IMPLEMENTATION OF A NUTRIENT TRADING STRATEGY IN OKLAHOMA

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EXECUTIVE SUMMARY

The trading of effluent credits related to nutrients between point and nonpoint sources, is examined to determine the potential for a program in Oklahoma. A review of the literature reveals a number of considerations that potentially influence the success of these programs. Many of these factors are technical; however, a significant number are socio-political in nature.

The potential for trading of nutrient discharge credits is examined from technical and financial aspects. Technical means exist for the reduction of both point and nonpoint sources of nutrients, although much more information is known about on the effectiveness of point source controls. These methods have proven to be effective in reducing phosphorous levels in municipal wastewater treatment facilities by >90%. Information regarding the effectiveness of nonpoint source controls is less well-developed, although adequate information is present to support their use as effective controls. Nonpoint source controls are shown to be much less expensive than point source controls, driving the consideration of implementing these procedures as a more cost-effective means of reducing nutrient loading on a watershed scale.

Nutrient loading information was estimated from discharge monitoring reports from municipal wastewater treatment facilities and a nonpoint source nutrient loading database developed at Oklahoma State University. Data was divided by 8-digit Hydrologic Unit Code watersheds and organized by land use to produce an inventory of point and nonpoint sources of nutrients within these watersheds. The data indicates that several watersheds have significant (>30%) contributions of nutrients from both point and nonpoint sources and may warrant further consideration.

The Lower North Canadian watershed in central Oklahoma was examined as a potential case study for a nutrient trading program. The preponderance (>90%) of point source contributions and other factors makes this watershed unsuitable for a point source/nonpoint source exchange; however, the large number of point sources raises the possibility of trading between point sources.

A significant amount of information will need to be obtained before consideration of a nutrient credit program can proceed. Water quality under ambient conditions is poorly understood for most of the state's waters and conditions during runoff events is practically non-existent except in a few small-scale nonpoint source implementation watersheds. Authorities and responsibilities for conducting a nutrient trading program will be complex and much work needs to be done to address this issue in the area of administrative control.

INTRODUCTION

Effluent credit trading has been investigated as a means of achieving environmental goals for air and water for different chemical constituents. This approach to pollution control has also commonly been called pollution credit trading but for the purposes of this document it will be referred to as nutrient credit trading, or more simply, nutrient trading, since control of nutrient pollution is the focus of this report. Although trading schemes may be complex, their usefulness can be succinctly described as achieving the desired results (goals) with the greatest efficiency (least cost). This method of environmental remediation is not universally viewed as an appropriate or ethical means of achieving environmental protection; however, it does provide a practical approach for achieving pollution reduction in areas where this has proven to be difficult by other means. Some have expressed the opinion that allowing polluters to buy the permission to pollute is inherently unethical. The purpose of this report is to investigate the potential for addressing nutrient pollution in Oklahoma through pollution trading. Specifically, this report examines whether reductions in nutrient levels can be more efficiently achieved through reductions in nonpoint source (NPS) pollution loading as opposed to the use of nutrient removal technologies on point sources.

It has been proposed that the trading of effluent pollutants (nutrients) would provide many potential economic, environmental, and societal benefits (Table 1). It should be stressed that these are merely *potential* benefits and that all are not likely to occur in every situation. A list of undesirable factors related to nutrient trading could also be constructed.

Table 1. Potential Economic, Environmental, and Societal Benefits of Effluent Trading
(after EPA, 1996)

Economic Benefits

- reduces treatment-related costs for individual sources contributing to water quality problems
- allows dischargers to take advantage of economies of scale and treatment efficiencies that vary from source to source
- reduces overall cost of addressing water quality problems in the watershed

Environmental Benefits

- achieves equal or greater reduction of pollutant discharges for the same or less cost
- creates an economic incentive for dischargers to go beyond minimum pollution reduction and also encourages pollution prevention and the use of innovative technologies
- reduces cumulative pollutant loading, improves water quality, accommodates human population growth and development, and prevents future environmental degradation
- facilitates the achievement of broader environmental goals within a trading area, e.g., ecosystem protection, ecological restoration, improved wildlife habitat, endangered species protection, etc.

Social Benefits

- encourages dialogue among stakeholders and fosters concerted and holistic solutions for watersheds with multiple sources of water quality impairment

NUTRIENTS IN OKLAHOMA WATERS

Nutrient loading in Oklahoma is one of the most commonly reported sources of pollution and the effects can be witnessed through the increasing eutrophication of the state's reservoirs. Through state and local efforts, especially during the 1980s, most of the state's municipal wastewater treatment facilities were built, re-built, or significantly upgraded to decrease pollution of surface waters. Unfortunately, the major focus of environment damage from municipal waste water during this time was oxygen depletion and occasionally ammonia toxicity, and plants were not designed to address/reduce the primary cause of eutrophication - phosphorous. There are a number of effective technologies available to remove phosphorous from waste streams; however, these systems are relatively expensive and are seldom used without a permit requirement. Only one municipal wastewater treatment facility (WWTF) in the state (Tahlequah) has a phosphorous limitation in its OKPDES permit and actively practices phosphorous removal; one other is designed to remove phosphorous but does not utilize this section of the treatment plant.

Nonpoint sources of nutrient pollution have received increasing attention over the past decade as the awareness of its magnitude and as have increased in relative importance due to reductions in point source pollution. Control of nutrient pollution from nonpoint sources has proven to be much more difficult than that from point sources for several reasons: 1) the effects of engineering controls on points sources are easy to model while the effects of controls are relatively difficult to predict; 2) the effects of source controls are subject to high variability due to climate and other factors; 3) source controls on a watershed scale must cover wide areas and often involve many landowners; 4) maintenance of controls on private lands creates government control issues. All of these factors have had some influence on the failure to implement effective controls; however, the greatest reason for the lack of implementation has been a lack of funding. The federal government provided hundreds of millions of dollars for municipal WWTF construction during the 1980s while control funding since 1990 has been far less than 100 million. Given this disparity, it is not surprising that control of NPS pollution has been relatively unsuccessful.

With Oklahoma's increasing problem with nutrient pollution, it is certain that control policies, such as the implementation of TMDLs, will result in the call for reductions in nutrient loadings. The nature of current management systems require nutrient reduction on a wider geographical scale than before (mixing zone) and should eventually be accomplished at the watershed level. These management schemes set goals for nutrient levels in a waterbody and attempt to allocate pollution levels (credits) to various contributors. A reduction in the total number of credits available in a system is the desired goal and, given that each contributor is allowed to contribute a level of pollution, a reduction by one could be offset by the rise of another (as long as there is no net increase in the discharge of pollutants). In this scenario, pollution credits may be traded between sources or even traded in a bartering system. The most likely scenario is that a municipality may find that it is more cost effective to pay for implementation of controls than it is to pay for a costly upgrade of their wastewater treatment facility.

ISSUES IN POINT/NONPOINT SOURCE TRADING

Malik, et al (1994) raise several issues about point/nonpoint source trading which can be divided into two main points: trading as a subsidy scheme and the necessity for a strong government role.

1) The point/nonpoint market is likely to be one-sided unless there are enforceable requirements for abatement by nonpoint sources. In the absence of such requirements, point sources would have to reduce their loadings to be in compliance, but no actions would be required of nonpoint sources. As a result, all the buyers in the market would be point sources and all the sellers would be nonpoint sources. In this setting, the trading program would effectively be a subsidy scheme, with point sources inducing nonpoint sources to undertake abatement activities by subsidizing their activities.

Some of the standard problems associated with pollution subsidy schemes are likely to arise in the point/nonpoint source trading program. For instance, establishing the appropriate baseline from which to estimate loading reductions by nonpoint sources is likely to be an issue, given the difficulties in estimating nonpoint loadings. In addition, nonpoint sources may not have a strong motivation to change practices before implementation of a trading scheme if this could reduce potential incentives in the future. These problems could be mitigated, and some eliminated, by imposing minimum enforceable BMPs on nonpoint sources. Baseline loadings could then be defined in terms of the required BMPs. Nonpoint sources would likely be more receptive to proposals for trades from point sources if they already had to implement some controls.

2) Point/nonpoint source trading requires close government supervision of transactions. An appropriate authority must determine what control measures would reduce loadings by the required amount. This determination could not be left to the parties to the transaction, since they would have an obvious incentive to overstate the effectiveness of any proposed measures. Moreover, fairly sophisticated fate and transport analyses would have to be conducted to determine the effectiveness of the proposed measures. Neither the point source nor the nonpoint sources is likely to have the capability to undertake such analyses. Uncertainty about the costs of implementing nonpoint control measures is also likely to complicate the trading process. Control measures are likely to call for changes in farming practices and management inputs. Predicting the effects of these changes on farm profits is likely to be more difficult than predicting the costs of installing point source pollution control equipment. Here again, government participation may be necessary to provide credible and accurate estimates of the costs of nonpoint controls. It should be noted that this need for government involvement is likely to exist for any policy targeted to NPS pollution.

The importance of establishing an appropriate trading ratio is raised by many authors and is well described by Bartfeld (1993):

A trading ratio is defined as the amount of nonpoint source control that a point source discharger must undertake to generate a unit of credit at the point source. This ratio is generally set higher than one. Choosing the correct trading ratio is the most difficult, and perhaps the most important aspect of a trading program. If set too high, the economic incentives to trade will be reduced form the point of view of the point source, and trading may not occur. If set too low, water quality could be compromised, especially if the point source relies on trading to meet substantial levels of its discharge reduction obligation.

Because a trading ratio determines the number of point source credits generated by nonpoint source control, it alters the choice of treatment strategies. A simple example illustrates how the choice of a trading ratio affects the economics of point source decision-making. Assume that nonpoint source control costs $100 per unit controlled. Using a 2:1 trading ratio, a point source would need to reduce two units of nonpoint source loading to receive one unit of credit. In this example, the costs to a point source would be $200 for each unit of credit. Using marginal cost analysis, $200 would be the threshold at which a point source would choose nonpoint source control. A point source would select in-plant improvements up to $200 per unit reduced pollutant discharge. Above that cost, a point source discharger could meet its pollutant reduction obligations more cheaply through trading. With a higher trading ratio, nonpoint source control becomes more expensive from the perspective of the point source. Under a 3:1 trading ratio, each credit would cost the point source $300, because it would need to control three units of nonpoint source loading for each unit of credit received. Therefore, it would only choose the nonpoint source control alternative when its own control costs exceed $300 per unit, as opposed to $200 with a 2:1 trading ratio.

Despite their importance, economic factors are only one consideration in choosing the best trading ratio. Ideally, a trading ratio should reflect all relevant social costs, including the relative costs of abatement, environmental damage, monitoring, and enforcement, as these costs are borne by society. Most importantly, a trading ratio must incorporate both the uncertainty of nonpoint source control and the difference in environmental impacts caused by point versus nonpoint sources of pollution.

OPTIONS FOR NUTRIENT TRADING

Several different options are available for effluent (nutrient) trading (Table 2), although the focus of this project is on Option 4, the trade between point and nonpoint sources. When conducting a more detailed watershed scale assessment than is provided in this document, Option 2 should be given serious consideration. This is particularly applicable for watersheds having multiple point sources, especially where there are numerous small dischargers. In such cases, small dischargers may pool resources to assist the upgrade of a smaller number of point sources.

Table 2. Potential Nutrient Trading Scenarios (EPA, 1996)

1. Intra-plant trading which allows a single facility with more than one outfall to allocate pollutant discharges among outfalls in a cost-effective manner.
2. Point-point source trading which allows one point source to purchase or lease effluent reduction credits from other point source(s) who have reduced their pollutant discharges below permitted levels.
3. Pretreatment trading which allows facilities that discharge wastewater to POTWs to alter their pollutant load allocations to meet local effluent limitations more cost-effectively.
4. Point-nonpoint source trading programs which allow point sources to reduce environmental compliance costs and meet water quality standards by funding reductions in nonpoint source loadings within the same watershed, with these reductions typically being less expensive than additional source reductions.
5. Nonpoint-nonpoint source trading programs which allow nonpoint sources to reduce pollutant loads at other nonpoint source sites.

NUTRIENT TRADING IN PRACTICE

The practice of nutrient trading between point and nonpoint sources has been described as adhering to the following prototype trade:

Point source A trades its loading by some amount X by paying nonpoint source B to undertake control measures, such as altering its input use, adopting BMPs, or retiring land that are estimated to reduce its loadings by at least X.

