North Canadian River Pathogens TMDL

Oklahoma Department of Environmental Quality
FY05/06 Section 106
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water resources division
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Response to EPA Comments on Draft TMDL Final Report

Comments #1-4 refer to the submittal process of the TMDL report document and apply to the submittal of final TMDL reports. Our recent submittal was a draft TMDL for technical review and as a grant deliverable. We apologize for not stating this clearly in our cover letter to the Office of the Secretary of the Environment and we regret the inconvenience this has caused. At this stage, we are still seeking technical review of the draft document. Public participation will be pursued after approval of the draft TMDL report document is confirmed.

Following are responses to comments #5-10.

5. The TMDL must contain the priority ranking of the waterbody.

   "Table I a Partial Integrated Report Listing for North Canadian River" lists the priority ranking as Category 5.

6. TMDL must include the antidegradation policy.

   Antidegradation policy attached as Appendix C.

7. EPA suggests where it is possible to separate natural background from nonpoint sources, load allocations should be described separately for background and for nonpoint sources.

   There is an ongoing discussion as to the methodology on exactly how this should be done (see "Response to DEQ Comments on Draft TMDL Final Report" Question #2). Obviously the low flow values should be associated with point sources and higher flow values with nonpoint sources. There does not seem to be a consensus yet in the community as to where to draw the line – is it a 70% exceedence value?

8. Document discusses using a 90% confidence limit. However, graphs of load duration curves indicate a 95% interval was used and Section V Margin of Safety indicates a 95% confidence interval was used. Please correct this discrepancy.

   Discrepancy corrected. A 90% confidence limit is used in all calculations (see "Response to DEQ Comments on Draft TMDL Final Report" Question #3).

9. Section VI Loading Allocation and Table IV-a Total TMDL Reduction Goals are in percentage reductions. It would be beneficial to demonstrate this calculation in the appendices.

   Calculation demonstrated in Section IV Linkage Between Sources and Receiving Water. Also included in Appendix B.

10. The TMDL should describe where the different sample locations are located and discuss the difference between samples taken at identical locations such as OC01 and NC06.

    Sampling site descriptions and photos were included in the accompanying data report.

Response to DEQ Comments on Draft TMDL Final Report

Page 25, 2nd paragraph from the bottom: "This report utilizes the Kansas delineations". I think you meant Texas delineations.

See #2.

1. Page 25, 2nd paragraph from the bottom: provide some explanations or justifications about the concept of 10-75, 75-85, 85-90 for NPS, mixed sources and point sources. Under low flow condition, non-point source pathogen loading is at minimum and may be neglected. However, there will be point source discharges at all flow conditions. Point source loading may be very small comparing to NPS loading under higher flow condition. But it needs to be explained.

   I agree that there is point source discharges at all flow conditions, and find that the attempt both in Texas and Kansas to draw a line as to where each loading begins and ends to be rather arbitrary. TDEC (2004) in Region IV makes no distinction on point vs. nonpoint in their load duration analyses.

   Upon further reflection, I have revised the report to eliminate the distinction between loads. Until the literature on the load duration methodology agrees on a rationale to define certain exceedence values as point vs. nonpoint, it is probably better not to make the distinction.

2. Page 25, last paragraph: the linear regression is performed only for the samples that exceed the standards. This could be a very conservative assumption. The physical meaning of the regression line would be: for every sample which exceeds the standard, there is 95% chance this sample will fall within the 95% confidence interval. However, it does not tell anything about the possibility for a sample to exceed the standard. In addition, since the USAP allows up to10% exceedence in samples, using 95% confidence interval is another conservation assumption.

   The Texas methodology uses the 95% value. The data has been recalculated to reflect the 90% confidence level to conform to the USAP protocols.

3. Page 25, last paragraph: "… Data less than 10% or greater than 90% exceedence values are not included as well, due to their excessive values". Please give more explanations why those data are excluded.

   The Texas methodology excludes <10% values and >90% values; Kansas excludes <10% values to conform to their surface water quality standards (KDHE, 2003).

   Since much of the data was collected during the summer months, when low flows are common, it would seem to be more logical to include this data. Therefore the calculations have been revised to include all data.

4. Page 26, Table IV-a: the meaning of the reduction factor is not straightforward and sometimes confusing. For a reduction factor of 10, people tend to think that is a 90% reduction (1 – 1/10 = 0.9) which is not much off the actual reduction rate. However, for a reduction factor of 2, the answer I got from others I have asked is 50% reduction while the actual reduction rate should be 66.7%. Therefore, I think it is better to use percent reduction instead of reduction factor.

   An entirely nonscientific poll was taken among various colleagues concerning this issue, and I came to similar results. Report has been modified to reflect percent reduction.

Executive Summary

The North Canadian River is in violation of Oklahoma Water Quality Standards with respect to pathogens. Samples taken from eight stations during summer 2003 along a reach from El Reno to Dale, Oklahoma showed repeated violations with respect to §785:45-5-16. ***Primary Body Contact Recreation.*** This verifies the 303-(d) pathogen listing.

Calculations utilizing load-duration curves show that the assimilative capacity of the river has been exceeded, in some areas by two orders of magnitude. The calculations show a strong nonpoint source component. Samples at point source flows were lacking at some stations; therefore the point source contribution is only estimated at these stations. More pathogen sampling will fill this data gap.

Loading must be reduced – a summary chart detailing these load reductions is shown in Table VI-a Summary Table Suggested TMDL values.

Education is a huge priority – the population must understand the impact of nonpoint sources in the North Canadian River. The Phase II stormwater educational components can be a significant start to address this problem. The health issue must be made clear to the part of the population that uses this waterbody for recreation.

Introduction

The North Canadian River study acquired data to characterize bacteria loads to the river from various sources and to describe the transport and fate of those loads. Water quality monitoring from May 2003 to September 2003 was used to collect data on bacteria sources.

Data collection activities and quality assurance analysis have been addressed in a previous report titled "North Canadian River Pathogens TMDL FY03/04 106 Grant Carryover Project #18". This report will focus on the calculation of the Total Maximum Daily Load for pathogens, utilizing the report form outlined in the Oklahoma Total Maximum Daily Load Practitioners Guide (ODEQ, 2004).

I. Problem Definition

Location of the TMDL study area

The project study area is focused on the North Canadian River, from the intersection of Highway 81 in Canadian County north of the city of El Reno to the intersection of Westech Road east of the town of Dale, Oklahoma. This project concerns approximately 101 river miles through Canadian, Oklahoma, and Pottawatomie Counties (see Figure I-1).

The project area is diverse in land use. In the Canadian County area, land use is dominantly agricultural in nature, although future population projections suggest that urbanization of the east side of the county will rapidly take place over the next twenty years, especially with the completion of the northwest quadrant of the Outer Loop. The cities of Yukon and El Reno have grown by a factor of ten percent over the past decade and this rate is expected to persist.

The west and central portions of Oklahoma County is urban in nature; the North Canadian River flows within two miles of the downtown area and has recently been the focus of an urban renewal project (MAPS Project). The North Canadian River has been transformed into a 7-mile-long series of river lakes bordered by landscaped areas, trails and recreational facilities. Dams at Eastern, Western and May Avenues will raise the level of the river. Locks at Western and May Avenues will allow boats to navigate the entire 7-mile length of the river project.

Land use on the east side of Oklahoma County gradually proceeds from urban to developing rural in nature. Again, urbanization is proceeding at a rapid pace in these areas. At the last sampling point east of Dale, the land use is rural in nature again, with wheat farming the dominant crop.

Pollutants Addressed

As part of the 2002 Integrated Report, the North Canadian River segment is listed for pathogens and turbidity (Table I-a). This report will address the pathogen impairment.

The Oklahoma Water Quality Standards has several beneficial uses which are pathogen-related, including the standards listed under §785:45-5-10 - Public And Private Water Supplies and 785:45-5-16 - Primary Body Contact Recreation. Under primary body contact recreation, the standards further addresses pathogen impairments by defining three separate categories of pathogens, namely Coliform Bacteria, Escherichia coli (E. coli), and Enterococci. All three of these categories have separate criteria that define the water quality standard.

Table I-a Partial Integrated Report Listing for North Canadian River

Integrated Report Waterbodies										
WBIDSEGID	**NAME**	**TYPE**	**SIZE**	**CATEGORY**	**TMDL_ DATE**	**WWAC**	**PBCR**	**PPWS**	**PATHOGENS**	**TURBIDITY**
OK520530000 010_10	Canadian River, North	R	101	5	2005	N	N	I	9000	9000
A = Attaining I = Insufficient Data N = Not Attaining X = Not Assessed										

