state assistance programs to the principal activities influencing the quality of the streams in the watershed during the implementation period of this TMDL.

Milestone for 2010 The year 2010 marks the next foray into the Kansas-Lower Republican Basin to examine new and existing TMDL issues. At that point in time, milestones should be reached which will have at least two-thirds of the landowners responsible for buffer strip restoration or other stream restoration measures, cited in the local assessment, participating in the implementation programs provided by the state. Additionally, sample data from Site 238 should indicate evidence of improved dissolved oxygen levels during the season of concern relative to the conditions seen prior to 2004.

Delivery Agents: The primary delivery agents for program participation will be the conservation districts for programs of the State Conservation Commission, the Natural Resources Conservation Service and City Wastewater and Stormwater Programs. On-site waste system inspections will be performed by Local Environmental Protection Program personnel for primarily Shawnee County. Producer outreach and awareness will be delivered by Kansas State Extension and agricultural interest groups such as Kansas Farm Bureau or Kansas Livestock Association, the Kansas Pork Producers Council and the Kansas Dairy Association. WRAPS activity in the watershed will be coordinated by Kansas Alliance for Wetlands and Streams (KAWS).

Reasonable Assurances:

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

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.

2. 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.

3. K.A.R. 28-16-69 to -71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.

4. 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.

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

6. 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.

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

8. The *Kansas Water Plan* and the Kansas/Lower Republican 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 High Priority consideration.

Effectiveness: Buffer strips are touted as a means to filter sediment before it reaches a stream and riparian restoration projects have been acclaimed as a significant means of stream bank stabilization. The key to effectiveness is participation within a finite subwatershed to direct resources to the activities influencing water quality. The milestones established under this TMDL are intended to gauge the level of participation in those programs implementing this TMDL.

6. MONITORING

KDHE will continue to collect bimonthly samples at Station 238 in 2007-2015 including dissolved oxygen samples, in order to assess progress and success in implementing this TMDL toward reaching its endpoint. Should impaired status remain, the desired endpoints under this TMDL will be refined and more intensive sampling may need to be conducted under specified lower flow conditions after 2015. Use of the real time flow data available at the Soldier Creek (USGS Station 0688950) stream gaging station can help direct these sampling efforts.

Local program management needs to identify its targeted participants of state assistance programs for implementing this TMDL. This information should be collected in 2007 - 2008 in order to support appropriate implementation projects.

7. FEEDBACK

Public Notice: Public notification of the second round of TMDLs in the Kansas-Lower Republican Basin was made in the Kansas Register in January 5, 2006. An active Internet Web site was established at http://www.kdheks.gov/tmdl/ to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Kansas-Lower Republican Basin. Comments on the draft TMDL were received by the City of Topeka.

Public Hearing: Public Hearings on the second round of TMDLs for the Kansas-Lower Republican Basin were held in Olathe on January 19, and in Topeka on January 30, 2006.