This is a simple description of a complex process and there are a number of factors that must be considered as this process is contemplated (after USEPA, 1996):

1. Trading participants must meet applicable CWA requirements
    - preserves minimum levels of water quality protection mandated by the CWA
    - promotes fairness by allowing only those sources which meet fundamental requirements to benefit from trading

2. Trades must be consistent with water quality standards throughout a watershed, as well as the anti-backsliding policy and other requirements of the CWA, other federal laws, state laws, and local ordinances.
    - ensures a minimum level of water quality prior to implementation of a trading program
    - promotes fairness by allowing only those sources which meet baseline requirements to benefit from trading

3. Trades must be developed with a TMDL process or other equivalent analytical and management framework.
    - allocates pollution control responsibilities among covered dischargers using a process than can be easily utilized to document trades
    - data and analyses enable water quality managers to better understand and predict general effects of proposed trades

4. Trades must occur in the context of current regulatory and enforcement mechanisms
    - trading partners must work with federal, state, tribal, and/or local regulatory authorities on a case-by-case basis to ensure an appropriate level of accountability and enforceability

5. Trading boundaries must generally coincide with watershed or water body segment boundaries, and trading areas are of a manageable size
    - ensures that trading partners are affecting the same water body or stream/river segment, thus protecting against adverse local effects
    - boundaries may vary for different pollutants
    - boundaries may also be affected by the governing body or management structure of the trading program

6. Trading will generally add to existing ambient monitoring
    - Assessing the water quality impacts of trades may involve water quality analysis and modeling. The data required depend on the sophistication of the analysis, the pollutant(s) involved, and the hydrodynamic and quality characteristics of the receiving water. In general, data on current water quality conditions, predicted effectiveness of pollution reduction options, and assessment of trading results are required.

7. Careful consideration must be given to the types of pollutants traded.
    - Analysis of trades, including the potential impacts of spatial or temporal variations in loadings, is necessary to avoid local violations in water quality standards
    - USEPA does not currently envision a situation in which cross-pollutant (interpollutant) trading could work under current regulatory conditions and technical limitations

8. Stakeholder involvement and public participation must be key components of trading
    - educates stakeholder groups and the general public about the cost savings and environmental benefits of effluent trading
    - educates effluent trading program managers about the concerns of the general public
    - builds new alliances among stakeholders and between stakeholders and the general public, thus fostering better management approaches and more effective environmental protection

SELECTING WATERSHEDS FOR NUTRIENT TRADING PROGRAMS

Not all watersheds are eligible for consideration of nutrient trading programs. Obviously, a nutrient problem must exist for this control approach to be considered. One of the biggest hurdles for any state is the lack of effective monitoring at the watershed level where these programs could be implemented. Quantitative assessment of the impact of nonpoint source pollution is a time-consuming process and sufficient data is generally lacking. The NPS loading values used in this report have been estimated from land use and other factors. These values may differ significantly from actual loadings. It is unlikely that trading would be workable in a setting with numerous small point and/or nonpoint sources due to high costs associated with coordinating the actions of the parties involved would be too high. Trading is more feasible in settings where there are a small number of large point sources and a fairly small number of large nonpoint sources. In such settings, the costs savings from trading are likely to dominate the transaction costs associated with negotiating trades. Bartfeld (1993) and Senjem (1997) have identified several conditions which must be met for successful trading programs (Table 3).

Crutchfield et al. (1994) identified three screening criteria that coastal watersheds must meet to be considered suitable for potential effluent trading programs and produced a matrix which can be used as a decision-making tool in identifying potential watersheds (Table 4).

1) Both point sources and agricultural nonpoint sources must contribute significantly to total pollutant loadings of nitrogen, phosphorous, and/or sediment. Although coastal watersheds were considered minimally eligible for trading if both point and agricultural nonpoint sources contributed at least 20 percent of total pollutant loadings, researchers selected the 35 watersheds where point and nonpoint sources each accounted for at least 30 percent of total loadings for further analysis. A survey of 41,733 waterbodies in 37 states estimated that only 10% would meet this requirement (Apogee).

2) In order to decrease the administrative burdens and transaction costs associated with effluent trading programs, the coastal watershed should contain only a few point sources of significant size. Water quality data were used to estimate each point source’s contribution to total loadings of nitrogen, phosphorous, and sediment. Watersheds were deemed eligible for trading if the total loadings of the five largest point sources accounted for at least 75 percent of point source loadings of at least one pollutant. Fourteen of the 35 watersheds met the criteria for all three pollutants, 20 watersheds met the criteria for at least two pollutants, and 22 watersheds met the criteria for at least one pollutant.

3) The third screening criteria estimated the percentage of land in each watershed where BMPs could be applied to reduce agricultural nonpoint loadings. Overall, researchers concluded that BMPs to improve water quality could be implemented for approximately 30 percent of the agricultural land in the selected watersheds.

Table 3. Necessary Conditions For Trading Programs (Bartfeld, 1993).

Location. Point sources and nonpoint sources included in a trading program must be located in the same watershed.

Source. Both point and nonpoint sources must contribute significantly to the water quality problem. Too many sources attempting to trade could result in high transaction costs associated with individual trades.

Control Costs. For trading to be economically efficient for point source dischargers, nonpoint source controls must be less expensive than equivalent reductions achieved through additional point source controls. All point sources must meet technology-based effluent limitations for the pollutant(s) of interest.

Type of Pollutant. Conservative pollutants are the most likely candidates for trading because their adverse effects on water quality are felt through total accumulation. Timing and location of discharge within the watershed play only a minor role.

Water Quality Objective. A water quality objective is the environmental goal from which to develop and evaluate the success of a trading program. A TMDL is an example of this concept. Point source discharges must contribute, either individually or collectively, to a chronic violation of water quality standards, goals, or objectives.

Data and Modeling. This aspect is essential for establishing the relationship between pollutant loadings and water quality, assessing a waterbody's nutrient assimilative capacity, determining maximum allowable loadings, and in aiding allocation of loadings across different types of sources. Sufficient and reliable water quality and discharge data are critical.

Monitoring. Compared to conventional regulatory programs, any incentive-based control mechanisms forces greater reliance on water quality monitoring. This is especially true for point-nonpoint source trading, where achievement of water quality objectives depends to a great degree on the ability of nonpoint contorls to bear control burdens that would otherwise fall on point sources.

Enforcement and Compliance Mechanisms. Trading programs allow greater latitude in how and where reductions occur. Consequently, the need for detailed monitoring and enforcement is sharply increased. The success of a trading program could be eroded by insufficient mechanisms to ensure compliance and an inability to enforce against transgressors. Federal, state, and local laws and regulations authorizing the trading program must be identified. If any aspects of the trading program lack legal support, the trading program should be modified or the required laws and/or regulations developed. Laws or regulations that may discourage trading should also be identified and, if possible, amended.

Administration. A trading program cannot rely on market forces alone to achieve water quality objectives. An administrative agency must approve, amend, or reject trades, and monitor water quality results. Any costs incurred by the agency are real transactions costs and must be factored into trading program costs.

Time Period. The time period for which the trade is valid must be specified. A clear limitation on the time period of traded rights would help guard against establishment of property rights for a given level of pollution.

Community Involvement. A local community must support a trading program as a method to achieve water quality objectives. Public hearings are a necessary component to program development. Many factors must be considered in selecting appropriate watersheds for nutrient trading.

Table 4. Decision Matrix Used to Determine Trading Potential for Coastal Watersheds (Crutchfield et al., 1994)

If the number of pollutants for which Level 2 criteria (small number of large point sources) are met is:	And the value of the Level 3 criteria (percent of land with identified conservation needs) is:	Then the Potential for Point-Nonpoint Source Trading is:
None	Any Value	None
1, 2, 3	0-10%	None
1, 2, 3	11-25%	Low
1	26-50%	Low
2 or 3	26-50%	Medium
1	51-100%	Medium
2 or 3	51-100%	High

MANAGEMENT OF NONPOINT SOURCES NUTRIENTS

The management and control of NPS pollution presents many challenges. As previously mentioned, one of the biggest hurdles lies in the fact that there is so little information concerning the influence of NPS on water quality. In addition, nonpoint sources of pollution are relatively difficult to characterize due to a number of factors such as: the observability of runoff and loadings; natural variability; heterogeneous geographic impacts; transboundary effects; poorly described/assessed water quality impacts; and time lags between discharge and effects, especially in regard to nutrient pollution. Given that of nutrients are so poorly described on such a wide scale, it is imperative that the expensive process of data generation should be a high priority in state monitoring programs.

Even in the presence of adequate information concerning the influence of NPS of nutrients, a number of challenges are presented to decision-makers concerning effect control methods. Six considerations should be made when selecting tools for reducing NPS pollution: economic performance; administration and enforcement costs; flexibility; innovation; political feasibility; and acceptability to landowners. Traditionally, there has been some reluctance on the part of landowners to accept implementation of BMPs (Table 5).

Table 5. Constraints to Adoption of Alternative Management Practices
1. Basic information about the practice is lacking.
2. Cost of obtaining information is too high.
3. Complexity of the proposed production system is too great.
4. Practice is too expensive.
5. Labor requirements are excessive
6. Planning horizon is too short.
7. Supporting infrastructure is lacking.
8. Producer lacks adequate managerial skill.
9. Producer has little or no control over adoption decision.
10. Information about the practice is inconsistent and conflicting.
11. Available information is irrelevant.
12. Current production goals and new technology conflict.
13. The practice is inappropriate for the physical setting.
14. Practice increases risk.
15. Belief in traditional practices outweighs new technology.

Technological Feasibility

Implementation of BMPs for the control of nonpoint source pollution have proven effective in reducing nutrient runoff in a number of implementation and demonstration projects, with average reductions of 35 and 15% for phosphorous and nitrogen, respectively. Reductions in nutrient runoff may require the implementation of physical or management controls, which can be effective in reducing soil and phosphorous loss (Table 6, 7). Management efforts alone have been shown to be very effective in reducing the application of nutrients (averaging 56 and 23% for nitrogen and phosphorous, respectively) and consequently the potential for nutrient runoff (Table 8). A number of BMPs have been identified as effective in controlling nutrient pollution (Appendix 1).

Table 6. Average Phosphorus Removal of Various Stormwater Control Measures (EPA, 1984)

Stormwater Control Measure	Unit Area Loss Reduction (%)
Diversion of first flush materials to a storage/ percolation basin	99+
Retention/percolation	100
Detention in natural swales/percolation	92
Percolation and collection by underdrains	93
Detention/sedimentation	76

Table 7. Reported Changes in Average Annual Nutrient Application Rates on Land with Practice Adoption in 18 USDA Demonstration and Hydrologic Unit Area Projects, 1991-1995.

					Percent Reduction					
					Uplands		Ridge		Lowlands	
Farm Practice	Convent. Till	No-Till	Chisel Plow	Terrace	Soil Loss	P UAL	Soil Loss	P UAL	Soil Loss	P UAL
Corn	*			*	29	17-26	29	17-26	29	18-26
Corn			*		55	33-49	55	33-49	53	32-48
Corn			*	*	68	41-60	67	40-60	68	41-61
Corn		*			74	44-66	74	44-66	74	44-66
Corn-Soy	*				3	2	3	3	3	2
Corn-Soy			*		43	26-38	43	26-39	41	25-37
Corn-Soy		*			57	34-51	57	34-51	56	34-50
Corn-Soy		*		*	69	42-62	69	42-62	71	42-64
Corn-Soy-Wheat-Hay	*				84	50-75	84	50-75	85	51-77
Corn-Soy-Wheat-Hay	*	*			90	54-81	90	54-91	88	53-79

Table 8. Reported Changes in Average Annual Nutrient Application Rates on Land with Practice Adoption in 18 USDA Demonstration and Hydrologic Unit Area Projects, 1991-1995.			
Project	**Purpose**	**Nitrogen Reductions (lbs/ac)**	**Phosphorous Reductions (lbs/ac)**
AL HUA	N, P	129	106
IN HUA	N, P	21	30
MI HUA	N, P	41	18
NY HUA	N, P	14	21
DE HUA	N, P	118	96
IL HUA	N, P	117	36
OR HUA	N	52	na
MD DP	N, P	43	42
NC DP	N, P	72	na
WI DP	N, P	78	48
FL DP	N, P	41	3
MN DP	N, P	30	21
NE DP	N	21	na
TX DP	N, P	21	18
CA DP	N, P	47	11
Mean		**56**	**23**

MANAGEMENT OF POINT SOURCE NUTRIENTS

Municipal wastewater treatment facilities receive influent from a wide variety of domestic and commercial sources, especially in urban areas. The concentration of phosphorous in wastewater influent ranges between 6 and 20 mg/L (Table 9) and has been shown to be fairly consistent over time with an average of 9.3 mg/L in one study (Table 10).

Table 9. Phosphorous in Domestic Wastewater (WPCF, 1983)

	Concentration as P (mg/L)	Phosphorus Generation (Kg/yr)
Total	6-20	0.8-1.8
Organic	2-5	0.3-0.6
Inorganic	4-15	0.5-1.2

Table 10. Raw Influent: York River, Virginia (Randall, 1992)

Sample	BOD (mg/L)	TP (mg/L)	TKN (mg/L)
1	174	9.15	30.2
2	156	8.64	28.6
3	172	9.24	29.9
4	208	9.74	32.0
5	225	9.66	33.0
6	204	10.17	33.0
7	161	8.88	25.3
8	135	7.31	24.4
9	130	7.34	23.2
10	145	7.66	24.3
11	182	8.38	27.2
12	207	8.99	35.5
13	254	9.58	29.1
14	270	10.27	29.5
15	286	10.51	30.4
16	304	11.83	30.4
Mean	**209**	**9.26**	**28.4**

There are a variety of methods available for treating municipal wastewater including lagoons, oxidation ditches, activated sludge processes, fixed film (rotating biological contact, trickling filters), sequential batch reactors, and others. These processes are primarily designed to lower the load of organic substances in the effluent, as measured by biochemical oxidation demand (BOD) and total suspended solids (TSS). Typical plant design does not take into account the need for nutrient removal, beyond that which occurs through the normal treatment, although ammonia reduction may be required to protection wildlife. Because of this, nutrient removal from influents is generally low. Removal of BOD and TSS can exceed 90%, while nitrogen and phosphorous removal is low, 45 and 16%, respectively (Table 11). Passive systems, such as lagoons, often demonstrate a nutrient removal efficiency of >50% (Table 12), although phosphorous removal up to 90% has been reported (Assenzo and Reid, 1966).