Figure I-1 Project Location Map

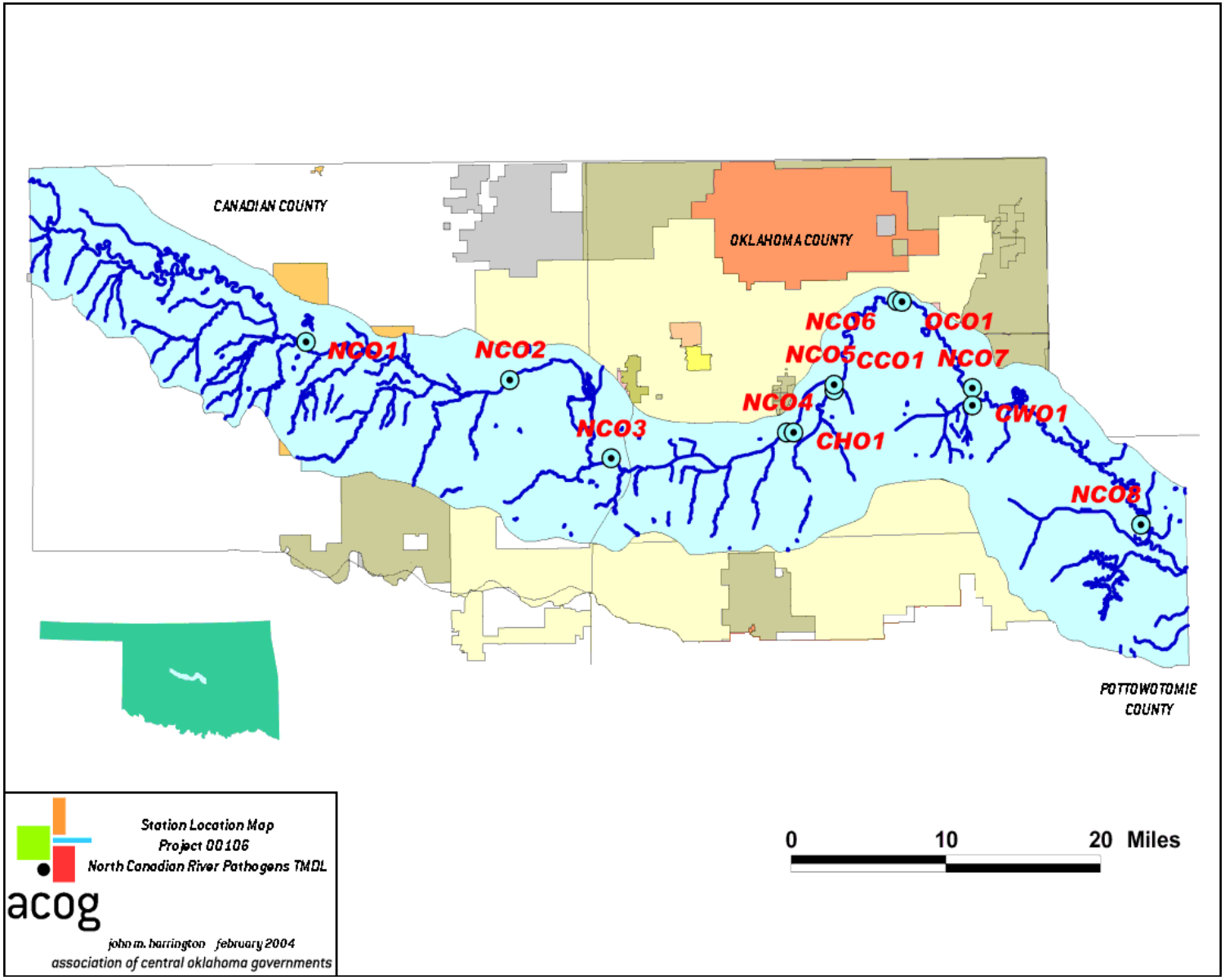


Figure I-2 Point Source Identification

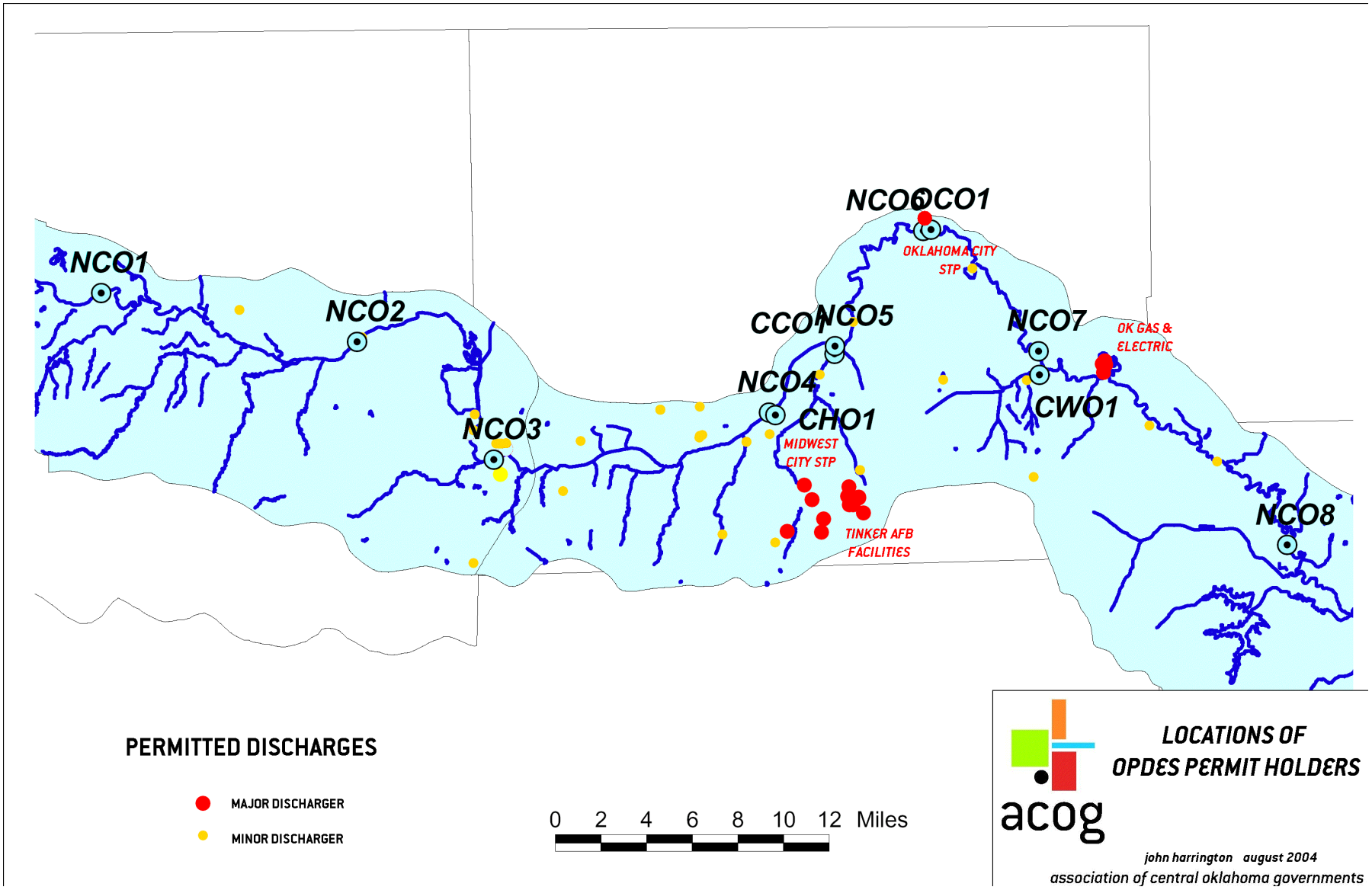
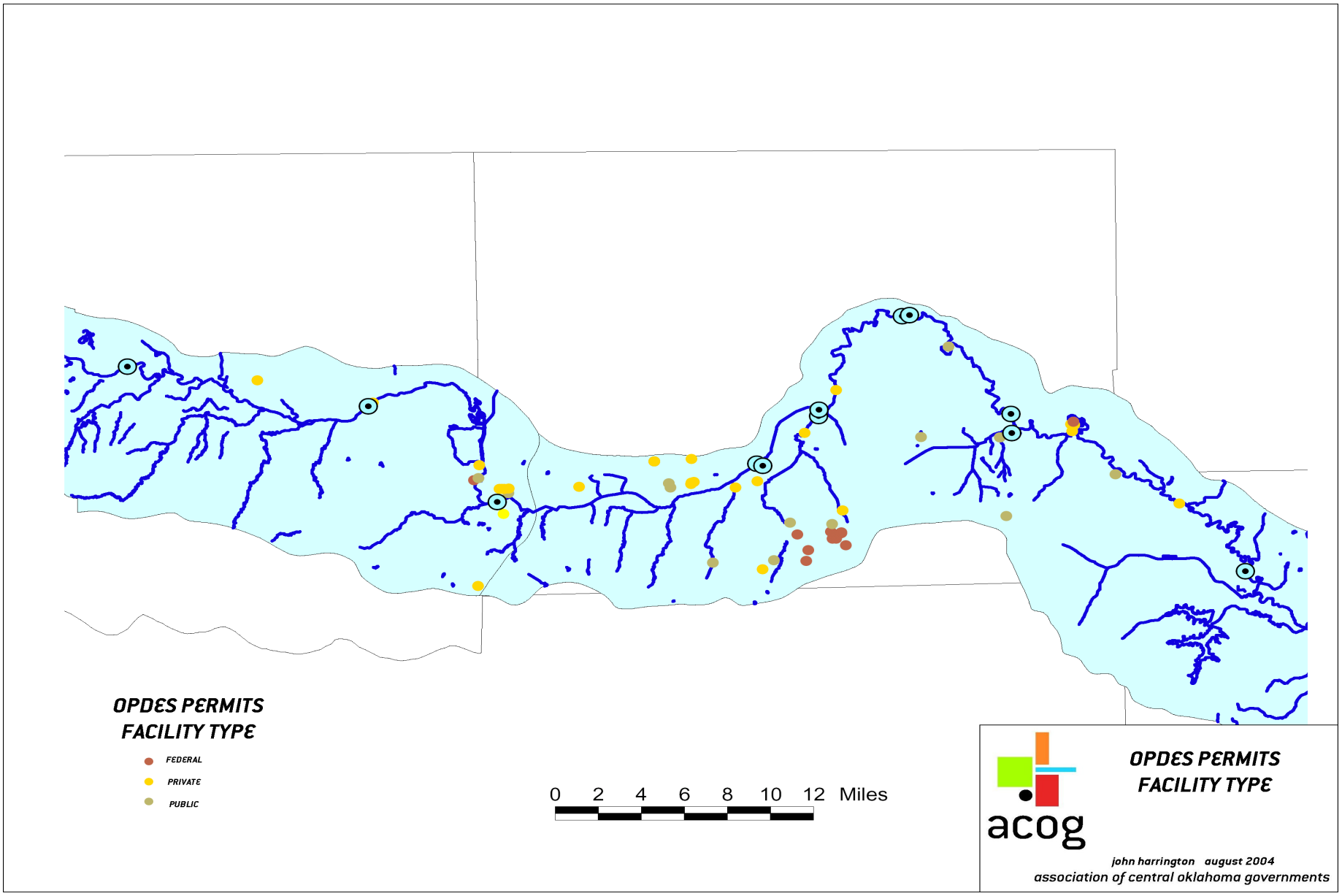


Figure I-3 Point Source Identification - Facility Type



To avoid potential conflict regarding which set of standards to apply, §785:45-5-10-(3)-(D) states: "In cases where both public and private water supply and primary body contact recreation uses are designated, the primary body contact criteria will apply."

Existing Permits For Point Sources Within The Study Area

The North Canadian River has multiple sources of regulated discharges, including 25 major point sources and 40 minor point sources. A map illustrating the location of these sites is shown Figure I-2 and Figure I-3. Most of the major point sources are in Oklahoma County. Municipal sources include the Oklahoma City North Canadian Treatment plant near Jones, OK, discharges along Crutcho Creek (Midwest City) and Cherry Creek (Del City). Federal sources include Tinker Air Force Base, which is located in the headwaters of Crutcho Creek. Most private holders are small facilities, such as trailer parks and car washing facilities. A listing of these sources is given in Appendix A.

Pathogen Types Sampled

Pathogens sampled at the station locations during summer 2003 were analyzed for three basic types: Coliform Bacteria, Escherichia coli (E. coli), and Enterococci.

Coliform Bacteria

Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in the intestines of man and warm- and cold-blooded animals. They aid in the digestion of food.

Escherichia coli (E. coli)

A specific subgroup of this collection is the fecal coliform bacteria, the most common member being Escherichia coli. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals. The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. At the time this occurred, the source water might have been contaminated by pathogens or disease producing bacteria or viruses that can also exist in fecal material. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in ambient water as a result of the overflow of domestic sewage or nonpoint sources of human and animal waste (EPA, 2001).

Enterococci

Enterococci are bacteria found in the faeces of most humans and many animals. There are two types of enterococci associated with normal healthy people and which also occasionally cause human disease. They are called Enterococcus faecalis and Enterococcus faecium. The commonest infections caused by enterococci are urinary tract infections and wound infections. These, and a variety of other infections, including infection of the blood stream (bacteraemia), heart valves (endocarditis) and the brain (meningitis) can occur in severely ill patients in hospital. Enterococci also frequently colonize open wounds and skin ulcers. In these circumstances the bacteria can be grown from a lesion but they are not causing the patient any illness (Association of Medical Microbiologists, 1997).

Enterococci are amongst the most antibiotic resistant bacteria isolated from humans. Minor infections can usually be treated by antibiotics such as penicillins, macrolides or tetracyclines, taken by mouth. However, only penicillins, or teicoplanin and vancomycin (two expensive and potentially toxic antibiotics which can only be given by injection) are reliably effective against serious enterococcal infections such as endocarditis or meningitis. Serious infections often need prolonged treatment, usually with several antibiotics being given together by injection.