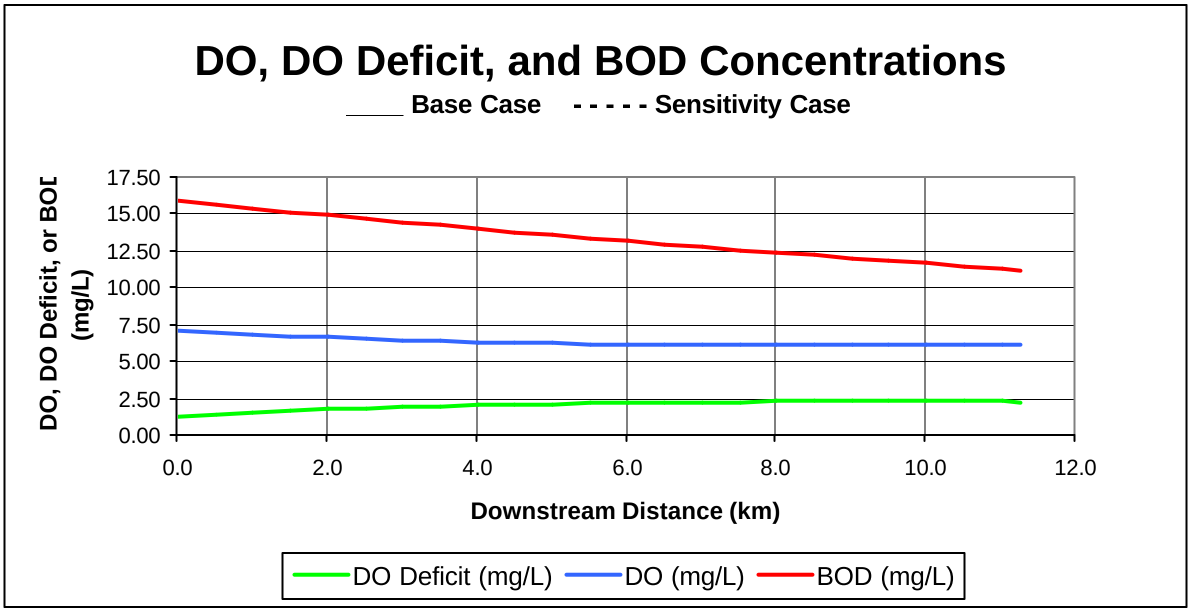
Basin Advisory Committee: The Kansas-Lower Republican Basin Advisory Committee met to discuss the second round of TMDLs in the basin on April 7, 2005 in Lawrence, July 26, 2005 in Concordia, October 20, 2005 in Lawrence and January 24, 2006 in Topeka.

Milestone Evaluation: In 2010, evaluation will be made as to the progress in implementing Best Management Practices in Topeka and Shawnee County. 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 dissolved oxygen monitoring data collected between 2006 and 2015. Therefore, the decision for delisting will come about in the preparation of the 2016 303(d) list. Should modifications be made to the applicable water quality criteria during the 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 will come in 2007 which will emphasize revision of the Water Quality Management Plan. 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 2007-2015.

Revised February 23, 2007



Distance (km)	Travel Time (day)	DO Deficit (mg/L)	DO (mg/L)	BOD (mg/L)
0.0	0.00	1.12	6.91	15.68
0.5	0.05	1.26	6.77	15.44
1.0	0.10	1.38	6.64	15.20
1.5	0.16	1.49	6.53	14.96
2.0	0.21	1.59	6.43	14.73
2.5	0.26	1.68	6.34	14.50
3.0	0.31	1.76	6.27	14.28
3.5	0.36	1.82	6.20	14.06
4.0	0.41	1.88	6.14	13.84
4.5	0.47	1.93	6.09	13.62
5.0	0.52	1.98	6.05	13.41
5.5	0.57	2.01	6.01	13.20
6.0	0.62	2.04	5.98	13.00
6.5	0.67	2.07	5.96	12.80
7.0	0.72	2.09	5.94	12.60
7.5	0.78	2.10	5.93	12.40
8.0	0.83	2.11	5.91	12.21
8.5	0.88	2.12	5.91	12.02
9.0	0.93	2.12	5.90	11.83
9.5	0.98	2.12	5.90	11.65
10.0	1.04	2.12	5.91	11.47
10.5	1.09	2.12	5.91	11.29
11.0	1.14	2.11	5.92	11.12
11.3	1.17	2.10	5.92	11.03

APPENDIX B – INVENTORY OF WASTEWATER FACILITIES IN SHUNGANUNGA WATERSHED

Facility	NPDES #	KS Permit #	Expiration Date	Design Flow	WLA
Sherwood Improvement District	KS0117731	M-KS72-OO27	8/31/2010	2.4 MGD	400.6 #/D BOD
Shawnee Hills Mobile Home Park	KS0119903	C-KS72-OO11	5/31/2009	0.0153 MGD	3.8 #/D BOD
Meier's Ready Mix South Plant	KSG460028	I-KS72-PR01	9/30/2007	Infrequent	0.0
Meier's Ready Mix 21st St. Plant	KSG110130	I-KS72-PR02	9/30/2007	Infrequent	0.0
East Side Baptist Church	KSJ000183	C-KS72-NO16	12/31/2007	Non-Q	0.0
Dairy	NA	A-KSSN-M003	2/4/2009	220 AU	0.0