Table 11. Constituent Removal by Activated Sludge, York River, Virginia (Randall, 1992)

Parameter	**Influent (mg/L)**	**Effluent (mg/L)**	**% Removal**
BOD	168	3.5	98
COD	411	27	93
TSS	154	9	94
TPO_4	9.2	7.7	16
SPO_4	-	6.8	-
TN	34.0	16.6	45
TKN	30.4	2.4	92
NO_x	0	14.2	-

Table 12. Wastewater Characteristics from Lagoon Systems (Middlebrooks et al, 1982)

	Mt. Shasta WWTF			**Moriarty WWTF**			**Ailey WWTF**			
Parameter	**Infl.**	**Effl.**	**% Red.**	**Infl.**	**Effl.**	**% Red.**	**Infl.**	**Effl.**	**% Red.**	***Avg. % Red.***
BOD (mg/L)	114	8	93	148	17	89	67	6	91	***91***
TSS (mg/L)	83	16	81	143	13	91	109	13	88	***87***
TKN (mg/L)	15.5	5.2	67	60	12.1	80	14.2	2.2	85	***77***
TP (mg/L)	4.68	2.72	42	10.3	2.8	73	4.96	2.45	51	***55***

Phosphorous Removal

Situations requiring further reduction in phosphorous levels involve the installation of more advanced treatment systems, which can be divided into two broad categories: chemical and biological. The level of treatment (phosphorous removal) required is the primary determinant of the cost of the system. A selection matrix for choosing between phosphorous removal options is listed in Table 13, many of which are currently in operation in the U.S. (Table 14). The efficacy of nutrient removal can be high and effluent phosphorous levels of <1.0 mg/L can reliably be achieved (Table 15, 16). More technical information regarding the degree of treatment for achieving low phosphorous levels is shown in Table 17.

Table 13. Process selection matrix for phosphorous removal for new plants and retrofitting of existing plants (Henze et al, 1995)

		1.0 mg/L P Effluent				2.0 mg/L P Effluent			
Process	Alone	w/MS	w/F	w/MS & F	Alone	w/MS	w/F	w/MS & F	Ability of Process to Remove Nitrogen
PhoStrip	Y	Y	Y	Y	Y	Y	Y	Y	No
Modified Bardenpho	M	Y	M	Y	Y	Y	Y	Y	Yes
A/O	M	Y	M	Y	Y	Y	Y	Y	No
SBR	M	Y	M	Y	Y	Y	Y	Y	Yes
UCT/VIP	M	Y	M	Y	Y	Y	Y	Y	Yes
Modified A.S.	M	Y	M	Y	Y	Y	Y	Y	No
Metal Salt	Y	-	Y	-	Y	-	Y	-	-

Alone: Ability of alternative to meet effluent limits alone based on T_{BOD}/T_P ratio being above 20.
M: marginal for meeting effluent limits
Y: Will meet effluent limits
MS: Metal salt addition to secondary clarifier effluent
F: Filtration of secondary clarifier effluent
MS&F: Metal salt addition to secondary clarifier and secondary clarifier effluent filtration.
A/O: Two state process involving an anaerobic and aerobic stage.
SBR: Sequencing batch reactor
Bardenpho process: A combination process involving two anoxic and two aerobic reactors
A.S.: Activated sludge

Table 14. Summary of Biological Nutrient Removal WWTFs by Process Type (WEF, 1998)			
Process Type	Number in Operation	Process Type	Number in Operation
Modified Bardepho	34	Multiple Sludge	9
Modified Ludzack-Ettinger	32	PhoStrip	8
Sequencing Batch Reactor	26	Other Anoxic/Aerobic Processes	8
Ditch Nitrification	26	Bardenpho	7
Schreiber	23	Phase Isolation Ditch	7
A/O	20	Intermittent Aeration	4
Denitrification Filters	20	UCT/VIP	3
A2/O	18	Immobilized Cells	3
Oxidation Ditch w/ Integral Anoxic Zone	15	Submerged Packed Cells	2
Oral Simpre	10		

Table 15. Effluent from Biological Nutrient Removal Systems (WEF, 1998)				
Plant #	**Soluble P**	**Total P**	**Ammonia**	**TKN**
1	0.28	0.39	0.15	1.28
1	0.50	0.79	0.05	1.61
1	0.40	0.79	0.55	1.81
1	0.39	0.53	0.10	1.23
1	0.26	0.43	0.29	1.50
1	0.20	0.42	0.10	1.44
1	0.21	0.81	-	-
1	0.15	0.64	-	-
2	0.22	0.45	-	-
3	-	0.66	-	-
4	0.50	0.76	0.50	1.34
5	0.49	0.52	-	-
Mean	**0.33**	**0.60**	**0.25**	**1.46**

Table 16. Monthly Average Performance Bonnybrook WWTF, Calgary, Alberta (Randall et al, 1992)						
	BOD (mg/L)		**TSS (mg/L)**		**Total P (mg/L)**	
Month	**PE**	**FE**	**PE**	**FE**	**PE**	**FE**
January	154	7	117	11	5.3	1.4
February	141	7	89	12	4.6	1.1
March	144	5	79	7	4.8	0.5
April	128	4	79	7	4.5	0.5
May	128	4	79	7	4.5	0.5
June	104	3	66	6	4.1	0.4
July	101	3	63	7	3.8	0.6
August	100	2	60	6	3.7	0.6
Average	**111**	**2**	**65**	**7**	**4.1**	**0.4**

PE = primary effluent
FE = final effluent

Table 17. Treatment Criteria for Achieving Different Phosphorous Levels.	
Effluent concentration 2-3 g P/m3	Biological phosphorus removal Simultaneous precipitation, Fe2+ or Al3+, Molar Ratio 0.8 Precipitation Al3+, Molar ratio 1.0
Effluent concentration 1-2 g P/m3	Simultaneous precipitation, Fe2+ or Al3+, Molar ratio 1.0 Pre precipitation, Ca2+, Fe3+ pH 8-9, Molar ratio (Fe3+) 1.0 Direct precipitation Ca2+, pH 10-11 Direct precipitation Al3+, pH 6.5-7.2, Molar ratio 1.5 Post precipitation Al3+, pH 6.5-7.2, Molar ratio 1.0
Effluent concentration 0.5-1 g P/m3	Simultaneous precipitation, Fe2+ or Al3+, Molar ratio 1.5 Simultaneous precipitation + pre precipitation or soil ponds, Fe2+ or Al3+, Molar ratio 1.5 Post precipitation Al3+, pH 5-5-6.5, Molar ratio 2.0. Direct precipitation Ca2+, pH 10-11 + sea water Pre precipitation, Ca2+, Fe3+ pH 9-10, Molar ratio (Fe3+) 1.5
Effluent concentration 0.3-0.5 g P/m3	Simultaneous precipitation, Fe2+ or Al3+ + contact filtration Fe2+ or Fe3+, Molar ratio both processes 2.0. Post precipitation, Al3+, pH 5.5-6.0, Molar ratio 2.0, + contact filtration, Fe3+, Molar ratio 2.0
Example of processes of technical-financial relevance to obtain given effluent concentrations for total phosphorus. Molar Ratio – Moles of metal ions per mole of total phosphorus in the influent.	

COSTS OF NUTRIENT MANAGEMENT PROGRAMS

Control of nutrient pollution is expensive from both point and nonpoint sources since point source controls require advanced treatment facilities and nonpoint sources may cover hundreds of square miles. It is difficult to predict the actual cost of nutrient management programs because of the many factors which confound calculations; however, some generalities about costs are known. In this section, an attempt will be made to describe the range of costs that have been experienced in areas where control practices have been implemented. Although nutrient trading has been widely discussed as a management alternative, implementation has been infrequent. In areas where it has been used, the costs comparisons between point and nonpoint control measures have shown that control of nonpoint sources can be less expensive (Table 18).

Table 18. Estimated Marginal Phosphorus Abatement Costs for Point and Nonpoint Sources (Nowak, 1991)

Location	Abatement Cost	
	Point Source	**Nonpoint Source**
	$/pound	
Dillon Reservoir, CO	860-7,861	119
Upper Wicomico River, MD	16-88	0-12
Honey Creek, OH	0-10	0-34
Boone Reservoir, TN	2-84	0-305

Point Source Costs

Point source costs involve either the upgrade of existing plants with new technologies or construction of an entirely new facility. Given that most of the municipal wastewater treatment facilities in Oklahoma are fairly new, it is unrealistic to expect new facilities to be built in response to a need for greater nutrient control. Upgrading existing facilities is much more economically feasible; however, the reduced cost may lessen the incentive for nutrient trading. The costs of nutrient removal facilities have been combined with their respective design flow to generate mathematical equations for predicting costs of other facilities (for example it cost $188,503 to upgrade the plant (24.6 MLD capacity) at York River, VA to biological nutrient removal (Table 19). Estimated operation and maintenance costs of various plants are provided in Tables 20, 21, and 22. These figures will be useful in estimating the costs of upgrading plants in Oklahoma.

Table 19. Summary of Reported BNR Capital Costs (WEF, 1998)				
Process Type	# of Plants	R2	Best-Fit Equation	Upper 90 Percentile Equation
Two-stage (A/O and modified Ludzak-Ettinger)	20	0.80	$\$ = 2.0 \times 10^4 Q^{0.647}$	$\$ = 9023 \times Q^{0.779}$
Four- & Five-Stage (Bardenpho)	17	0.77	$\$ = 1/[(1.02 \times 10^{-3}/Q) + 4.1 \times 10^{-8}]$	$\$ = 1/[(7.62 \times 10^{-4}/Q) + 6.14 \times 10^{-8}]$
Upgraded Plants	7	0.78	$\$ = 240Q + 3.34 \times 10^6$	$\$ = 335Q + 7.51 \times 10^6$
Expanded and Upgraded Plants	23	0.62	$\$ = 395Q + 5.70 \times 10^6$	$\$ = 513Q + 8.97 \times 10^6$
New Plants	44	0.95	$\$ = 636Q + 2.88 \times 10^6$	$\$ = 9690Q + 5.70 \times 10^6$

Q = Design capacity in m^3/d

Table 20. Summary of Reported Biological Nutrient Removal - Operations and Maintenance Costs			
Reported Unit Operating Costs - $/100m³ ($/1000 gal)			
Cost Component	**Average**	**Maximum**	**Minimum**
Chemicals	1.43(0.054)	5.92(0.224)	0.002(0.00008)
Labor	8.40(0.318)	32.50(1.23)	2.09(0.079)
Maintenance	1.84(0.070)	5.07(0.192)	0.21(0.008)
Miscellaneous	8.61(0.326)	34.61(1.31)	0.72(0.027)
Power	5.13(0.194)	13.58(0.514)	0.32(0.012)
Total	**22.56(0.854)**	**57.07(2.16)**	**6.66(0.252)**

Table 21. Costs to Achieve Various Effluent Phosphorous Concentration (*per capita* costs) (1980 $$) (USEPA, 1984)			
Effluent Total Phosphorous Concentration (mg/L)	**Capital**	**O & M**	**Total**
4.0	12.15	6.25	18.40
1.0	12.70	8.18	20.88
0.5	13.12	8.85	21.97
0.3	17.93	10.74	28.67
0.1	17.52	33.23	50.75

Table 22. Chemical Phosphorous Treatment Costs at Municipal Wastewater Treatment Facilities (USEPA, 1984)			
Total Cost ($/capita/yr)	Plant Sizes Represented in Sample (mgd)	P Content of Influent (mg/L)	P Content of Effluent (mg/L)
4.01	1.4-17.5	-	1.0
2.48	1	10	-
1.51	10	10	-
4.31	1	10	-
4.20	5	10	-
3.65	1	10	-
3.47	5	10	-
2.35	6-950	-	-

Nonpoint Source Costs

Nonpoint source costs are relatively difficult to predict, compared to point sources, for several reasons. The primary reason is that the specific nature of loading within most individual watersheds or the relative degree of effort that it would take to control these inputs are not known. In some cases, such as nutrient management through better planning and soil testing, costs would be very modest. In other cases, such as severe erosion or extensive areas of unpaved roads, the costs would be very high. The inventory of nonpoint source loadings by land use provides an excellent place to start the necessary monitoring that would be required to assess control requirements.

Nonpoint source controls must be both technically and economically efficient, as well as verifiable, for a trading program to be successful. The economically efficient solution to pollution can be defined by three conditions:

1) For each input and each site, the marginal net private benefits from the use of the input on the site must equal the expected marginal external damages from the use of the input.
2) A site should be brought into production as long as the profits on this site are larger than the resulting expected increase in external damage.
3) Technologies should be adopted on each site such that the incremental impact of each technology (relative to the next best alternative) on expected social benefits is greater than or equal to the incremental impact on expected damages.