Figure I-4 E. Coli

II. Endpoint Identification

Endpoint identification is quite specifically detailed in the Oklahoma Water Quality Standards. The following is from §785:45-5-16. ***Primary Body Contact Recreation*** (OWQS, 2003)**.**

(a) Primary Body Contact Recreation involves direct body contact with the water where a possibility of ingestion exists. In these cases the water shall not contain chemical, physical or biological substances in concentrations that are irritating to skin or sense organs or are toxic or cause illness upon ingestion by human beings.

(b) In waters designated for Primary Body Contact Recreation the following limits for bacteria set forth in (c) of this section shall apply only during the recreation period of May 1 to September 30. The criteria for Secondary Body Contact Recreation will apply during the remainder of the year.

(c) Compliance with 785:45-5-16 shall be based upon meeting the requirements of one of the three (3) options specified below for bacteria. Upon selection of one (1) group or test method, said method shall be used exclusively over that thirty (30) day period.

(1) Coliform Bacteria: The bacteria of the fecal coliform group shall not exceed a monthly geometric mean of 200/100 ml, as determined by multiple-tube fermentation or membrane filter procedures based on a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. Further, in no more than 10% of the total samples during any thirty (30) day period shall the bacteria of the fecal coliform group exceed 400/100 ml.

(2) Escherichia coli (E. coli): E. coli shall not exceed a monthly geometric mean of 126/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. No sample shall exceed a 75% one-sided confidence level of 235/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 406/100 ml in all other Primary Body Contact Recreation beneficial use areas. These values are based upon all collected samples. Analysis procedures shall follow EPA-600/4-85/076, "Test Methods for Escherichia coli and Enterococci in Water by the Membrane Filter Procedure."

(3) Enterococci: Enterococci shall not exceed a monthly geometric mean of 33/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. No sample shall exceed a 75% one-sided confidence level of 61/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 106/100 ml in all other Primary Body Contact Recreation beneficial use areas. These values are based upon all collected samples. Analysis procedures shall follow EPA-600/4-85/076, "Test Methods for Escherichia coli and Enterococci in Water by the Membrane Filter Procedure."

Water Quality Analyses

Water samples were collected and analyzed to determine water quality standards violations and the magnitude of the violations. All three pathogen groups in the standards (Coliform bacteria, e. coli, and Enterococci) were analyzed. The following tables show the numerical results of the sample in each of the respective pathogen groups with respect to the Oklahoma Water Quality Standards.

Coliform Bacteria

Violations with respect to coliform bacteria occurred throughout the study area at each of the project stations. Samples exceed numeric criteria using both 30-day and geometric mean procedures. Table II-a and Table II-b detail the results of the numeric procedure outlined in §785:45-5-16-(c)-(1).

Table II-a Numeric Criteria Analysis – Coliform Bacteria Stations NC01 to CC01

	STATION IDENTIFICATION											
	NC01	NC01	NC02	NC03	NC03	NC03	CH01	CH01	NC04	NC04	CC01	CC01
DATE	COLIFORM BACTERIA COUNT											
	30-DAY PERIOD	GEOMETRIC MEAN	30-DAY PERIOD	GEOMETRIC MEAN	30-DAY PERIOD	GEOMETRIC MEAN	30-DAY PERIOD	GEOMETRIC MEAN	30-DAY PERIOD	GEOMETRIC MEAN	30-DAY PERIOD	GEOMETRIC MEAN
19-May	1,000		8,000		31,000		41,000		37,000			
27-May	130		30		400		21,000		5,000		200	
2-Jun	130		200		800		7,000		3,000		7,000	
9-Jun	11,000		8,000		300		500		100		22,000	
16-Jun	200	518	200	599	200	901	700	4,622				
23-Jun	200	375	200	286	120	297	800	2,103	300		900	
30-Jun	100	356	60	329	100	225	200	829	120		170	
7-Jul	40	281	130	302	120	154	490	487	600		33,000	
14-Jul	3,000	217	6,000	285	700	182	5,000	772				
21-Jul									200		300	
28-Jul	3,000		220		290		1,100		700		1,100	
4-Aug	260		170		200		2,000		500		500	
11-Aug	370		40		7,300		800		600		400	
18-Aug	130		300		90		210		10	211	210	425
25-Aug	530	457	700	199	460	445	800	784	100	184	1,700	601
2-Sep	170	257	200	196	300	448	3,200	970	700	184	2,200	691
9-Sep	10	134	600	252	20	283	1,900	960	60	120	1,100	809
16-Sep	200	119	100	302	400	158	4,100	1,332	400	111	1,500	1,053
23-Sep	110	115	500	335	130	170	33,700	3,677	700	259	1,700	1,600
30-Sep	80	79	300	283	30	99	4,100	5,098	1,700	457	300	1,131
NUMBER OF VIOLATIONS	4	2	6	1	7	3	17	11	11	1	12	7

Table II-b Numeric Criteria Analysis – Coliform Bacteria Stations NC06 to NC08

	STATION IDENTIFICATION											
	NC05	NC05	OC01	OC01	NC06	NC06	NC07	NC07	CW01	CW01	NC08	NC08
DATE	COLIFORM BACTERIA COUNT											
	30-DAY PERIOD	GEOMETRIC MEAN	30-DAY PERIOD	GEOMETRIC MEAN	30-DAY PERIOD	GEOMETRIC MEAN	30-DAY PERIOD	GEOMETRIC MEAN	30-DAY PERIOD	GEOMETRIC MEAN	30-DAY PERIOD	GEOMETRIC MEAN
19-May	41,000				6,000		14,000				1,000	
27-May	1,100				2,000		290		200		400	
2-Jun	3,000		10		3,000		8,000		1,300		500	
9-Jun	5,000		20		210		400		9,000		500	
16-Jun			10				3,100	2,094	200		10	251
23-Jun	700		120		200		200	895	300	675	100	158
30-Jun	300		10	19	10		90	709	50	512	40	100
7-Jul	900		200	34	130		600	422	50	267	60	65
14-Jul					800		1,000	507	6,000	246	140	51
21-Jul	800		200		120	120	1,100	412	50	186	200	92
28-Jul	500		700		2,000	190	700	529	260	181	10	58
4-Aug	500		70		1,000	478	500	746	600	298	200	80
11-Aug	200		300		700	669	200	599	200	393	370	116
18-Aug	90	325	400	259	20	320	90	370	10	109	10	68
25-Aug	500	295	310	283	500	426	500	316	100	126	200	68
2-Sep	4,900	466	150	208	2,300	438	1,700	377	300	129	1,100	175
9-Sep	600	484	2,100	411	120	287	670	400	60	82	110	155
16-Sep	2,700	814	10	208	700	287	2,200	646	110	72	1,100	193
23-Sep	3,100	1,652	10	100	700	583	3,100	1,312	800	174	600	437
30-Sep	400	1,580	700	117	200	486	2,300	1,780	1,700	306	300	474
NUMBER OF VIOLATIONS	15	5	4	1	11	6	15	12	6	2	7	2

LEGEND VIOLATION

Escherichia coli (E. coli)

Violations with respect to Escherichia coli (E. coli) occurred throughout the study area at each of the project stations. Samples exceed numeric criteria using both 30-day and the 90% one-sided confidence level procedures. Table II-c and Table II-d detail the results of the numeric procedure outlined in §785:45-5-16-(c)-(2).

Table II-c Numeric Criteria Analysis – E.Coli Stations NC01 to CC01

	STATION IDENTIFICATION											
	NC01	NC01	NC02	NC03	NC03	NC03	CH01	CH01	NC04	NC04	CC01	CC01
DATE	E.COLI BACTERIA COUNT											
		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN
19-May	528		650		5794		24192		2481			
27-May	63		41		63		1616		2187		132	
2-Jun	20		97		288		906		1968		530	
9-Jun	581		933		52		388		52		232	
16-Jun	143	141	183	213	195	254	301	1,328				
23-Jun	20	73	85	142	74	106	586	631	256		226	
30-Jun	51	70	41	142	41	98	373	471	31		109	
7-Jul	41	81	63	130	30	62	259	366	9.999		122	
14-Jul	41	48	132	88	9.999	45	1726	494				
21-Jul	63	40	171	87	41	33	2723	767	109		109	
28-Jul	74	53	41	75	98	35	379	703	10		109	
4-Aug	72	56	41	75	63	38	565	764	10		173	
11-Aug	41	56	110	84	609	69	206	730	31		74	
18-Aug	63	61	74	75	31	86	410	548	85	31	52	95
25-Aug	185	76	121	70	52	90	301	353	74	29	571	133
2-Sep	63	74	120	87	85	88	384	353	74	43	393	172
9-Sep	10	50	148	112	20	70	388	328	10	43	10	97
16-Sep	121	62	121	114	142	52	860	436	109	55	173	115
23-Sep	63	62	262	147	63	60	11,196	845	206	66	248	157
30-Sep	10	34	41	118	10	43	1,785	1,207	146	75	171	124
AVERAGE	113		174		388		2,477		436		202	
STD	157		224		1,280		5,654		825		158	
NUMBER	20		20		20		20		18		17	
90% CONFIDENCE	182		272		949		4,955		817		277	
NUMBER OF VIOLATIONS		1		5		1		16		0		2

Table II-d Numeric Criteria Analysis – E. Coli Stations NC06 to NC08

	STATION IDENTIFICATION											
	NC05	NC05	OC01	OC01	NC06	NC06	NC07	NC07	CW01	CW01	NC08	NC08
DATE	E.COLI BACTERIA COUNT											
		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN
19-May	8164				1935		3076				288	
27-May	465				10		97		384		85	
2-Jun	959		52		226		281		689		318	
9-Jun	663		74		122		275		275		161	
16-Jun			108				238	353	52		9.999	105
23-Jun	185		63		98		74	168	155	226	10	53
30-Jun	41		20	55	9.999		31	133	74	162	9.999	35
7-Jul	52		10	40	9.999		10	68	30	87	10	17
14-Jul					292		31	44	63	65	9.999	10
21-Jul	369		4611		132	52	443	50	52	65	31	13
28-Jul	41		122		1112	84	175	59	20	43	98	20
4-Aug	52		605		9.999	84	41	63	9.999	29	10	20
11-Aug	63		110		41	112	227	117	9.999	23	41	26
18-Aug	85	84	96	324	10	57	84	143	9.999	16	52	36
25-Aug	110	66	84	146	41	45	233	126	30	14	63	42
2-Sep	120	82	275	171	41	23	231	133	148	21	120	44
9-Sep	51	82	122	124	20	27	30	125	408	45	20	50
16-Sep	309	112	63	111	41	27	262	129	30	56	145	65
23-Sep	350	149	10	71	41	36	285	165	134	94	107	75
30-Sep	158	160	285	90	74	40	10	88	223	140	134	87
AVERAGE	680		395		225		307		147		86	
STD	1,884		1,096		484		663		180		90	
NUMBER	18		17		19		20		19		20	
90% CONFIDENCE	1,550		916		442		597		228		126	
NUMBER OF VIOLATIONS		2		3		0		7		3		0

LEGEND VIOLATION

Enterococci

Violations with respect to Enterococci occurred throughout the study area at each of the project stations. Samples exceed numeric criteria using both 30-day and the 90% one-sided confidence level procedures. Table II-c and Table II-d detail the results of the numeric procedure outlined in §785:45-5-16-(c)-(3).

Table II-e Numeric Criteria Analysis - Enterococci Stations NC01 to CC01

	STATION IDENTIFICATION											
	NC01	NC01	NC02	NC03	NC03	NC03	CH01	CH01	NC04	NC04	CC01	CC01
DATE	ENTEROCOCCI BACTERIA COUNT											
		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN
19-May	5,000		3,000		29,000		63,000		51,000			
27-May	300		600		200		2,000		5,000		500	
2-Jun	200		400		15,000		12,000		46,000		1,100	
9-Jun	7,000		5,000		300		3,000		100		1,000	
16-Jun	900	1,136	6,000	1,849	300	1,509	900	5,275				
23-Jun	2,000	946	5,000	2,048	200	558	1,000	2,303	100		10,000	
30-Jun	900	1,178	500	1,974	90	475	5,000	2,766	7,000		600	
7-Jul	1,500	1,763	900	2,322	90	171	600	1,519	4,000		700	
14-Jul	6,000	1,709	1,100	1,715	200	158	10,000	1,933				
21-Jul	600	1,576	500	1,044	100	127	600	1,783	7,000		700	
28-Jul	1,200	1,423	300	594	110	112	1,000	1,783	4,000		500	
4-Aug	600	1,312	100	431	2,600	220	700	1,203	300		7,000	
11-Aug	1,100	1,233	300	346	1,100	363	1,700	1,482	700		600	
18-Aug	2,100	1,000	300	267	250	379	1,200	970	2,500	1,712	300	849
25-Aug	1,600	1,216	800	293	110	387	1,300	1,132	2,200	1,358	4,700	1,242
2-Sep	800	1,121	3,300	473	500	524	1,900	1,287	600	929	2,400	1,700
9-Sep	90	767	800	717	30	214	1,700	1,537	1,000	1,182	600	1,040
16-Sep	2,500	904	2,700	1,113	800	201	1,900	1,571	300	998	1,300	1,214
23-Sep	800	746	13,700	2,391	11,200	430	5,100	2,098	200	602	500	1,345
30-Sep	700	632	5,100	3,463	100	422	2,500	2,392	1,100	524	100	623
AVERAGE	1,795		2,520		3,114		5,855		7,394		1,918	
STD	1,946		3,281		7,279		13,799		15,151		2,752	
NUMBER	20		20		20		20		18		17	
90% CONFIDENCE	2,647		3,958		6,304		11,903		14,394		3,226	
NUMBER OF VIOLATIONS		16		16		16		16		7		7

Table II-f Numeric Criteria Analysis – Enterococci Stations NC06 to NC08

	STATION IDENTIFICATION											
	NC05	NC05	OC01	OC01	NC06	NC06	NC07	NC07	CW01	CW01	NC08	NC08
DATE	ENTEROCOCCI BACTERIA COUNT											
		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN		GEOMETRIC MEAN
19-May	42,000				15,000		16,000				400	
27-May	900				60		110		200		90	
2-Jun	9,000		210		400		300		700		200	
9-Jun	2,000		10		300		100		4,000		300	
16-Jun			50				300	436	200	579	60	167
23-Jun	300		10		100		800	240	300	507	410	168
30-Jun	10,000		10	25	160		40	196	200	507	100	171
7-Jul	3,000		50	19	117,000		700	232	230	406	110	152
14-Jul					36,000		8,000	557	300	242	300	152
21-Jul	400		400		7,000	3,426	900	694	500	291	90	165
28-Jul	3,000		20		157,000	14,925	1,100	740	600	334	460	169
4-Aug	700		40		47,000	46,507	13,000	2,353	90	284	140	180
11-Aug	1,300		100		3,100	22,498	1,100	2,575	120	250	400	234
18-Aug	1,300	1,073	50	69	312,000	34,652	2,100	1,971	200	230	110	191
25-Aug	1,500	1,397	40	44	68,800	54,729	1,800	2,264	200	192	300	243
2-Sep	900	1,098	60	54	1,300	20,981	600	2,005	1,200	220	1,500	308
9-Sep	200	855	60	59	1,900	11,045	700	1,118	600	322	50	251
16-Sep	1,500	880	10	37	1,800	9,907	2,600	1,328	220	363	230	224
23-Sep	1,300	880	10	27	2,700	3,832	1,400	1,224	800	479	400	291
30-Sep	300	638	400	43	6,700	2,405	3,600	1,406	3,300	840	700	344
AVERAGE	4,422		90		40,964		2,763		735		318	
STD	9,783		126		79,015		4,420		1,072		326	
NUMBER	18		17		19		20		19		20	
90% CONFIDENCE	8,942		150		76,493		4,699		1,217		460	
NUMBER OF VIOLATIONS		7		6		11		16		3		16

LEGEND VIOLATION

III. Source Analysis

An important part of TMDL analysis is the identification of individual sources, or source subcategories of pollutants in the watershed that affect pathogen loading and the amount of loading contributed by each of these sources.

Under the Clean Water Act, sources are classified as either point or nonpoint sources. Under 40CFR §122.2, a point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges. Point source discharges can be described by three broad subcategories: 1) NPDES regulated municipal and industrial wastewater treatment facilities (WWTF); 2) NPDES regulated industrial and municipal storm water discharges; and 3) NPDES regulated Concentrated Animal Feeding Operations (CAFOs). A TMDL must provide Waste Load Allocations (WLAs) for all NPDES regulated point sources.

Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For the purposes of this TMDL, all sources of pollutant loading not regulated by NPDES permits are considered nonpoint sources. The TMDL must provide a Load Allocation (LA) for these sources.

Point Sources

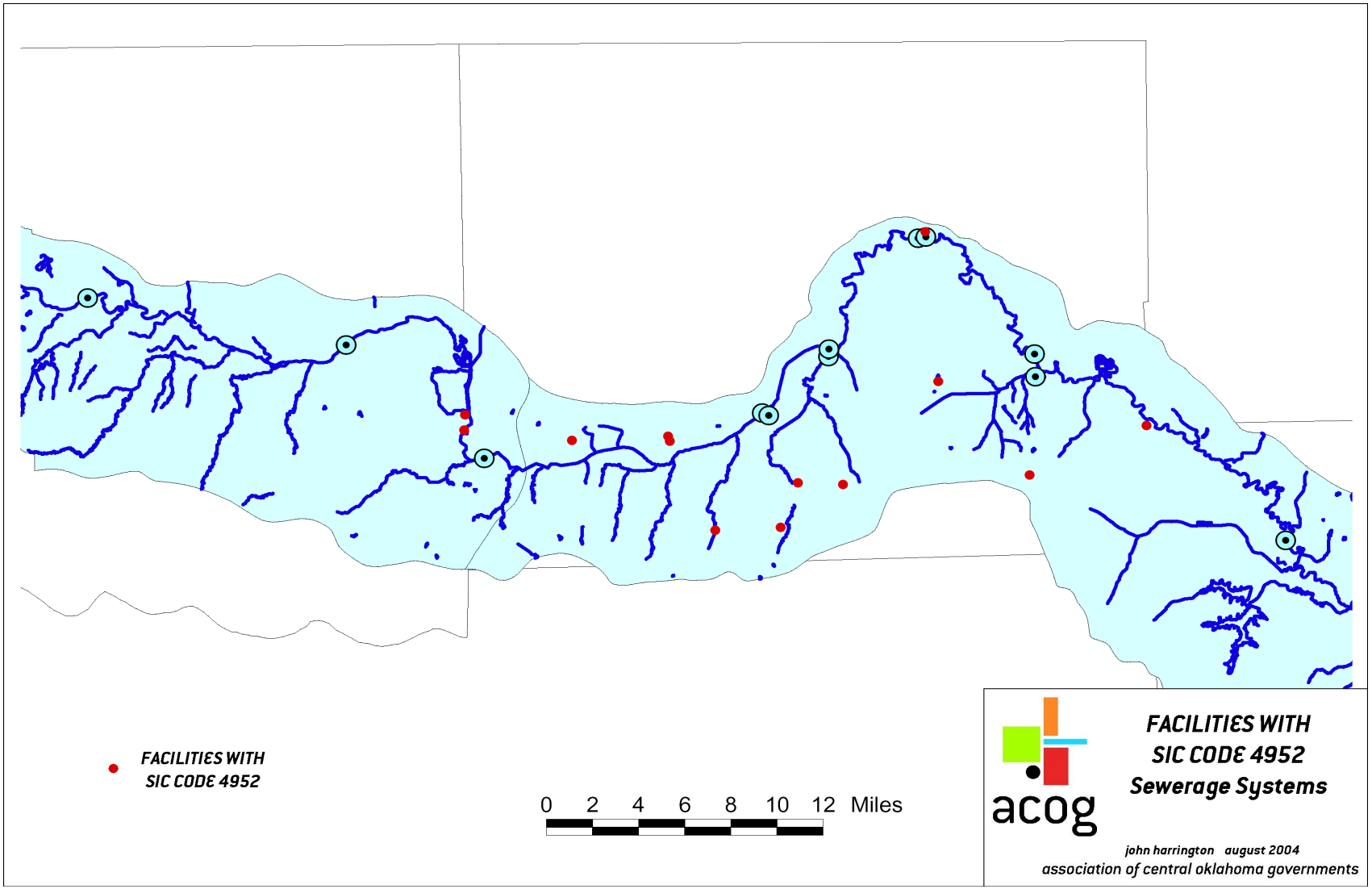
Both treated and untreated sanitary wastewater contains fecal coliform bacteria. There are 65 permitted dischargers in the project area. Of these, 13 are classified with a SIC code of 4952 (Sewerage Systems) (see Figure III-1). These WWTFs must have pathogen requirements in the effluent monitoring data, submitted on Discharge Monitoring Reports (DMR). Most of these facilities are located in Oklahoma County.

Stormwater and MS4s – Phase I

In response to the 1987 Amendments to the Clean Water Act (CWA), the U.S. Environmental Protection Agency (EPA) developed Phase I of the NPDES Storm Water Program in 1990. It was mandated that cities nationwide develop programs addressing the issue of storm water pollution. The Phase I program targeted sources of storm water runoff that had the greatest potential to negatively impact water quality. Under Phase I, EPA required permit coverage for storm water discharges from "Medium" and "large" municipal separate storm sewer systems (MS4s) located in incorporated places or counties with populations of 100,000 or more; and Eleven categories of industrial activity, including construction projects that disturbs five or more acres of land. A medium MS4 is a system that services a population between 100,000 - 249,999. A large MS4 is a system that services a population of 250,000 or more (EPA, 1996).

With a population of nearly one-half million, Oklahoma City was designated as a Phase I City and required to monitor and maintain water quality in our storm drains, rivers and creeks. The Storm Water Quality Management Division of Oklahoma City researches and initiates innovative measures to manage, monitor, investigate, control and remediate pollution of both surface and storm water (City of OKC, 2004).