Costs for the control of nutrients vary greatly, further complicating the process of estimating the costs of an implementation strategy (Tables 23, 24). The amount of nutrient removed per effort may also be relatively expensive (Table 25); therefore, a control strategy must focus on which process results in the greatest nutrient removal at the least costs.

Table 23. Costs of Various Rural Runoff Control Measures (EPA, 1984)

Practice	**Unit Cost**
Permanent Vegetative Cover	$125.00/acre
Animal Waste Management System	$30,000.00/unit
Stripcropping System	$6.00/acre -$20.00/acre
Diversion System	$0.70/ft. - $5.00/ft.
Waterway System	$200.00/acre
Conservation Tillage System	$0/acre - $9.00/acre
Stream Protection System	$2.00/ft.
Sediment Retention, Erosion or	
Water Control Structures	$2,500.00/unit
Tile Drain	$.80/ft.
Contour Farming	$4.00/acre
Terrace System	$1.00/ft.
Cover Cropping	$18.00/acre
Fertilizer Management	$6.00/acre

Table 24. Costs of Various Runoff Control Measures (EPA, 1984)

Method		**Cost ($/ft)**
Diversion dike		4.24
Runoff interception trench		7.22
Strawbale sediment barrier		2.49
Sandbag sediment barrier		3.67
Filter berm		8.08
Filter fence		3.31
Filter inlet		2.30
Siltation berm		8.52

Table 25. Pollutant Removal Efficiencies of Street Cleaning Operations (EPA, 1984)		
Pollutant	**Average Removal (lbs./curb-mile)**	**Average Unit Cost ($/lb. Removed)**
Total Solids	205	0.11
Suspended Solids	103	0.22
Chemical Oxygen Demand	22	1.04
Biochemical Oxygen Demand	11	2.07
Orthophosphate	0.03	951.4
Kjeldahl Nitrogen	0.96	46
Lead	0.57	39.2
Zinc	0.11	191.4
Chromium	0.09	246.6
Copper	0.18	134.4
Cadmium	0.005	35376

IMPLEMENTING A NUTRIENT TRADING PROGRAM IN OKLAHOMA

The biggest barrier to the implementation of nutrient trading programs in Oklahoma is the lack of water quality and loading data. It has been stressed that much more accurate data than is currently available will be required for an effective program to be implemented. Long-term monitoring and modeling of individual watersheds is the next step towards approaching the undertaking such a program; however, there are a number of other steps that should be taken before implementation can be realized (Table 26).

Table 26. Implementation Steps for Point-Nonpoint Source Pollutant Trading Programs (after Senjem, 1997)

1. The administering agency must define a trading ratio for point and nonpoint sources of the pollutant(s) of interest.
2. The trading ratio should include a safety factor to compensate for the uncertainties associated with quantifying, monitoring, and enforcing reductions in nonpoint source pollutants.
3. The administering agency must establish pollutant reduction targets and collect sufficient data to accurately assess progress toward the selected targets.
4. The water quality goal must force point sources and/or nonpoint sources to take action to reduce their pollutant loadings.
5. The administering agency must designate a schedule for achieving required loading reductions.
6. Individual point sources must determine whether it is less expensive to meet their reduction requirements by sponsoring nonpoint source controls, by installing additional abatement equipment, or by implementing pollution prevention measures at their facilities.
7. In order to make the decision described in Step 6, the point source must obtain information on the effectiveness of nonpoint source BMPs. Program participation may be encouraged if this information is provided by the administering agency.
8. Trading agreements should be based on the predicted quantities of pollutant reduction resulting from the installation of approved BMPs.
9. All nonpoint source reductions must be equivalent, additional, and accountable.
10. An institutional structure to facilitate trading and monitor the results of the ETP must be established.
11. The roles of all participants (stakeholders) in the ETP, including point sources, nonpoint sources, and the administering agency, must be clearly defined.
12. The administering agency must ensure that BMPs are properly implemented and maintained. The administering agency should also instigate a water quality monitoring program to determine the long-term impacts of the ETP.
13. Demonstration projects may be useful to introduce the concept of ETPs to regulators, pollutant sources, and the general public.

Selecting Watersheds in Oklahoma for Nutrient Trading

Methods

For the purposes of this report 8-digit HUC watersheds were used which effectively divides the state into 44 watersheds or management units for the purpose of analyzing the feasibility of nutrient trading. It is unlikely that larger scale (6-digit) watersheds could be used for management due to the potential for confounding factors such as the distance of sources from a receiving water and the sheer size of the watersheds at this scale. On the other hand, smaller watersheds (11-digit) could be used but may not provide enough land (generate enough credits) for NPS management potential. In reality, any real attempt to institute nutrient trading will have to rely on a customized watershed size that is likely to be a hybrid of the 8- and 11-digit scale. The names of the 6-digit watersheds from which the names of the corresponding 8-digit watersheds can be derived are provided in Table 27.

Table 27. Verbal Descriptions of 6-Digit HUC Watersheds

6-Digit HUC	**Description**
110400	Upper Cimarron
110500	Lower Cimarron
110600	Arkansas - Keystone
110701	Verdigris River Basin
110702	Neosho River Basin
110901	Middle Canadian
110902	Lower Canadian
111001	Upper Beaver
111002	Lower Beaver
111003	Lower North Canadian
111101	Robert S. Kerr Reservoir
111201	Prairie Dog Town Fork Red
111202	Salt Fork Red
111203	North Fork Red
111301	Red-Pease: Red River
111302	Red – Lake Texoma
111303	Washita
111401	Red Little

Both phosphorous and nitrogen can be used for nutrient trading. For this report, phosphorous has been chosen since it is often the most critical limiting nutrient and the one for which management is most needed. In some cases, nitrogen management may be relatively more important and NPS management activities are likely to reduce both nutrients. Point source upgrades of WWTFs are most often directed towards phosphorous removal as it is most common source of nutrient problems. Nonpoint source nutrient loadings were obtained from a state inventory of landuse and loadings organized by watershed.

This project focused on nutrients from municipal wastewater treatment facilities as they are the most common point source of nutrients. In addition, more information is available concerning treatment efficiency and expected influent/effluent quality. The study used an estimated phosphorous level of 10 mg/L for WWTF influent in estimating loadings based upon a review of the literature. Conventional treatment is estimated to remove 5-50% of influent phosphorous; however, this is largely dictated by operational systems in place. Since only one plant in Oklahoma is required to monitor for phosphorous, actual efficiencies are unknown; therefore, this report assumes a 20% reduction or an average phosphorous effluent of 8.0 mg/L. Obviously, extensive monitoring of current point and nonpoint sources would have to occur before any watershed could be seriously considered for a trading program. Discharge rates were calculated from periodic measurements made at individual facilities which were averaged to derive annual discharge rates. This value combined with the estimated phosphorous concentration in municipal wastewater effluent produces an estimated discharge per facility.

The annual phosphorous loading in the 65 8-digit HUC watersheds was generated by combining estimated loadings by land use from nonpoint sources (Storm et al., 2000) with estimated discharge. Point source discharge estimates were also organized by location within 8-digit HUCs. The data for all landuses and individual facilities are organized by watershed (Appendix 2). The total point and nonpoint source loading by 8-digit HUC were then tabulated along with the percent contribution from each for watersheds with both point and nonpoint sources (Table 28).

Table 28. Annual Phosphorous Loading by 8-Digit HUC Code					
Watershed	**Size (km2)**	**NPS Loading (Kg/yr)**	**PS Loading (Kg/yr)**	**% NPS**	**% PS**
11090202	4750	71668	1526953	4	96
11100302	4647	191409	767294	20	80
11070107	2944	108158	380178	22	78
11050002	8029	222147	316876	41	59
11110101	3385	270088	234970	53	47
11130202	2080	71956	161974	31	69
11100303	6574	226407	141611	62	38
11110104	3733	506427	106817	83	17
11130303	6498	230771	87926	72	28
11130302	8266	200208	59518	77	23
11090203	2537	13070	11100	46	54
11060004	4982	161144	54858	75	25
11070209	5900	271216	53021	84	16
11070105	1851	170607	52423	76	24
11090204	5134	127109	49812	72	40
11120303	3564	70592	46292	60	40
11070206	1858	146988	45451	76	24
11130208	2235	42504	39033	52	48
11110103	2291	99853	36399	73	27
11100301	4790	29649	35003	46	54
11110105	3475	352672	34949	91	9
11140101	1450	116218	29958	80	20
11140107	2641	54154	29770	65	35
11060006	5479	283628	19765	93	7
11140105	4719	80740	19455	81	19
11070106	3003	110292	15316	88	12
11060005	965	106265	16739	86	14
11090201	5162	24856	15383	62	38
11130201	3810	71446	11144	87	13
11130102	972	21694	10713	67	33
11070103	1406	101409	9639	91	9
11050003	3589	125732	89265	58	42
11130304	1878	67855	9163	88	12
11110102	2627	279131	8167	97	3
11140103	3684	87865	7935	92	8
11120202	1838	30589	6275	83	17
11120302	2227	7899	4648	63	37
11140104	2602	100402	3608	97	3
11130210	1470	63963	2258	97	3
11140106	1022	93971	2247	98	2
11130203	2850	121292	1262	99	1
11140102	1755	72351	797	99	1
11060001	2589	55394	636	99	1
11130101	1296	31605	346	99	1

Eligible Watersheds

Eligible watersheds were defined as having at least a 30% contribution from both point and nonpoint sources as suggested by other studies which produces 13 potential candidate watersheds (Table 29). Further study may indicate that an alternative ratio is warranted. Three watersheds were dominated (>70%) by point sources while twenty-nine were dominated by nonpoint sources. Twenty-one watersheds had no identified WWTF discharges (Table 30). Three of the twelve potential watersheds did not have a major WWTF which reduces their potential for participation in a trading scheme.

Table 29. Watersheds with ≥30 percent Phosphorous Loading from Point and Nonpoint Sources

8 –digit watershed	**Area ($km^{2)}$**	**Loading %**	**PS Loading %**	**# Point Sources**	**# Major PS (>3.8 MLD)**
11050002	8029	41	59	16	5
11090201	5162	67	33	3	1
11090203	2537	46	54	2	0
11100301	4790	46	54	3	1
11100303	6574	62	38	16	2
11110101	3385	54	46	13	3
11120302	2227	68	32	1	0
11120303	3564	60	40	4	3
11130102	972	67	33	2	0
11130202	2080	31	69	1	1
11130208	2235	52	48	3	1
11105003	3589	58	42	10	4
11140107	3641	65	35	3	1

Table 30. 8-digit HUC Watersheds With No Point Source Discharges (municipal waste water treatment)

11040001	11100102
11040002	11100103
11040006	11100104
11040007	11100201
11040008	11100203
11050001	11120304
11070205	11130301
11070207	11140108
11070208	11140109
11090103	11170103
11100101	

NUTRIENT TRADING IN THE LOWER NORTH CANADIAN RIVER WATERSHED IN CENTRAL OKLAHOMA

The Lower North Canadian River watershed in Central Oklahoma covers 5809 km2 and stretches from Canton to Dale. This watershed is a combination of the entire 8-digit 11100301 watershed combined with 2 11-digit (11100302010, 11100302020) watersheds from 11100302. Thirteen municipal WWTFs discharge into the basin with average and design flows of 242 and 388 MLD, respectively. The major landuses in the watershed are range (43%) and small grain (36%) production; however, there is a significant urban area around Oklahoma City (9.6%) (Table 31). Small grain (43%), urban areas (26%), and pasture (18.3%) are the greatest contributors of phosphorous. Point and nonpoint sources contribute 92.4% and 7.6% of phosphorous, respectively. Five of the municipal WWTF point sources have a design flow greater than 3.78 MLD (376 MLD total) and have the greatest potential for upgrades to nutrient removal. Costs can be estimated for biological nutrient removal of between 80 and 240 million dollars for these four plants using the formulas for different designs (Table 32):

Two-Stage	$\$ = 2.0 \times 10^{4} \times (376{,}000)^{0.647}$	=	\$80,942,485
Four- and Five- Stage	$\$ = 1/[(1.02 \times 10^{-3}/376{,}000) + 4.1 \times 10^{-8}]$	=	\$22,727,273
Bardenpho	$\$ = 240(376{,}000) + 3.34 \times 10^{6}$	=	\$93,580,000
Upgraded and Expanded	$\$ = 395(376{,}000) + 5.70 \times 10^{6}$	=	\$151,860,000
New Plants	$\$ = 636(376{,}000) + 2.88 \times 10^{6}$	=	\$242,016,000

Table 31. Nutrient Sources in the Lower North Canadian Watershed			
NONPOINT SOURCES			
Land Use	Area (km2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Bare	5	961	110
Forest	42	794	21
Pasture	557	18273	10596
Range	2497	21094	6380
Row Crop	42	5967	994
Small Grain	2110	84755	24785
Urban	556	119314	15117
Total	5809	251158	58003
POINT SOURCES			
WWTF	Average Flow (MLD)	Design Flow (MLD)	Total P Export (Kg/yr)
Watonga	2.340	1.890	6854
Mustang	4.336	5.670	12691
Yukon	7.386	11.340	21620
Valley Brook	0.166	2.570	487
Oklahoma City (northside)	194.15	302.4	568424
Oklahoma City – Dunjee	0.166	0.737	487
Jones	0.374	0.548	1099
Spencer	0.662	1.134	1938
Harrah	1.111	1.474	3250
Del City	10.433	11.340	30544
Midwest City	18.870	45.360	55251
McCloud	0.737	1.134	2154
Choctaw	1.743	2.835	5102
Total	242.474	388.432	709901

Table 32. Costs of Upgrading WWTFs in the Lower North Canadian Watershed					
	Treatment Type				
Facility	Design Flow (m3/d)	Two-Stage	Bardenpho	Upgraded & Expanded	New Plant
Oklahoma City	302,400	70,301,795	75,916,000	125,148,000	195,206,400
Mustang	5670	5,365,352	4,700,800	7,939,650	6,486,120
Yukon	11340	8,401,651	6,061,600	10,179,300	10,092,240
Del City	11340	8,401,651	6,061,600	10,179,300	10,092,240
Midwest City	45360	20,601,434	14,226,400	23,617,200	31,728,960

Upgrading the five facilities to reduce phosphorous effluent concentrations to 1.0 mg/L, the system would result in an approximate phosphorous loading decrease of 602,466 Kg/yr or a 84.9% decrease in point source loading. Upgrade of the Oklahoma City – North Canadian facility alone would result in a 70.1% decrease or a reduction of 497,375 Kg/yr.

Small grain, urban areas, and pasture represent the greatest potential for control of nonpoint sources of phosphorous. Urban nonpoint sources would be relatively difficult to control since there are so many sources and should probably be excluded from consideration. Removing 90% of phosphorous from small grain and pasture areas would result in a reduction of 31,843 Kg/yr or 4.1% of the phosphorous in the watershed.

Given the overwhelming role of point source discharges in the watershed, the lower North Canadian watershed does not appear to be a good candidate for a PS/NPSs nutrient exchange program. Although it is not possible to calculate the actual costs of potential controls, they would likely be far less than those listed for point source upgrades; however, even if 100% of NPS were removed, they would be unlikely to significantly affect water quality in the watershed. Additional factors which mitigate point/nonpoint source exchange programs are: 1) populations are likely to increase in the watershed, especially in urban areas, 2) point sources of phosphorous will increase in relative importance as facilities approach design capacity; and, 3) a 2:1 or 3:1 trading ratio further complicates the availability of adequate land for implementation of NPS controls.

A more likely scenario would involve Option 2 (Table 2) which involves nutrient trading between point sources as the many small WWTFs in the basin might benefit from paying the larger plant for controlling its phosphorous levels. This report focused on municipal WWTFs and there are likely other point sources of nutrient discharge within the watershed. A more thorough inventory of these minor sources and their relative contribution to phosphorous loading could be conducted to make this determination as, collectively, they might make a significant contribution to phosphorous loading. These facilities could then be included in a nutrient trading program.

CONCLUSIONS

Nutrient trading programs offer a unique perspective on environmental management and may present a more effective approach for addressing pollution problems where both point and nonpoint sources of nutrients are present. Many questions must be answered before implementation of such a program can be considered in a watershed as illustrated by the 10 points listed below (after Edwards and Canter, 1998):

1. Watershed Suitability:

- Does the watershed (or watershed segment) have a clearly defined geographic border?
- Are temporal variations in flow well understood?
- Do existing water quality conditions or other circumstances within the watershed encourage the use of a nutrient trading program?
- Are there circumstances within the watershed that would discourage the use of a nutrient trading program?

2. Pollutant Type

- Are all forms of the pollutant of interest interchangeable with regard to their impacts on ambient water quality?
- Do the environmental effects of the pollutant of interest result more from total loading over time than local, short-term effects?
- Can mass- or concentration-based limits be established for the pollutant of interest?

3. Trading Market Size and Characteristics

- Have all sources of the pollutant of interest been identified?
- Are the relative contributions of all source categories (point, nonpoint, and background) known?
- Are temporal variations in loadings of the pollutant of interest well understood?
- Are there significant differences in marginal abatement costs among sources in the same category and/or sources in different categories?
- Could sources and/or governmental entities within the watershed be unwilling to trade?
- Are there unique circumstances that may influence the behavior of market participants?

4. Legal Authority

- Are there water quality standards, goals, and/or objectives that can be used as a basis for the nutrient trading programs?
- Do existing federal, regional, state, and/or local laws clearly support effluent trading as a compliance alternative, or could they be amended to do so?
- Is there an existing agency with sufficient authority to implement and enforce a nutrient trading program, can such authority be conferred on an existing agency, or can such an agency by created?
- Does the implementing agency have sufficient authority to require all contributing sources to meet their discharge allocations?

5. Administrative Acceptability and Capability

- Does the administering agency have sufficient knowledge and information to designate the maximum allowable pollutant loading for the watershed, to allocate portions of that loading to all dischargers, to evaluate proposed trades, and to monitor the results of individual trades as well as the overall trading program?
- Is the administering agency willing to use effluent trading as a management strategy to supplement traditional regulation?
- Does the administering agency have sufficient resources to design and implement a nutrient trading program?

6. Specific Policies, Procedures, and Trading Rules

- If nonpoint sources are to be included in the nutrient trading program, do policies or procedures account for their inherent variability?
- Have procedures been clearly defined for the following aspects of the nutrient trading program? determination of the maximum allowable pollutant loading for the watershed allocating portions of the loading to all sources within the watershed that discharge the pollutant of interest types of trades that will be allowed trading ratio
- Have rules or procedures been clearly defined for the following operational aspects of the nutrient trading program?
- quantifying and certifying pollution reduction credits
- quantifying the environmental impacts of trades
- application procedures for proposed trades
- administrative procedures for the evaluation of proposed trades
- time periods that trades remain in effect
- treatment of banked or shutdown credits
- reporting and record keeping requirements
- Will non-dischargers, such as environmental groups, be allowed to purchase and retire pollution reduction credits?

7. Pre- and Post-Trade Monitoring

- Are responsibilities for pre- and post-trade source and ambient water quality monitoring clearly defined?
- Have specific monitoring protocols, including record keeping and reporting procedures, been clearly established for both source and ambient water quality monitoring?
- Will source monitoring requirements discourage trading activity?

8. Enforcement Mechanisms

Can trading agreements be effectively enforced for each source category?
Should uncontrollable circumstances for both point and nonpoint sources be considered in the enforcement process?

9. Program Evaluation

- Are responsibilities for evaluating nutrient trading program performance clearly defined?
- How often will the nutrient trading program be reviewed?
- Have the criteria that will be used to evaluate nutrient trading program performance been specified?

10. Public Involvement

- Was the public, including industries and municipalities, actively involved in nutrient trading program design and operation?
- In general, did industries, municipalities, government agencies, and the public support the development of the nutrient trading program?
- Does nutrient trading program include any educational and/or outreach efforts designed to increased public support?

For any of the watersheds in Oklahoma, and for most of the questions listed, the answer is that the required information is absent or insufficient. An enormous amount of additional work will be necessary to gather additional information before any watershed can be seriously considered for nutrient trading. Given current budgets and staffing, it seems unlikely that adequate resources can be directed towards approaching this subject on a statewide level; therefore, only those few watersheds with some identified potential should currently be considered. Watersheds with completed or planned TMDL development offer an additional factor to be considered. For the one watershed where this concept has been considered (Lower North Canadian), it appears that point sources are too dominant for NPS/PS trading to be effective.

Despite the absence of sufficient technical information, progress could be made in the areas of administration, authority, and information gathering. With the fractured nature of state environmental authority, significant cooperation will be required to implement trading programs, especially for such factors as monitoring responsibility. The literature emphasizes the need for a strong government role in trading programs and a focused effort should be made on determining the legal authority for implementing and/or enforcing NPS controls on private lands. Finally, adequate information concerning water quality conditions is available for few, if any, watersheds on the scale discussed in this document, especially related to conditions during runoff events. Given the high degree of variability in water quality during these conditions, a large body of information will have to be gathered for trading to be contemplated within a reasonable degree of certainty.

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Appendix 1

NRCS conservation practices, pollutants potentially controlled, and sources of pollutants (USDA-NRCS, 1977)

NRCS Codes	Practice	Pollutant to be controlled							
		TP	OP	TN	TKN	ON	AM	BOD	FC
575	Animal Trails and Walkways						**		**
310	Bedding	**		**					
317	Compost Facility	**		**		**	**		**
327	Conservation Cover	**	**	**					
322	Channel Vegetation	**	**		**		**		
324	Chisel Tillage	**	**	**	**	**	**		
328	Conservation Crop Rotation	**	**	**	**	**	**		
330	Contour Farm	**	**	**	**	**	**		**
335	Controlled Drainage	**	**	**	**	**			
340	Cover and Green Manure Crop	**		**					
342	Critical Area Planting	**		**	**	**	**		**
352	Deferred Grazing		**	**	**		**		**
362	Diversion	**			**		**		
382	Fencing	**	**	**	**	**	**		
386	Field Border	**				**			**
393A	Filter Strips	**		**	**	**	**		**
412	Grass Waterway	**		**	**		**		
548	Grazing Land Mechanical Trt.	**		**	**				
561	Heavy Use Area Protection	**		**					**
422	Hedgerow Planting	**		**					
423	Hillside Ditch	**		**					
320	Irrigation Canal or Lateral	**	**	**					
388	Irrigation Field Ditch	**	**	**					
464	Irrigation Land Leveling	**	**	**					
552A	Irrigation Pit or Reg. Reservoir	**	**	**					
552B	Irrig. Pit or Regulating Resv.	**	**	**					
436	Irrigation Storage Reservoir	**	**	**					
443	Irrig. System, Surface and Sub.	**	**	**					
441	Irrigation System, Trickle	**	**	**					
428	Irrig. Water Conveyance Ditch	**	**	**					
430	Irrig. Water Conveyance Pipe	**	**	**					
447	Irrigation System,	**	**	**					
472	Livestock Exclusion	**	**	**	**	**	**		**
482	Mole Drain	**	**	**					
484	Mulching	**	**	**	**		**		
329	No Till	**	**	**	**	**	**		
590	Nutrient Management	**	**	**	**	**	**		
512	Pasture and Hay Planting	**		**			**		**
378	Pond	**		**	**	**			
532	Pumped Well Drain			**					
550	Range Planting	**							
554	Regulating Water in	**	**	**					
	Drainage Systems								
344	Residue Management	**	**		**	**	**		

NRCS Codes	Practice	TP	OP	TN	TKN	ON	AM	BOD	FC
					Pollutant to be controlled				
391A	Riparian Forest Buffer	**		**	**	**	**		**
555	Rock Barrier	**							
558	Roof Runoff Management	**		**					**
570	Runoff Management	**	**	**	**		**		
	System								
350	Sediment Basin	**		**	**		**		
580	Streambank &	**			**		**		
	Shoreline Protection								
585	Stripcropping, Contour	**	**	**	**		**		**
587	Structure for Water Contour	**		**	**				
586	Stripcropping, Field	**	**	**	**		**		**
606	Subsurface Drain	**	**	**			**		**
607	Surface Drainage, Field Ditch	**		**	**		**		**
608	Surface Drainage, Main/Lateral	**		**					**
600	Terrace	**		**	**	**	**		
612	Tree Shrub Establishment	**		**	**		**		
312	Waste Management Syst.	**	**	**	**	**	**		**
313	Waste Storage Facility	**	**	**	**	**	**		**
359	Waste Treatment Lagoon	**	**	**	**	**	**		**
633	Waste Utilization	**	**	**	**	**	**		
638	Water & Sed. Control Basin	**	**	**	**	**			
640	Waterspreading	**		**					

Appendix 2

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Upper Cimarron	110400	11040001	range	102	1088	44
			road, impervious	2	413	0
			row crop	1	404	51
			small grain	1	202	26
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	106	2107	121
			total ps			0
Upper Cimarron	110400	11040002	range	1482	7802	423
			row crop	115	7906	4623
			small grain	91	3711	505
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1688	19419	5551
			total ps			0
Upper Cimarron	110400	11040006	range	454	538	188
			row crop	78	22569	4273
			small grain	292	16415	2643
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	824	39522	7104
			total ps			0

Name	6 digit HUC	8 digit HUC	Land Use	area (km²)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Upper Cimarron	110400	11040007	pasture	1	1	0
			range	29	20	6
				area (km²)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	30	21	6
			total point source			0
Upper Cimarron	110400	11040008	pasture	59	114	125
			range	410	3698	1284
			row crop	23	2493	667
			small grain	333	12584	2754
				area (km²)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	825	18889	4830
			total ps			0
Lower Cimarron	110500	11050001	bare	32	4687	510
			pasture	138	2351	1098
			range	4076	138470	21076
			road, impervious	36	12461	46
			row crop	76	25451	7676
			small grain	1828	143687	24957
				area (km²)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	6186	327107	55363
			total point source			447

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Lower Cimarron	110500	11050002	bare	14	3000	354
			forest	160	725	38
			pasture	703	39672	19572
			range	2302	132703	39628
			row crop	255	14489	3681
			small grain	4281	615426	150908
			urban	314	57104	7966