Figure III-1 Facilities with SIC Code 4952 (Sewerage)



Stormwater and MS4s – Phase II

Smaller entities will be soon implementing the Phase II stormwater regulations. Operators of small MS4s (primarily those located in urbanized areas – see Figure III-2) are required to implement programs and practices to control polluted storm water runoff from the jurisdiction serviced by the MS4. The operator must design its storm water management program to satisfy applicable CWA water quality requirements and technology standards. The program must include the development and implementation of best management practices (BMPs) and measurable goals for the following six minimum measures, and include evaluation and reporting efforts:

- Public education and outreach
- Public participation/involvement
- illicit discharge detection and elimination
- Construction site runoff control
- Post-construction runoff control
- Pollution prevention/good housekeeping for municipal operations.

All construction operators disturbing more than 1 acre and less than 5 acres are required to apply for an NPDES storm water permit for small construction activity. EPA already regulates construction activity disturbing more than 5 acres. A construction operator is usually the developer or landowner, but can also be the contractor or another party responsible for the operational control of erosion and sediment control practices on site (EPA, 2004).

Concentrated Animal Feeding Operations (CAFOs)

Animal feeding operations are agricultural enterprises where animals are kept and raised in confined situations. These operations congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland (USEPA, 2002).

Best Management Practices (BMPs) are implemented as the pollution controls at these facilities. Animal waste shall be isolated from outside surface drainage by ditches, dikes, berms, terraces or other such structures except for a twenty-five-year, twenty-four-hour rainfall event. No waters of the state shall come into direct contact with the animals confined on the animal feeding operations (§§9-201 et seq. Title 2 Oklahoma Statutes). Figure III-3 illustrates the location of CAFOs in the study area.

Nonpoint Sources

Nonpoint sources of fecal coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of fecal coliform bacteria on land surfaces and wash off as a result of storm events. Nonpoint sources of pathogen loading are primarily associated with agricultural and urban land uses. The vast majority of waterbodies identified on the 303(d) list as impaired due to pathogens are attributed to nonpoint agricultural or urban sources.

Figure III-2 Urbanized Areas – Phase I & II Stormwater

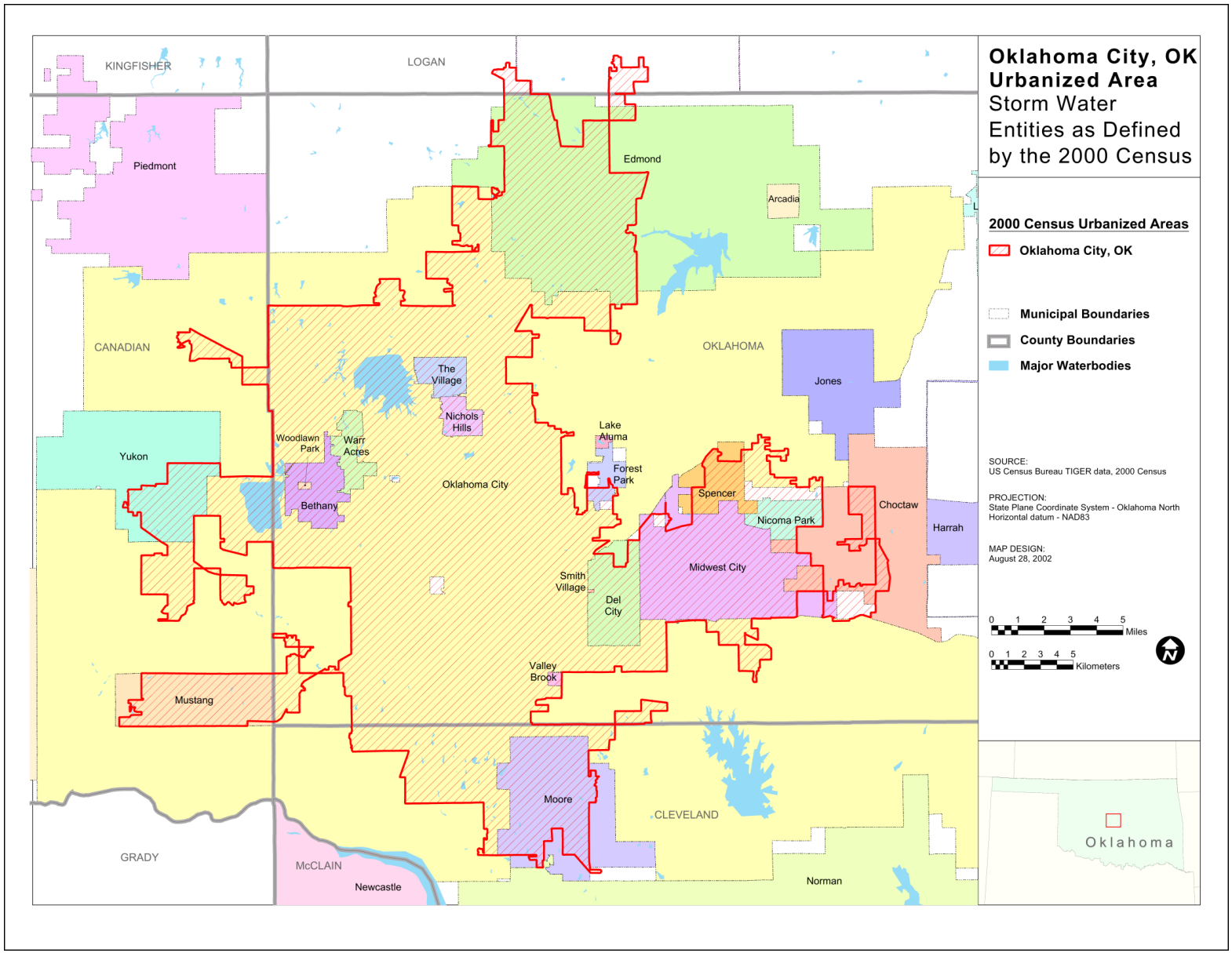
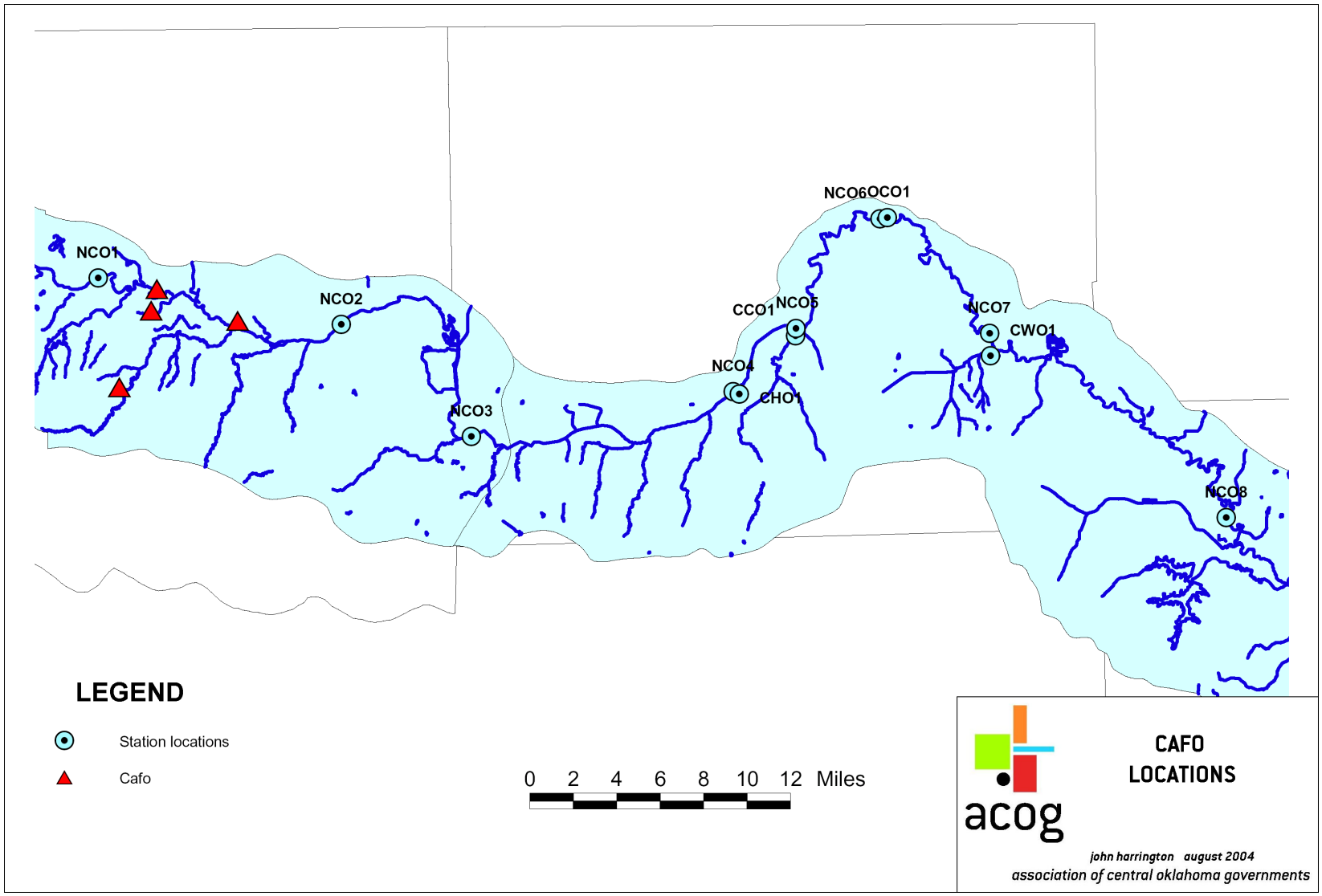


Figure III-3 CAFO Locations



Wildlife

Wildlife deposit fecal coliform bacteria, with their feces, onto land surfaces where it can be transported during storm events to nearby streams. Often referred to as feral animals, wildlife can be an important contribution to the pathogen loading in a stream.

The Stinchcomb Wildlife Refuge is located on the North Canadian River immediately above Lake Overholser (see Figure III-4). Blue herons, owls and ducks can be seen year round at this site. Egrets and cranes will often visit during the warmer months. The felled trees from the many wild beaver in the refuge may be seen every few feet. The hoofed tracks of deer are abundant and deer sightings are common (Patterson, 2003).

Land Application Sites

Land application of municipal sludge is common in Oklahoma County. In central Oklahoma, a principal cause of soil erosion is heavy rains that fall on sloping soils with thin vegetative cover. Municipal sewage sludge can be an important restorative for abused land and it can be substantially more effective than treatment of eroded areas that involves only grading and one-time fertilizing at planting. Sludge can improve soil condition, restore fertility, and maintain gentle contour while simultaneously solving the problem of disposal (Kessler, et al. 1985).

One of the potential hazards associated with the application of sewage sludge to land is the possibility of human exposure to pathogens. Because of this hazard, sewage sludge must undergo additional treatment to reduce pathogens before it can be used for land application (Krogmann, et. al., 2003).

Land application in the study area is concentrated in an area around the Oklahoma City Northside Plant near Jones, Oklahoma (see ***)

Agricultural Animals

Agricultural activities can be a significant source of fecal coliform bacteria loading to surface waters. The activities of greatest concern are typically those associated with livestock operations (Drapcho and Hubbs, 2002):

- Agricultural livestock grazing in pastures deposit manure containing fecal coliform bacteria onto land surfaces. This material accumulates during periods of dry weather and is available for washoff and transport to surface waters during storm events. The number of animals in pasture and the time spent grazing are important factors in determining the loading contribution.
- Processed agricultural manure from confined feeding operations is often applied to land surfaces and can provide a significant source of fecal bacteria loading.
- Agricultural livestock and other unconfined animals (i.e., deer and other wildlife) often have direct access to waterbodies and can provide a concentrated source of fecal loading directly to a stream.

Failing Septic Systems

Although most of the population in Oklahoma County is on municipal sewerage, the rural areas of Canadian and Oklahoma County still rely on septic systems, some which can reasonably be

assumed to be failing. As with livestock in streams, discharges of raw sewage provide a concentrated source of fecal bacteria directly to waterbodies.

Urban Development

Nonpoint source loading of fecal bacteria from urban land use areas is attributable to multiple sources. These include: storm water runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals. Impervious surfaces in urban areas allow runoff to be conveyed to streams quickly, without infiltration through soils and interaction with groundwater.

Figure III-4 Sinchcomb Wildlife Refuge

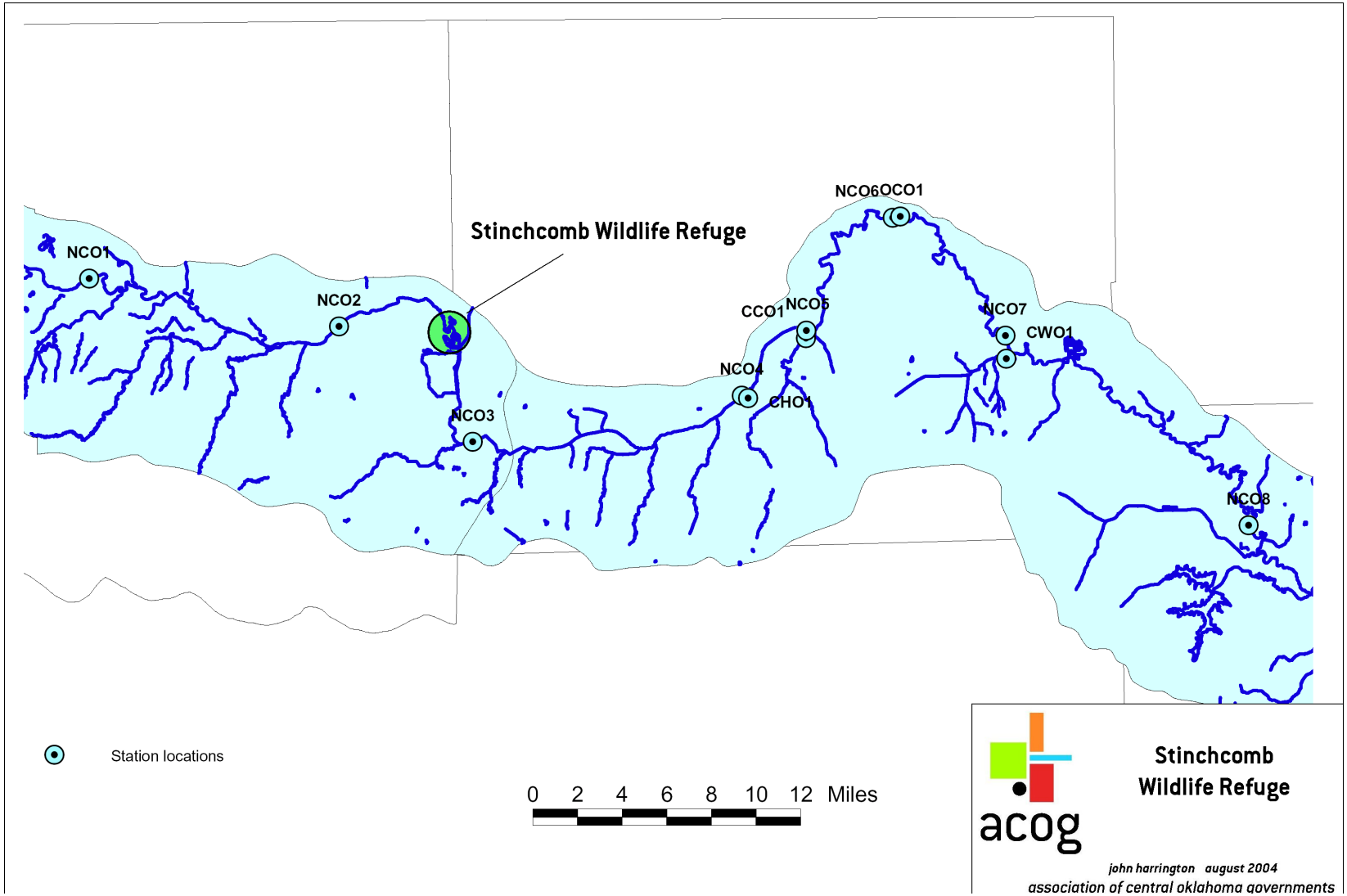
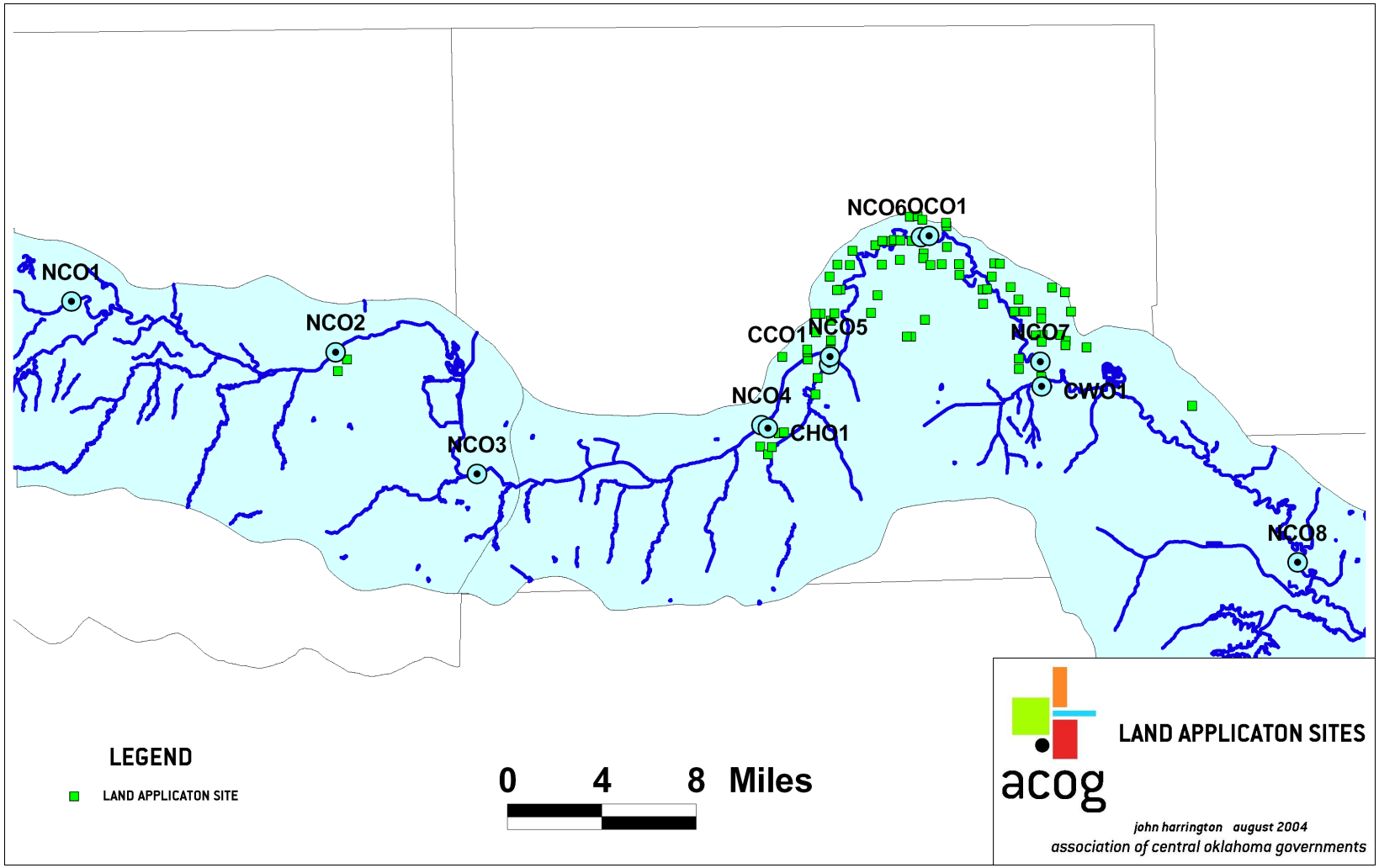


Figure III-5 Land Application Sites



IV. Linkage Between Sources and Receiving Water

Load-Duration Curve Analysis

As part of an emerging statistical methodology, load-duration analysis for nonpoint source pollution is gaining many adherents, especially as applied to pathogen load modeling. The approach uses traditional flow frequency distributions for streams as a basis to analyze type and magnitude of pathogen loading (Sullivan, et al., 2004). The advantage of this method is the simplicity, the need for minimal data requirements, can be used to identify broad sources of bacteria, assesses water quality throughout the range of flows, and uses confidence intervals for uncertainty in the estimation of TMDLs.

Four USGS stations were instrumental in this analysis (see Figure IV-2). Stations NC01 and NC02 used the El Reno Station (USGS 07239500) data, Station NC03 used the station below Lake Overholser (USGS 07241000), Stations NC04, NC05, and NC06 used North Canadian River at Britton Rd at OKC, OK (USGS 07241520) and Stations NC07 and NC08 used North Canadian River near Harrah, OK (USGS 07241550). The USGS station at Yukon (USGS 07239700 North Canadian River near Yukon, OK) was not used due to a short period of record.

Stream data can be obtained from the United States Geological Survey Site at http://nwis.waterdata.usgs.gov/ok/nwis/dvstat. Standard recurrence interval graphs can be generated using an Excel spreadsheet and the PERCENTILE function, or generating a curve utilizing data found in Statistical Summaries of Streamflow in Oklahoma through 1999 (USGS, 2000).