FACILITY	OKPDES#	Plant Design	Avg. Discharge (MLD)	Design Flow (MLD)		
FAIRVIEW	OK0020079	Extended Aeration	0.000	1.852		0
HITCHCOCK	OK0025801	Lagoon	0.000	0.076		0
MARSHALL	OK0028363	Stabilizing Lagoon	0.000	0.200		0
LAHOMA	OK0028690	Lagoon	0.000	0.284		0
OKEENE	OK0029092	Lagoon	0.000	0.567		0
N ENID	OK0027880	Aerated Lagoon	0.076	0.454		221
DRUMMOND	OK0035165	Lagoon	0.106	0.265		310
WAUKOMIS	OK0020648	Lagoon	2.344	0.775		6861
HENNESSEY	OK0030201	Lagoon	0.869	1.247		2545
KINGFISHER	OK0022811	Sequential Batch Reactor	2.608	3.024		7636
GUTHRIE	OK0027715	Activated Sludge	3.100	5.103		9075
OKC -CHISHOLM CR	OK0027553	Activated Sludge	14.213	18.900		41611
OKC - DEER CR	OK0027561	Bio-Disc	35.910	37.800		105135
ENID	OK0021628	Activated Sludge	36.326	32.130		106352
BETH.-WARR ACS	OK0026077	Activated Sludge	12.550	14.175		36742
ALINE	OK0028975	Lagoon	0.132	0.113		387

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	8029	863119	222147
total point source			316876

Name	6 digit HUC	8 digit HUC	Land Use	area (km²)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Lower Cimarron	110500	11050003	forest	682	9568	252
			pasture	561	72414	34675
			range	1640	194135	47105
			row crop	44	41363	8252
			small grain	502	140121	30287
			urban	160	42110	5161
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MLD)**	**Design Flow (MLD)**		
TRYON	OK0037176	Lagoon	0.243	0.000		188
MANNFORD - EAST	OK0024449	Extended Aeration	0.238	0.900		697
PERKINS	OK0028801	Lagoon	0.257	0.972		753
YALE	OK0028509	Extended Aeration	0.370	1.400		1085
OILTON	OK0035599		0.431	1.629		1262
LANGSTON	OK0027511	Extended Aeration	0.488	1.843		1428
MANNFORD - MAIN	OK0022802	Activated Sludge	1.005	3.801		2944
DRUMRIGHT	OK0022501	Trickling Filter	2.268	8.573		6640
CUSHING (SOUTH)	OK0026701	Bio-Disc	3.447	13.031		10093
STILLWATER	OK0027057	Trickling Filter	21.920	82.858		64176
				area (km²)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	3589	499711	125732
			total ps			89265

Name	6 digit HUC	8 digit HUC	Land Use	area (km²)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Arkansas - Keystone	110600	11060001	forest	39	232	11
			pasture	51	3727	1799
			range	1389	91858	20827
			road, impervious	18	8338	36
			row crop	343	49982	13323
			small grain	700	79528	17595
			urban	49	9021	1294
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
KAW CITY	OK0028878	Sequential Batch Reactor	0.174	0.189		509
				area (km²)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	2589	242686	55394
			total ps			636

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Arkansas - Keystone	110600	11060004	bare	61	2979	1479
			forest	12	28	1
			pasture	139	7802	3935
			range	1313	110625	23080
			row crop	173	96773	27892
			small grain	3229	413692	103313
			urban	55	10473	1444
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
TONKAWA	OK0021903	Lagoon	0.000	1.890		0
JET	OK0031887	Lagoon	0.042	0.132		122
POND CREEK	OK0028096	Lagoon	0.132	0.359		387
CHEROKEE	OK0020052	Lagoon	0.132	1.512		387
NEWKIRK	OK0031968	Lagoon	1.085	1.429		3176
PONCA CITY	OK0026069	Activated Sludge	17.346	34.020		50786
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	4982	642372	161144
			total ps			54858

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Arkansas - Keystone	110600	11060005	forest	20	280	21
			pasture	22	4321	779
			range	169	30285	7482
			road, impervious	2	676	6
			row crop	190	159229	42535
			small grain	537	270209	54614
			urban	25	2939	828
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
BLACKWELL	OK0031909		4.574	4.271		13391
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	965	467939	106265
			total ps			16739

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Arkansas - Keystone	110600	11060006	forest	512	7507	218
			pasture	341	80189	24162
			range	2966	434084	85248
			row crop	112	93341	16997
			small grain	1484	600888	154435
			urban	64	21665	2568
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
FAIRMONT	OK0020273	Lagoon	0.003	0.02		33
GARBER	OK0028932	Lagoon	0.048	0.15		531
GLENCOE	OK0028517	Oxidation Pond	0.055	0.064		609
SHIDLER	OK0022993	Lagoon	0.094	0.077		1040
FAIRFAX	OK0029017	Lagoon	0.187	0.206		2069
PAWNEE	OK0026654	Extended Aeration	0.212	0.3		2346
CLEVELAND (S.)	OK0028347	Sequential Batch Reactor	0.392	0.363		4338
PERRY	OK0027448	Extended Aeration	0.795	0.66		8798
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	5479	1237674	283628
			total ps			19765
Verdigris River	110701	11070103	bare	34	9867	1023
			forest	159	9801	481
			pasture	289	98183	21298
			range	764	292277	60706
			row crop	67	74137	11792
			small grain	58	26100	4521
			urban	25	11692	1425
			wetland	10	702	163
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**		**Design Flow (MGD)**	
DELAWARE	OK0020796	Lagoon	0.035	0.05		387
LANGLEY	OK0039128	Oxidation Ditch	0.046	0.13		509
S. COFFEYVILLE	OK0020117	Lagoon	0.105	0.159		1162
NOWATA	OK0025470	Oxidation Ditch	0.685	0.53		7581
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1406	522759	101409
			total ps			9639

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Verdigris River	110701	11070105	bare	19	28970	3145
			forest	224	11104	699
			orchard	11	1022	204
			pasture	677	191275	66615
			range	337	32649	9871
			road, impervious	3	1236	20
			row crop	208	302218	52896
			small grain	131	102848	19941
			urban	241	143508	17216
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
OKAY	OK0027588	Lagoon	0.024	0.05		266
CATOOSA	OK0027090	Lagoon	0.079	0.3		874
INOLA	OK0033618	Aerated Lagoon	0.154	0.23		1704
WAGONER	OK0026832	Extended Aeration	1.445	0.94		15992
CLAREMORE	OK0027049	Trickling Filter	2.877	2.6		31839
OOLOGAH	OK0034223	Extended Aeration	0.158	0.12		1749
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1851	814830	170607
			total ps			52423
Verdigris River	110701	11070106	forest	537	18452	642
			orchard	25	4620	522
			pasture	407	78473	32930
			range	1721	138782	29258
			row crop	97	160212	23430
			small grain	90	77546	14548
			urban	126	70017	8962
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
RAMONA	OK0028339	Lagoon	0.056	0.06		620
OCHELATA	OK0034517	Aerated Lagoon	0.058	0.06		642
COPAN	OK0020168	Lagoon	0.105	0.075		1162
DEWEY	OK0022551	Activated Sludge	0.424	0.44		4692
COLLINSVILLE	OK0027375	Lagoon	0.741	0.77		8200
BARTLESVILLE (#1)	OK0030333	Activated Sludge	6.781	7		75044
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	3003	548102	110292
			total ps			15316

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Verdigris River	110701	11070107	bare	9	14560	1492
			forest	704	23598	512
			pasture	318	87075	34198
			range	1585	113663	20761
			road, impervious	17.24	6836	103
			row crop	24	56150	12698
			small grain	32	45765	7854
			urban	255	249972	30539
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
TMUA NORTH	OK0026221		30.93	36.8		342296
AVANT	OK0027243	Lagoon	0	0.091		0
SPERRY	OK0033464	Lagoon	0.021	0.132		232
WYNONA	OK0031585	Lagoon	0.043	0.04		476
BARNSDALL	OK0027308	Lagoon	0.156	0.156		1726
PAWHUSKA	OK0028274	Aerated Lagoon	0.168	0.5		1859
SKIATOOK	OK0028118	Aerated Lagoon	0.23	0.35		2545
HOMINY	OK0027618	Activated Sludge	0.3	0.375		3320
SKIATOOK (W.)	OK0040461	Aerated Lagoon	0.426	0.9		4714
OWASSO	OK0020303	Oxidation Ditch	2.079	0.88		23008
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	2944.24	597619	108158
			total ps			380178
Neosho River	110702	11070205	forest	1	61	4
			orchard	1	61	23
			pasture	3	1009	359
			range	5	2093	474
			row crop	1	2376	544
			small grain	1	871	539
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	12	6471	1943
			total ps			0

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Neosho River	110702	11070206	bare	20	16414	2182
			forest	370	9757	522
			orchard	15	947	392
			pasture	933	205369	75843
			range	71	9760	2803
			road, impervious	4	1217	26
			row crop	182	175244	39831
			small grain	116	61124	15878
			urban	147	72863	9511
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
QUAPAW	OK0028258	Lagoon	0.015	0.13		166
CARDIN	OK0038962	Lagoon	0.019	0.05		210
FAIRLAND	OK0021504	Lagoon	0.05	0.115		553
AFTON	OK0020656	Oxidation Ditch	0.142	0.14		1571
PICHER	OK0032263	Lagoon	0.22	0.22		2435
COMMERCE	OK0020320	Aerated Lagoon	0.222	0.32		2457
MIAMI UTILITIES	OK0031801	Extended Aeration	0.429	0.55		4748
SENECA (MO)	OK0030236	Lagoon	0.496	0.353		5489
GROVE	OK0028886	Activated Sludge	0.571	0.67		6319
MIAMI - SE WSTW	OK0031798	Extended Aeration	1.943	1.5		21503
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1858	552694	146988
			total ps			45451
Neosho River	110702	11070207	forest	71	2002	107
			pasture	144	37642	12384
			range	8	1399	417
			row crop	17	14153	2820
			small grain	12	3802	972
			urban	3	1404	187
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	256	60401	16887
			total ps			0

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Neosho River	110702	11070208	forest	37	938	44
			pasture	84	27420	9865
			row crop	4.21	7815	1642
			small grain	2.8	4051	736
			urban	5.7	995	121
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	255	41219	12409
			total ps			0
Neosho River	110702	11070209	bare	12	16241	1832
			forest	1720	42539	1889
			pasture	2779	438169	137415
			range	848	128181	35216
			row crop	250	342467	67612
			small grain	121	92048	18314
			urban	170	68318	8938
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
BIG CABIN	OK0031577	Lagoon	0	0.07		0
PENSACOLA	OK0040410	Extended Aeration	0.021	0.016		232
HULBERT	OK0032328	Lagoon	0.053	0.075		587
SALINA	OK0020338	Lagoon	0.077	0.12		852
ADAIR	OK0027197	Lagoon	0.082	0.065		907
WELCH	OK0028657	Lagoon	0.086	0.09		952
CHELSEA	OK0022781	Lagoon	0.177	0.26		1959
JAY	OK0031976	Extended Aeration	0.609	1.1		6740
FORT GIBSON	OK0021938	Lagoon	0.795	1.1		8798
VINITA	OK0037788	Oxidation Ditch	1.308	1.5		14475
PRYOR	OK0040479	Sequential Batch Reactor	1.323	1.67		14641
CHOUTEAU	OK0022764		0.26	0.25		2877
BLUEJACKET	OK0031771		0.021	0.025		232
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	5900	1127963	271216
			total ps			53021

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Middle Canadian	110901	11090103	range	6	31	5
			row crop	2	778	136
			small grain	1	576	80
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	9	1384	221
			total ps			0
Lower Canadian	110902	11090201	forest	53	48	5
			pasture	113	1219	1330
			range	3369	24590	6911
			small grain	1605	65439	16271
			urban	22	2739	339
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
THOMAS	OK0038971	Lagoon	0.005	0.09		55
HYDRO	OK0028185	Activated Sludge	0.168	0.14		1859
WEATHERFORD	OK0021563	Activated Sludge	0.939	1.998		10392
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	5162	94035	24856
			total ps			15383

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Lower Canadian	110902	11090202	forest	310	6065	187
			pasture	1118	33516	21199
			range	2023	42904	14877
			row crop	67	39205	8749
			small grain	957	102121	22052
			urban	270	40251	4545
			urban	5	382	59

FACILITY	OKPDES#	Plant Design	Avg. Discharge (MGD)	Design Flow (MGD)		
CALVIN	OK0037818	Lagoon	0	0.028		0
ASHER	OK0027154	Lagoon	0.006	0.06		66
FRANCIS	OK0036064	Lagoon	0.01	0.045		111
TUTTLE	OK0029173	Lagoon	0.055	0.186		609
MINCO	OK0032182	Lagoon	0.073	0.08		808
WAYNE - EAST	OK0028665	Lagoon	0.08	0.075		885
UNION CITY	OK0038393	Lagoon	0.107	0.2		1184
NEWCASTLE	OK0028614	Extended Aeration	119	0.54		1316949
LEXINGTON	OK0022756	Extended Aeration	0.164	0.25		1815
KONAWA	OK0021873	Trickling Filter	0.185	0.32		2047
PURCELL	OK0028533	Lagoon	0.656	0.65		7260
NOBLE	OK0031755	Extended Aeration	0.7	0.76		7747
NORMAN	OK0029190	Bio-Disc	9.807	10		108532
ADA	OK0026115	Sequential Batch Reactor	2.469	3.2		27324
MOORE	OK0027391	Extended Aeration	4.357	4.5		48218
OKEMAH	OK0020737	Lagoon	0.3	0.52		3320
BRIDGE CREEK	OK0038458	Sequential Batch Reactor	0.007	0.03		77

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	4750	264444	71668
total ps			1526953

Name	6 digit HUC	8 digit HUC	Land Use	area (km²)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Lower Canadian	110902	11090203	forest	578	7003	154
			pasture	603	19546	5521
			range	1050	23158	4738
			row crop	12	2870	492
			small grain	38	1366	326
			urban	256	13994	1839
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
MAUD	OK0029181	Oxidation Ditch	0.201	0.2		2224
HOLDENVILLE	OK0028428	Extended Aeration	0.802	0.6		8876
				area (km²)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	2537	67937	13070
			total ps			11100
Lower Canadian	110902	11090204	forest	2252	84724	2846
			pasture	1898	273301	97290
			range	750	50429	10612
			road, impervious	9	2052	36
			row crop	32	44970	5037
			small grain	21	13612	3136
			urban	172	56956	8152
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
STIGLER	OK0020711	Aerated Lagoon	0	0.34		0
STUART	OK0036382	Lagoon	0.012	0.02		133
CANADIAN	OK0035297	Extended Aeration	0.017	0.03		188
PITTSBURG	OK0027782	Lagoon	0.037	0.035		409
SAVANNA	OK0030708	Lagoon	0.053	0.095		587
CROWDER	OK0035301	Submerged Rock Filter	0.081	0.06		896
HARTSHORNE	OK0022861	Oxidation Ditch	0.252	0.27		2789
HAILEYVILLE	OK0028843	Activated Sludge	0.332	0.13		3674
KREBS	OK0030686	Lagoon	0.409	0.215		4526
MCALESTER (E.)	OK0026107	Extended Aeration	1.013	2		11211
MCALESTER (W.)	OK0026093	Oxidation Ditch	1.743	2.5		19289
EUFAULA	OK0035611	Oxidation Ditch	0.552	0.36		6109
				area (km²)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	5134	526044	127109
			total ps			49812

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Upper Beaver	111001	11100101	range	1999	5312	246
			row crop	1449	82311	11831
			small grain	1242	52174	3759
			urban	11.59	226	7
			total nps	**area (km^2)**	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total ps			0
Upper Beaver	111001	11100102	range	1042	1632	401
			row crop	954	27763	3847
			small grain	1339	17372	2613
			urban	9.77	178	9
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	3345	46945	6870
			total ps			0
Upper Beaver	111001	11100103	range	531	4157	263
			row crop	235	27218	4404
			small grain	154	10291	1234
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	920	41666	5901
			total ps			0
Upper Beaver	111001	11100104	range	313	617	110
			row crop	63	4610	774
			small grain	65	3986	573
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	441	9213	1457
			total ps			0
Lower Beaver	111002	11100201	pasture	50	209	132
			range	1826	3068	966
			row crop	192	8896	1033
			small grain	808	17079	2660
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps			
			total ps			0

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Lower Beaver	111002	11100203	pasture	13	5	7
			range	602	301	120
			row crop	241	1687	434
			small grain	851	8230	1493
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	851	8230	2054
			total ps			0
Lower North Canadian	111003	11100301	pasture	297	2309	2115
			range	2274	9281	3820
			row crop	24	314	124
			small grain	2001	73225	21464
			urban	194	12911	2126
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
WATONGA	OK0021911	Trickling Filter	0.0619	0.5		685
MUSTANG	OK0026816	Sequential Batch Reactor	1.147	1.5		12694
YUKON	OK0028584		1.954	3		21625
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	4790	98040	29649
			total ps			35003

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Lower North Canadian	111003	11100302	bare	5	961	110
			forest	949	39528	945
			pasture	1309	188814	86366
			range	1410	102196	38987
			road, impervious	7	2301	32
			row crop	178	149008	27568
			small grain	284	73856	16186
			urban	505	163447	21215

FACILITY	OKPDES#	Plant Design	Avg. Discharge (MGD)	Design Flow (MGD)		
HENRYETTA	OK0028266	Sequential Batch Reactor	1.394	2.18		15427
DUSTIN	OK0029050	Lagoon	0.029	0.032		321
WETUMKA (S.)	OK0032417	Lagoon	0.042	0.102		465
VALLEY BROOK	OK0032239	Activated Sludge	0.044	0.68		487
OK CITY - DUNJEE	OK0030520	Extended Aeration	0.044	0.195		487
EARLSBORO	OK0030244	Lagoon	0.053	0.015		587
WETUMKA (N.)	OK0032425	Lagoon	0.064	0.05		708
WELEETKA	OK0028525	Lagoon	0.095	0.144		1051
JONES	OK0030996	Extended Aeration	0.099	0.145		1096
SPENCER	OK0022535	Extended Aeration	0.175	0.3		1937
MCLOUD	OK0029009	Extended Aeration	0.195	0.3		2158
PRAGUE	OK0027740	Lagoon	0.284	0.25		3143
HARRAH	OK0038482	Sequential Batch Reactor	0.294	0.39		3254
TECUMSEH	OK0020788	Trickling Filter	0.572	1.05		6330
SHAWNEE - NORTH	OK0037893	Extended Aeration	2.195	3		24292
SEMINOLE	OK0022870	Trickling Filter	1.789	2.38		19799
SHAWNEE - SOUTH	OK0026051	Trickling Filter	1.651	3.59		18271
DEL CITY	OK0026085	Sequential Batch Reactor	2.76	3		30544
MIDWEST CITY (N.)	OK0026841	Bio-Disc	4.927	12		54526
WEWOKA	OK0022659	Extended Aeration	0.803	0.5		8887
OKC - N. CANADIAN	OK0036978	Advanced Treatment	51.363	80		568424
CHOCTAW	OK0037834	Sequential Batch Reactor	0.461	0.75		5102

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	4647	720111	191409
total ps			767294

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Lower North Canadian	111003	11100303	bare	5	5431	653
			forest	1740	49697	1351
			pasture	1624	232815	103517
			range	2424	177739	55767
			road, impervious	9	3103	51
			row crop	98	106993	22549
			small grain	282	119587	26396
			urban	372	112637	15948
			wetland	20	504	175

FACILITY	OKPDES#	Plant Design	Avg. Discharge (MGD)	Design Flow (MGD)		
KENDRICK	OK0043915	Lagoon	0	0.06		0
PADEN	OK0028835	Lagoon	0.014	0.045		155
DEPEW	OK0021890	Lagoon	0.019	0.05		210
WELLSTON	OK0032476	Lagoon	0.038	0.12		421
CARNEY	OK0028321	Lagoon	0.085	0.105		941
BEGGS	OK0028177	Lagoon	0.086	0.112		952
MEEKER	OK0026883	Extended Aeration	0.096	0.2		1062
DEWAR	OK0027537	Lagoon	0.102	0.13		1129
MORRIS (NW)	OK0028924	Lagoon	0.142	0.24		1571
DAVENPORT	OK0022641	Lagoon	0.195	0.115		2158
STROUD - SOUTH	OK0027359	Lagoon	0.17	0.5		1881
STROUD - NORTH	OK0027367	Sequential Batch Reactor	0.31	0.224		3431
CHANDLER	OK0027120	Lagoon	0.333	0.8		3685
OKMULGEE	OK0028134	Activated Sludge	2.832	5		31341
EDMOND - COFF. CR.	OK0026026	Extended Aeration	7.707	3		85292
BRISTOW	OK0032549	Extended Aeration	0.667	0.945		7382

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	6574	808506	226407
total ps			141611

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
R.S. Kerr Reservoir	111101	11110101	forest	823	31818	685
			pasture	953	288188	120757
			range	773	105337	33828
			row crop	257	320713	50104
			small grain	149	98719	21210
			urban	430	382617	43504
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
TMUA SOUTH	OK0026239		12.151	21		134473
HASKELL	OK0032271	Aerated Lagoon	0	0.39		0
KELLYVILLE	OK0034541	Lagoon	0.092	0.1		1018
MOUNDS	OK0022888	Lagoon	0.11	0.16		1217
KIEFER	OK0028771	Lagoon	0.141	0.12		1560
BIXBY (SOUTH)	OK0026913	Aerated Lagoon	0.293	0.45		3243
BIXBY (NORTH)	OK0036153	Aerated Lagoon	0.421	0.5		4659
COWETA	OK0020281	Lagoon	0.753	0.9		8333
GLENPOOL	OK0027138	Aerated Lagoon	0.766	1.44		8477
SAND SPRS (MAIN)	OK0030864	Bio-Disc	2.504	2.76		27711
BROKEN ARROW	OK0040053	Activated Sludge	3.381	8		37417
JENKS	OK0037401	Oxidation Ditch	0.565	0.7		6253
PORTER	OK0027570	Oxidation Ditch	0.055	0.08		609
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	3385	1227392	270088
			total ps			234970

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
R.S. Kerr Reservoir	111101	11110102	bare	7	6173	785
			forest	577	34124	1221
			pasture	901	401770	153144
			range	939	289644	84101
			row crop	81	102170	19839
			small grain	33	23745	5324
			urban	89	134021	14717

FACILITY	OKPDES#	Plant Design	Avg. Discharge (MGD)	Design Flow (MGD)		
BOYNTON	OK0034347	Lagoon	0	0.065		0
BRAGGS	OK0034444	Oxidation Ditch	0.027	0.04		299
WEBBERS FALLS	OK0034631	Lagoon	0.034	0.045		376
WARNER	OK0031003	Lagoon	0.061	0.28		675
PORUM	OK0021636	Lagoon	0.063	0.08		697
GORE	OK0033987	Lagoon	0.063	0.055		697
CHECOTAH	OK0028100	Sequential Batch Reactor	0.49	1.9		5423

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	2627	991647	279131
total ps			8167

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
R.S. Kerr Reservoir	111101	11110103	forest	1227	62207	2051
			orchard	8	700	367
			pasture	871	229479	87581
			range	96	9373	2459
			small grain	6	3129	945
			urban	83	49313	6450

FACILITY	OKPDES#	Plant Design	Avg. Discharge (MGD)	Design Flow (MGD)		
WESTVILLE	OK0028126	Aerated Lagoon	0.14	0.14		1549
STILWELL	OK0030341	RBC/Activated Sludge	0.38	0.5		4205
TAHLEQUAH	OK0026964	Activated Sludge	2.769	5.27		30644

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	2291	354201	99853
total ps			36399

Name	**6 digit HUC**	**8 digit HUC**	**Land Use**	**area (km^2)**	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
R.S. Kerr Reservoir	111101	11110104	bare	21	46741	5898
			forest	1672	116263	4416
			orchard	14	621	162
			pasture	1575	1386653	421961
			range	167	83207	17398
			road, impervious	6	3515	56
			row crop	144	199032	28072
			small grain	56	50016	9886
			urban	66	174247	16528
			wetland	12	32214	2050
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
GANS	OK0028673	Lagoon	0.03	0.045		332
KEOTA	OK0031186	Lagoon	0.066	0.075		730
QUINTON	OK0030694	Lagoon	0.085	0.111		941
VIAN	OK0021512	Lagoon	0.096	0.19		1062
ROLAND	OK0030392	Lagoon	0.255	0.24		2822
SPIRO	OK0027693	Extended Aeration	0.319	0.34		3530
MULDROW	OK0032573	Extended Aeration	0.395	0.65		4371
SALLISAW	OK0028169	Extended Aeration	1.25	3.25		13834
MUSKOGEE	OK0029131	Trickling Filter	7.156	13.74		79194
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	3733	2092509	506427
			total ps			106817

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
R.S. Kerr Reservoir	111101	11110105	bare	15	25695	3218
			forest	2064	329554	4503
			pasture	1288	1117047	323503
			range	41	31901	6196
			row crop	12	20221	2690
			small grain	5	5069	1055
			urban	47	106450	10810
			wetland	3	5167	698

FACILITY	OKPDES#	Plant Design	Avg. Discharge (MGD)	Design Flow (MGD)		
CAMERON	OK0028908	Lagoon	0.016	0.04		177
WILBURTON (N.)	OK0033804	Lagoon	0.019	0.068		210
BOKOSHE	OK0027731	Extended Aeration	0.042	0.06		465
WILBURTON (S.)	OK0033812	Lagoon	0.092	0.102		1018
PANAMA	OK0031054	Lagoon	0.184	0.165		2036
WISTER	OK0034118	Oxidation Pond	0.213	0.145		2357
POCOLA	OK0034134	Extended Aeration	0.252	0.122		2789
RED OAK	OK0031631	Lagoon	0.051	0.09		564
WILBURTON	OK0021881	Aerated Lagoon	0.37	0.33		4095
POTEAU	OK0021610	Contact Stabilization	1.919	3		21237