Selection of the time interval for the generating flow-duration curves was given careful consideration. The North Canadian River is a regulated flow system now. Canton Lake, Lake Overholser, and the new dam system just south of Oklahoma City regulate the flow through Canadian and Oklahoma counties. The El Reno station and the Lake Overholser station have long periods of record that include this regulation and the entire record was used to generate the curve. However, the new dam system south

Figure IV-1 Load Duration Curve – NC04

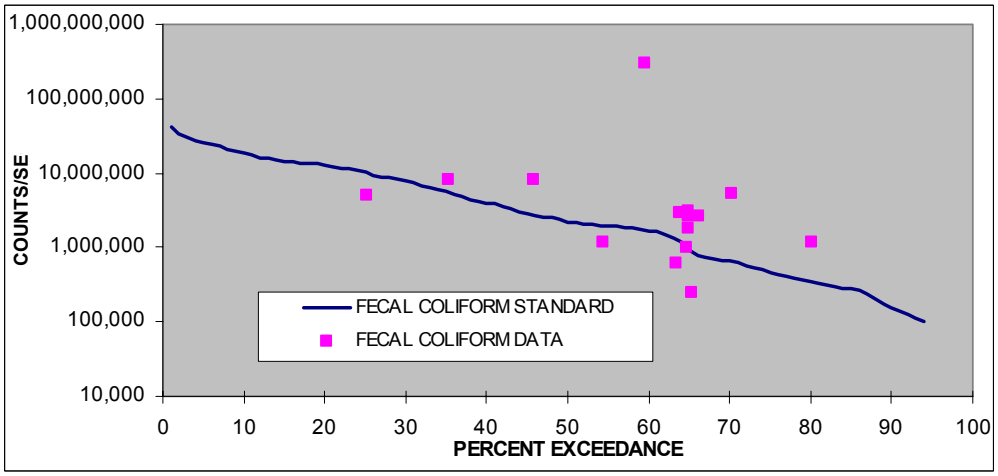
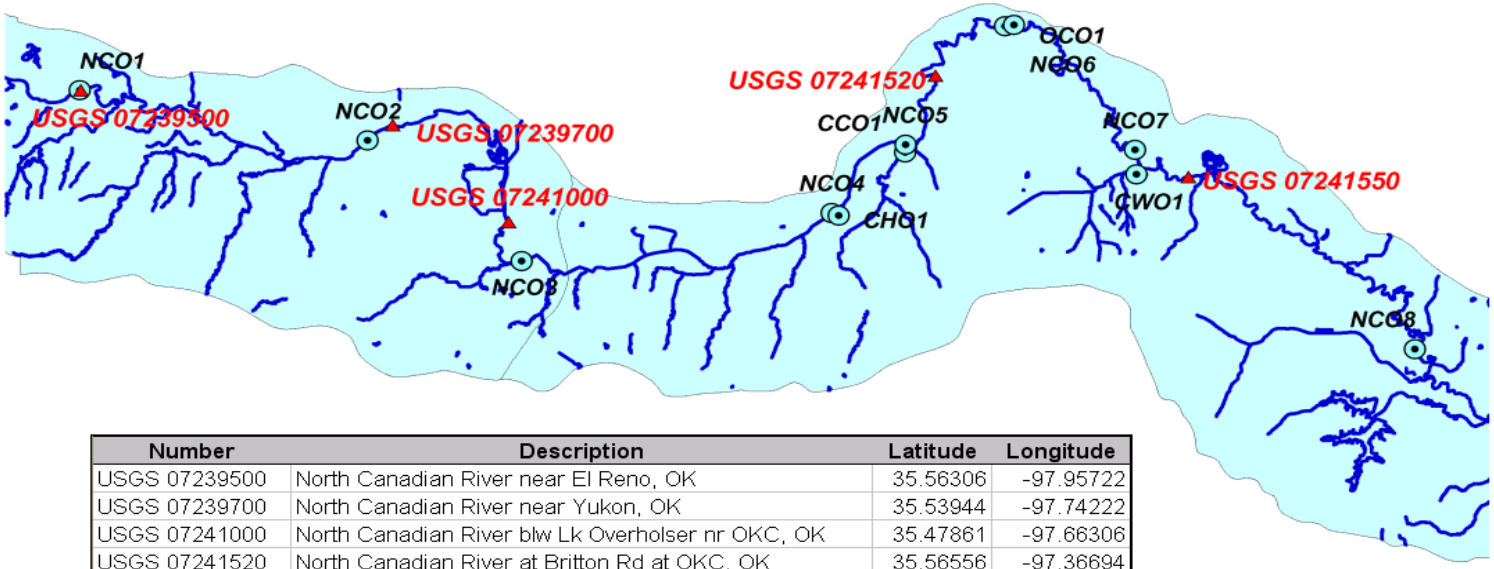


Figure IV-2 USGS Station Locations



Number	Description	Latitude	Longitude
USGS 07239500	North Canadian River near El Reno, OK	35.56306	-97.95722
USGS 07239700	North Canadian River near Yukon, OK	35.53944	-97.74222
USGS 07241000	North Canadian River blw Lk Overholser nr OKC, OK	35.47861	-97.66306
USGS 07241520	North Canadian River at Britton Rd at OKC, OK	35.56556	-97.36694
USGS 07241550	North Canadian River near Harrah, OK	35.50028	-97.19361

usgs station locations

acog

john m. barrington february 2004

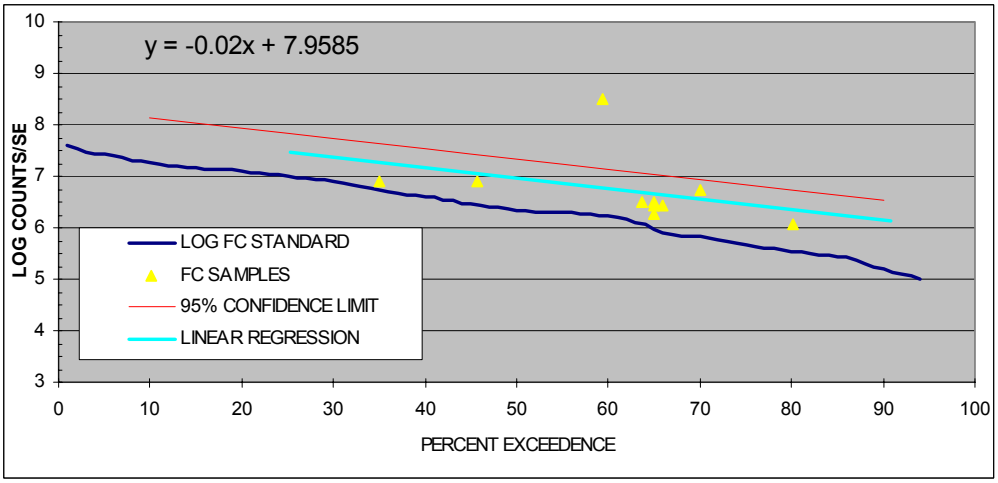
association of central oklahoma governments

0 10 20 Miles

of Oklahoma City is only about four years old; therefore, only four years of record were used for the analysis for stations NC04-NC08.

The first step in load duration curve methodology is to generate a graph with a curve representative of the water quality standard for the particular parameter. This is somewhat a break from the traditional view of TMDL, where loads are viewed at a static flow rate, i.e. the 7Q2 of a stream. The load-duration curve approach, however, recognizes the dynamic state of loads; e.g. loading varies directly with flow. The x-axis is the traditional recurrence interval, but the y-axis is now the loading or concentration. For coliform bacteria, this was achieved by using the monthly geometric mean concentration (200/100 ml) and multiplying the flow at each recurrence interval (using standard unit conversions) to achieve a loading function of coliform counts/sec (see Figure IV-3). Data from stream sampling is now plotted. As part of the pathogen data collection effort, flow was measured with a pygmy meter at the sites. If no flow data was collected at the site, the stream flow at the designated USGS site was used.

Figure IV-3 Load Duration Curve – NC04 – Regression Lines



Once the data is plotted, one can immediately see an advantage to this methodology. Flows to the left of the chart are associated with storm events; these samples would tend to represent nonpoint sources. Flows to the right of the chart would tend to be quite small and would tend to represent point sources. Flow in the middle of the chart would represent both types of sources.

The next step in the methodology is to regress the flow exceedence. Using standard linear regression methods, one draws a line through the points that violate the standard to define a function that characterizes the average exceedence. The linear function is displayed on the graph in Figure IV-3.

Now that there is a linear function characterizing the average exceedence of the standard, a margin of safety factor is addressed. This is addressed at length in the next section, but at this point it is sufficient to say that a confidence limit is calculated around the linear exceedence function (in this case, the 90% confidence limit).

Table IV-a Total TMDL Reduction Goals

Station	% Reduction Goal - E. Coli	% Reduction Goal - Fecal Coliform	% Reduction Goal - Enterococci
NC01	19.5%	96.8%	98.9%
NC02	52.1%	80.5%	98.9%
NC03	NONE	87.8%	95.1%
NC04	90.4%	97.5%	99.8%
NC05	90.6%	99.3%	99.9%
NC06	4.6%	50.9%	96.8%
NC07	62.5%	50.6%	75.5%
NC08	2.6%	66.0%	95.7%
Average	46.1%	78.7%	95.1%

Calculation of % Reduction Goal

The ideal goal of the TMDL is to achieve the water quality standard. To attain that goal, the load reduction is simply the difference between the 90% confidence interval line and the load exceedence curve. The percentage goal reduction is the difference normalized by the 90% confidence interval line. Keeping in mind the data is log transformed, the calculation is thus:

$$\Sigma(10^{(CI)} - 10^{(WQS)}) / 10^{(CI)}$$

where: CI is the 90% confidence interval
WQS is the water quality standard

Calculations were made at each 5% exceedence level from 10% to 90%. An arithmetic average was then calculated over the range of these values.

As Figure IV-3 illustrates, the load reduction goal can be an orders of magnitude – in this case, the loading must be reduced by 10.1 times. A summary chart of these load reduction goals is shown in Table IV-a.

Due to the specific nature of the water quality sampling, only the summer recreational season has been addressed. Pathogen sampling data in the winter months will need to be acquired and analyzed to determine the full seasonal extent of the water quality violation (and associated load reduction goals).

Magnitude Of Pollutant Sources

An average of 46.1% the E.Coli data violated standards, 78.7% of the fecal coliform data violated standards, and 95.1% of the Enterococci data violated standards. This may be due in part to the ability of these different pathogens to survive outside the host, with Enterococci having the highest survival rate (Warnemuende, et. al, 2000). Taken together, these various pathogen survival rates may also give an indication of proximity of the waterbody to the pathogen source. For example, pathogen sources are farther from the river at NC03 than

NC04, due to the fact that there is significantly less E.Coli at NC03. However, the higher survivability of Enterococci shows that the pollutant loading is still about the same magnitude.

Table IV-a shows the magnitude of violations varies over two orders, especially with enterococci. No clear distinction can be made between rural and urban areas. However, close association of larger magnitudes of violations with specific land use can be inferred, specifically regarding stations NC05 and NC06, where Enterococci samples are unusually high. Both these sites are located in the reach of the river where a high number of land application sites are permitted (Figure III-5).

Source Analysis

The number of samples is skewed towards higher flow events – at least twice as many samples were taken during the higher flows (less than 85% exceedence values) than low flows (a rather ironic observation, considering the sampling program was conducted during seasonal low flow!). Table IV-a also demonstrates that there does not seem to be a significant difference between urban vs. rural areas.

Table IV-b Source Analysis

Station	Source Analysis - E. Coli	Source Analysis - Fecal Coliform	Source Analysis - Enterococci
NC01	NONPOINT SOURCES	NONPOINT SOURCES	NONPOINT SOURCES
NC02	NONPOINT SOURCES	NONPOINT SOURCES	NONPOINT SOURCES
NC03		NONPOINT SOURCES	NONPOINT SOURCES
NC04	NONPOINT SOURCES	NONPOINT SOURCES	POINT SOURCES
NC05	NONPOINT SOURCES	NONPOINT SOURCES	NONPOINT SOURCES
NC06	NONPOINT SOURCES	POINT SOURCES	POINT SOURCES
NC07	NONPOINT SOURCES	POINT SOURCES	POINT SOURCES
NC08	NONPOINT SOURCES	NONPOINT SOURCES	NONPOINT SOURCES

Comparison of the slopes of the water quality standards vs. the pathogen data on the graph provides a glimpse into the type of flow regime that the pollutant concentration would favor. Although point sources will always be found in all flows, in general higher flows are associated with nonpoint sources while low flows are associated with point sources.