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	3475	1641104	352672
total ps			34949

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Prairie Dog Twn Fk. Red	111201	11120105	pasture	1	1	0
			range	18	196	52
			row crop	2	1944	333
			small grain	8	5410	843

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	29	7551	1228
total ps			0

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Salt Fork Red	111202	11120202	forest	6	4	0
			orchard	9	121	64
			pasture	58	249	256
			range	636	20364	5773
			row crop	240	47928	8312
			small grain	865	68620	15915
			urban	24	1941	278
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
MANGUM	OK0028827	Lagoon	0.336	0.3		3718
ALTUS (SW WDS)	OK0028045	Land Application	0.231			2556
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1838	139227	30598
			total ps			6275
North Fork Red	111203	11120302	forest	84	31	0
			pasture	251	253	316
			range	825	10102	1223
			road, impervious	20	5486	27
			small grain	1032	20557	6183
			urban	15	866	150
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
ERICK	OK0020745	Lagoon	0.07	0.14		775
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	2227	37295	7899
			total ps			4648

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
North Fork Red	111203	11120303	forest	95	236	18
			orchard	16	64	48
			pasture	123	1150	973
			range	878	39285	11522
			row crop	267	38914	8848
			small grain	2122	175794	48473
			urban	63	4912	710
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
CANUTE	OK0043940	Lagoon	0	0.078		0
HOBART	OK0028649	Lagoon	1.15	1.2		12727
ELK CITY	OK0029084	Extended Aeration	1.208	1.6		13369
ALTUS (SE WDS)	OK0028037	Extended Aeration	1.825	2		20197
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	3564	260355	70592
			total ps			46292

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
North Fork Red	111203	11120304	forest	15	8	0
			pasture	36	267	243
			range	910	41215	9888
			road, impervious	9	2300	16
			row crop	9	3864	269
			small grain	483	38566	7640
			urban	6	583	83
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1468	86803	18140
			total ps			0

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Red-Pease: Red River	111301	11130101	forest	6	2	0
			orchard	3	11	7
			pasture	18	36	42
			range	365	17476	4035
			row crop	218	72601	11198
			small grain	681	78840	16225
			urban	5	870	99
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
HOLLIS	OK0021547	Lagoon	0.025	0.25		346
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1296	169836	31605
			total ps			346
Red-Pease: Red River	111301	11130102	pasture	54	888	294
			range	181	413	95
			row crop	131	51475	9460
			small grain	599	46019	11722
			urban	7	1030	123
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
FREDERICK (IND. PK)	OK0027189	Lagoon	0.458	0.15		5069
FREDERICK (MAIN)	OK0027171	Land Application	0.51	0.55		5644
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	972	99825	21694
			total ps			10713

Name	**6 digit HUC**	**8 digit HUC**	**Land Use**	**area (km^2)**	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
Red - Lake Texoma	111302	11130201	forest	601	5349	276
			orchard	41	824	355
			pasture	639	22389	14548
			range	1827	35830	16262
			road, impervious	4	1695	18
			row crop	18	15532	3003
			small grain	637	182135	35042
			urban	43	12442	1942
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
RINGLING	OK0021580	Lagoon	0	0.22		0
LONE GROVE	OK0034274	Lagoon	0.028	0.09		310
LONE GROVE	OK0034282	Lagoon	0.041	0.072		454
WILSON	OK0021598	Lagoon	0.098	0.159		1085
TEMPLE	OK0032514	Lagoon	0.172	0.25		1903
HEALDTONF	OK0027413	Extended Aeration	0.317	0.5		3508
MARIETTA .	OK0020257	Oxidation Ditch w/ UV Disc	0.323	0.231		3575
LONE GROVE	OK0034266	Lagoon	0.028	0.018		310
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	3810	276196	71446
			total ps			11144
Red - Lake Texoma	111302	11130202	forest	103	1234	84
			pasture	82	9539	4683
			range	1081	46346	15677
			row crop	4	259	134
			small grain	701	238268	47024
			urban	109	38272	4354
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
LAWTON	OK0035246	Tertiary	14.636	18		161974
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	2080	333918	71956
			total ps			161974

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Red - Lake Texoma	111302	11130203	forest	104	1414	103
			pasture	64	13790	3848
			range	1252	155622	32145
			road, impervious	13	5959	47
			row crop	152	87257	13961
			small grain	1243	399285	70577
			urban	22	5059	611
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
DEVOL	OK0022578		0.08	0.06		885
MANITOU	OK0032484	Lagoon	0.034	0.035		376
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	2850	668386	121292
			total ps			1262
Red - Lake Texoma	111302	11130208	forest	86	1240	36
			pasture	321	16997	8531
			range	1089	22547	9782
			row crop	157	13838	3619
			small grain	493	71372	17603
			urban	89	25023	2969
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
RYAN	OK0032344	Lagoon	0	0.115		0
COMANCHE	OK0031763	Lagoon	0.937	0.1		10370
DUNCAN	OK0026638	Trickling Filter	2.59	3		28663
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	2235	151017	42504
			total p			39033

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Red - Lake Texoma	111302	11130210	forest	317	3221	135
			pasture	251	32615	18511
			range	678	45317	15018
			road, impervious	8	3382	35
			row crop	84	54163	18320
			small grain	66	17455	4829
			urban	66	57243	7114
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
KINGSTON	OK0027774	11130210	0.204	0.22		2258
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1470	213397	63963
			total ps			2258
Washita	111303	11130301	forest	70	114	5
			pasture	76	0	0
			range	1953	65706	9471
			small grain	559	80025	16871
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	2658	145845	26347
			total ps			0

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Washita	111303	11130302	forest	463	2396	130
			pasture	1034	28831	21054
			range	2725	133017	34045
			road, impervious	8	2083	16
			row crop	196	24437	7475
			small grain	3722	555007	134076
			urban	118	27401	3412

FACILITY	OKPDES#	Plant Design	Avg. Discharge (MGD)	Design Flow (MGD)		
CYRIL	OK0041467		0.121	0.135		1339
MOUNTAIN VIEW	OK0020311	Lagoon	0	0.102		0
CEMENT	OK0027766	Lagoon	0	0.085		0
LEEDEY+A916	OK0028240	Lagoon	0.03	0.05		332
VERDEN	OK0032557	Lagoon	0.042	0.063		465
CARNEGIE	OK0028401	Trickling Filter	0.187	0.25		2069
CORDELL	OK0032379		0.259	0.406		2866
ANADARKO	OK0028151	Aerated Lagoon	1.002	1.94		11089
CLINTON	OK0031011	Extended Aeration	1.544	1.7		17087
CHICKASHA	OK0026018	Activated Sludge	2.193	3		24269

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	8266	773172	200208
total ps			59517

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Washita	111303	11130303	forest	764	13513	435
			orchard	22	504	233
			pasture	1556	232790	108009
			range	3223	324755	81154
			row crop	101	34106	7429
			small grain	726	121866	29250
			urban	106	30726	4261

FACILITY	OKPDES#	Plant Design	Avg. Discharge (MGD)	Design Flow (MGD)		
DAVIS	OK0021644	Activated Sludge	0.286	0.38		3165
DOUGHERTY	OK0042676	Lagoon	0	0.014		0
ARDMORE	OK0030422	Activated Sludge	0	0.1		0
PAOLI	OK0030988	Lagoon	0.009	0.08		100
STRATFORD	OK0021865	Lagoon	0.185	0.16		2047
LINDSAY	OK0027871	Lagoon	0.199	0.42		2202
WYNNEWOOD	OK0028282	Trickling Filter	0.265	0.475		2933
LOCUST GROVE	OK0022772	Trickling Filter	0.405	0.175		4482
PAULS VALLEY	OK0039071	Lagoon	0.66	0.9		7304
SULPHUR	OK0020141	Sequential Batch Reactor	0.941	0.83		10414
ARDMORE CENTRAL	OK0038440	Bio-Disc	4.995	5.9		55279

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	6498	758260	230771
total ps			87926

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Washita	111303	11130304	forest	122	3586	202
			pasture	396	78635	37963
			range	1237	71175	22834
			row crop	18	6765	1972
			small grain	49	5553	1721
			urban	56	18518	3163
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
MILL CREEK (S.)	OK0027634	Lagoon	0	0.07		0
OAKLAND	OK0031933	Lagoon	0.077	0.06		852
TISHOMINGO	OK0031992	Extended Aeration	0.321	0.44		3552
MADILL	OK0031721	Sequential Batch Reactor	0.43	0.75		4759
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1878	184232	67855
			total ps			9163

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Red - Little	111401	11140101	forest	218	5501	285
			orchard	27	460	112
			pasture	897	140127	66821
			range	11	541	162
			road, impervious	4	753	17
			row crop	175	133542	22943
			small grain	108	65694	12939
			urban	10	6469	12939
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
ACHILLE	OK0027979	Lagoon	0.025	0.052		277
COLBERT	OK0035289	Lagoon	0.102	0.102		1129
CALERA	OK0031682	Lagoon	0.216	0.18		2390
DURANT .	OK0039063		2.364	2.9		26162
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1450	353087	116218
			total ps			29958

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Red - Little	111401	11140102	forest	143	2229	100
			orchard	9	156	50
			pasture	879	98659	50249
			range	593	20438	7411
			row crop	31	25280	4746
			small grain	68	39938	7742
			urban	32	10262	2053
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
BOKCHITO	OK0027014	Lagoon	0.072	0.065		797
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1755	196962	72351
			total point source			797

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Red - Little	111401	11140103	forest	1367	52420	2057
			orchard	12	452	128
			pasture	972	111898	53545
			range	1241	91497	23611
			row crop	51	42405	6735
			small grain	11	767	162
			urban	30	10757	1627
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
STRINGTOWN	OK0030449	Lagoon	0.023	0.048		255
ALLEN	OK0020206	Lagoon	0.06	0.1		664
COALGATE	OK0027006	Lagoon	0.193	0.22		2136
ATOKA	OK0028576	Extended Aeration	0.441	0.41		4880
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	3684	310196	87865
			total ps			7935

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Red - Little	111401	11140104	forest	483	11779	411
			pasture	1242	91771	72790
			range	778	61786	17827
			row crop	11	7616	1462
			small grain	62	33252	6008
			urban	26	12699	1904

FACILITY	OKPDES#	Plant Design	Avg. Discharge (MGD)	Design Flow (MGD)		
STONEWALL	OK0027286	Lagoon	0.029	0.07		321
ATOKA COUNTY	OK0037796		0.038	0.055		421
BOSWELL	OK0032255	Lagoon	0.042	0.065		465
WAPANUCKA	OK0034011	Lagoon	0.043	0.045		476
CADDO	OK0022730	Extended Aeration	0.174	0.132		1926

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	2602	218903	100402
total ps			3608

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Red - Little	111401	11140105	forest	3229	168403	5899
			orchard	10	183	44
			pasture	1198	164321	54502
			range	209	38205	7242
			road, impervious	6	2098	43
			row crop	42	67117	11928
			small grain	6	2161	407
			urban	19	4345	674

FACILITY	OKPDES#	Plant Design	Avg. Discharge (MGD)	Design Flow (MGD)		
TALIHINA	OK0028380		0.175	0.18		1937
CLAYTON	OK0029157	Lagoon	0.193	0.11		2136
ANTLERS	OK0020346	Activated Sludge	0.35	0.37		3873
HUGO (S. PLANT)	OK0028487	Oxidation Ditch	1.04	0.42		11509

	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
total nps	4719	446833	80740
total ps			19455

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Red - Little	111401	11140106	forest	351	20504	693
			orchard	9	368	167
			pasture	358	80842	37490
			range	53	5952	1108
			row crop	46	74826	13894
			small grain	196	225032	40172
			urban	9	2563	448
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
MILLERTON	OK0037028	Lagoon	0.013	0.028		144
VALLIANT	OK0022489	Aerated Lagoon	0.19	0.15		2103
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1022	410087	93971
			total ps			2247
Red - Little	111401	11140107	forest	3002	178619	4775
			pasture	530	94976	44946
			range	80	16012	2556
			urban	29	8479	1877
FACILITY	**OKPDES#**	**Plant Design**	**Avg. Discharge (MGD)**	**Design Flow (MGD)**		
BROKEN BOW	OK0021521	Extended Aeration	1.095	0.68		12118
IDABEL	OK0027677	Activated Sludge	1.49	1.65		16490
WRIGHT CITY	OK0032387	Lagoon	0.105	0.125		1162
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	3641	298086	54154
			total ps			29770
Red - Little	111401	11140108	forest	1434	117257	3172
			pasture	97	49446	18339
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	1531	166703	21511
			total ps			0

Name	6 digit HUC	8 digit HUC	Land Use	area (km^2)	Total N Export (Kg/yr)	Total P Export (Kg/yr)
Red - Little	111401	11140109	forest	475	30091	760
			pasture	44	16676	6337
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	519	46767	7097
			total ps			0
Verdigris River	110701	11700103	forest	91	2812	191
			pasture	123	26224	9656
			range	448	32077	3853
			row crop	43	82061	11683
			small grain	46	47044	8390
				area (km^2)	**Total N Export (Kg/yr)**	**Total P Export (Kg/yr)**
			total nps	751	190218	33773
			total ps			0