Table IV-b is a tabulation illustrating the tendency for the data to favor nonpoint vs. point source flows. As one can see, the E. Coli data suggests all nonpoint sources, while the Coliform and enterococci data show some point source issues at NC06 and NC07.

V. Margin of Safety

The traditional notation of a TMDL is:

$$TMDL = WLA + LA + MOS \text{ or } TMDL \text{ or}$$
$$\sum WLA + \sum LA + MOS, \text{ for multiple sources,}$$

Where: TMDL is the loading capacity of the stream;
WLA is the Wasteload Allocation for the point source(s);
LA is the Load Allocation for the non-point source(s)
and MOS is the Margin of Safety.

This notation implies a steady state; i.e.; loading at a single flow value (7Q2). The Load-duration curve approach, however, recognizes the dynamic state of loads; e.g. loading varies directly with flow.

The Oklahoma Continuing Planning Process (DEQ, 2000) gives a guidance of 25% for uncalibrated models with limited data and multiple sources. Assigning this margin of safety can be performed in several areas of the calculations in the load duration analysis. The first place could be in the translation of the water quality standard to the load-duration curve, using a simple scalar (i.e., the coliform standard is 200, use 0.75 x 200 = 150). Another place could be in the confidence interval, setting a confidence interval high enough to implicitly provide an adequate margin of safety.

The calculations in this TMDL utilize the scalar approach in the calculations, with a 90% confidence interval calculated around the linear regression.

VI. Loading Allocation

It is quite obvious that the maximum assimilative capacity of the North Canadian River has been greatly exceeded and the primary water quality goal is to reduce pathogens, in some areas by orders of magnitude.

Table VI-a summarize the load reduction calculated at each station, with the associated source analysis. NC05 and NC06 have extremely high Enterococci counts and probably have issues from the same source – either land application in this area, or possibly the impacts resulting from discharges from Crutcho Creek. NC08 and NC01 are dominantly rural areas with fecal

Table VI-a Summary Table Suggested TMDL values

Station	Source Analysis	Overall Reduction Factor	Pathogen	Applicable Location
NC01	NONPOINT SOURCES	19.5%	E.Coli	
NC01	NONPOINT SOURCES	98.9%	Enterococci	
NC01	NONPOINT SOURCES	96.8%	Fecal Coliform	From Highway 81 to Garth Brooks Blvd, Yukon
NC02	NONPOINT SOURCES	52.1%	E.Coli	
NC02	NONPOINT SOURCES	98.9%	Enterococci	
NC02	NONPOINT SOURCES	96.8%	Fecal Coliform	From Garth Brooks Blvd, Yukon to Lake Overholser
NC03		NONE	E.Coli	
NC03	NONPOINT SOURCES	95.1%	Enterococci	
NC03	NONPOINT SOURCES	87.8%	Fecal Coliform	From Lake Overholser to 10th Street
NC04	NONPOINT SOURCES	90.4%	E.Coli	
NC04	POINT SOURCES	99.9%	Enterococci	
NC04	NONPOINT SOURCES	99.3%	Fecal Coliform	From 10th Street to Midwest City Blvd
NC05	NONPOINT SOURCES	90.6%	E.Coli	
NC05	NONPOINT SOURCES	99.9%	Enterococci	
NC05	NONPOINT SOURCES	99.3%	Fecal Coliform	From Midwest City Blvd to North Anderson Rd
NC06	NONPOINT SOURCES	4.6%	E.Coli	
NC06	POINT SOURCES	96.8%	Enterococci	
NC06	POINT SOURCES	50.9%	Fecal Coliform	From North Anderson Rd to Triple X Rd
NC07	NONPOINT SOURCES	62.5%	E.Coli	
NC07	POINT SOURCES	75.5%	Enterococci	
NC07	POINT SOURCES	50.6%	Fecal Coliform	From Triple X Rd to Dale, OK
NC08	NONPOINT SOURCES	2.6%	E.Coli	
NC08	NONPOINT SOURCES	95.7%	Enterococci	
NC08	NONPOINT SOURCES	66.0%	Fecal Coliform	From Dale, OK to Shawnee, OK

coliform impacts.

Very little or no data was collected at the flows greater than 85% exceedence value (an extremely wet June contributed to high flows for most of the summer). The suggested TMDL values in Table VI-a reflect this reality and more data needs to be collected at lower flows to substantiate these values.

Pathogens come from a variety of sources, some of which may be beyond the ability for any statutory authority to regulate. Wildlife is an unknown contributing factor at the present time. A bacteria source study will be necessary to determine the causes of the pathogens and determine to what extent the water quality violations come from sources that can be regulated, such as people and pets.

Education is a priority issue. As part of the upcoming Phase II stormwater regulations, a strong educational component is mandated. Stormwater education for the communities in Oklahoma and Canadian counties is needed. Pathogen sampling may be considered as a specific part of the Phase II stormwater permit for those communities that the North Canadian River flows through. The Association of Central Oklahoma Governments is currently working on a public education program under the 106(b) grant program.

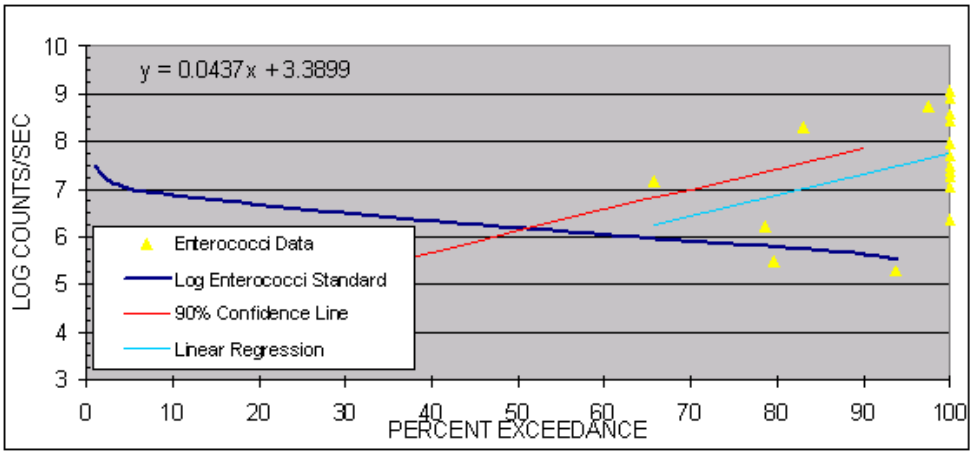
Health education is also necessary. Many people fish this river. The potential health effects of this activity need to be clearly explained to people who use the river for this mode of recreation.

The Issue of Regulated Flow

The impact of regulated flow from the new set of dams on the North Canadian River between May Ave and Eastern is significant. The load duration analysis in this report uses only the past four years of record for the duration curve – this corresponds to the time of record of the regulated flow that impacts the analysis of stations NC04-NC06. The flow is significantly less than the previous decade and thus has a major impact on loading. Load duration analysis is very sensitive to the choice of flow data.

For a comparison, an alternate load duration analysis of NC06 was done on the Enterococci data using flow data from 1988-2003. As a result, most of the collected samples are now plotted as point source loads and fall between 95%-100% exceedence values. The load

Figure VI-1 Load Duration Curve – NC06 with North Canadian flow data 1988-2003



reduction factor for the nonpoint sources is now none – because of the steep slope of the 90% reduction line and no data at high flows.

To complicate the issue further, one needs to point out that the Oklahoma Water Quality Standards mandates pathogen sampling during the summer months – exactly at the time when low flows would be sampled and thus be plotted above the 95% exceedence level.

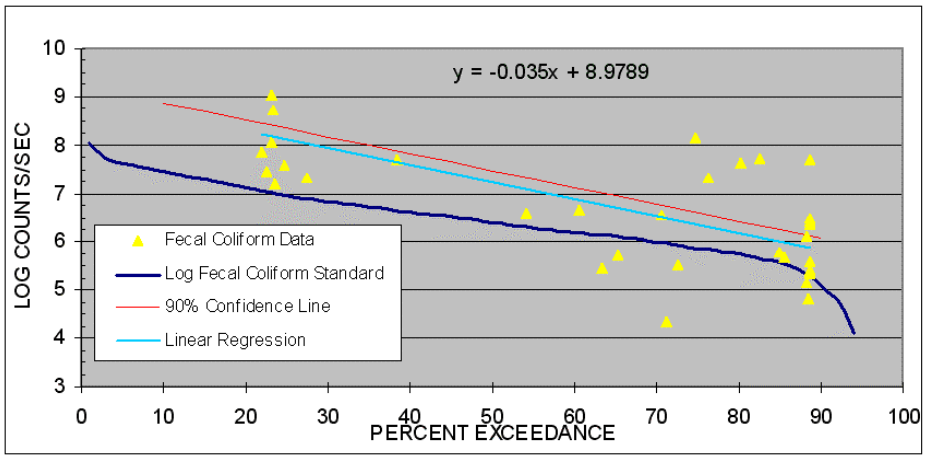
A Historic Perspective

A search through the STORET database on pathogens produced poor results for Oklahoma County, but some success in Canadian County. A sampling site was listed at the El Reno station for a period between 1980 through 1992 for fecal coliform data. The data may not represent present land use, but gives some perspective historically.

Thirty-four samples were listed taken during the primary body recreational season May 15-September 30. Of these, fifteen exceeded the water quality standard. Load duration curve analysis was performed on this data set, with a result shown Figure VI-2.

The data set shows much higher flows were sampled and also higher concentrations from point sources were obtained. Reduction goals of 89.9% were calculated, compared to the 96.8% for the 2003 data set. The results are similar and provide a degree of confidence that the analysis is consistent. The slight increase in reduction goal may indicate that loading is increasing due to the increase of human population and activity in Canadian County.

Figure VI-2 Load Duration Curve – NC01 Fecal Coliform Data 1980-92



VII. Conclusions and Recommendations

The North Canadian River is in violation of Oklahoma Water Quality Standards with respect to pathogens. Samples taken from eight stations during summer 2003 along a reach from El Reno to Dale, Oklahoma showed repeated violations with respect to §785:45-5-16. ***Primary Body Contact Recreation.*** This verifies the 303-(d) pathogen listing.

Calculations utilizing load-duration curves show that the assimilative capacity of the river has been exceeded, in some areas by two orders of magnitude. The calculations show a strong nonpoint source component; however due to high flows during summer 2003, samples at lower flows were lacking. More data needs to fill this gap.

Further studies must differentiate the sources of pathogens – a bacteria source study should be conducted to determine how much of the pathogen loading comes from sources that can be regulated, such as humans and pets. Further pathogen sampling must also occur once the new stormwater regulations are implemented – pathogen sampling may be a component of the permit process.

Education is a huge priority – the population must understand the impact of nonpoint sources in the North Canadian River. The Phase II stormwater educational components can be a significant start to address this problem. The health issue must be made clear to the part of the population that uses this waterbody for recreation.

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