NUTRIENT CRITERIA STUDY FOR THE GUADALUPE RIVER BASIN

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NUTRIENT CRITERIA STUDY FOR THE GUADALUPE RIVER BASIN

Prepared in Cooperation with:

the Guadalupe-Blanco River Authority and the
Texas Natural Resource Conservation Commission
under the Authority of the Texas Clean Rivers Act

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) has set a national goal of establishing numerical nutrient standards in the waters of the U.S. The target date to have criteria in place is now 2004, and Texas has committed to address criteria for lakes and reservoirs by the same time.

Nutrients, primarily nitrogen and phosphorus, are a water quality concern because in excess supply they can stimulate high concentrations of aquatic plants and degrade the quality of waters for particular uses. At the same time, a certain amount of nutrients are necessary to support the base of the aquatic life food web. There are many unique conditions that can affect the levels that actually result in degraded water quality. The challenge of setting numerical criteria is to define amounts that protect the designated uses such as aquatic life support and public water supply, without making unreasonable demands on sources of nutrients.

The EPA has published Guidance Manuals (EPA, 2000a, 2000b, 2001) for developing nutrient numerical criteria. The methodology proposed in the EPA Guidance Manuals is essentially empirical in that it recommends establishing criteria based on a percentile of existing data for systems that share some type of geographic similarity. The common factor in their method is being in one of 14 Ecoregions defined for the continental U.S. The Guidance Manuals suggest two ways to establish criteria. The first is to identify reference water bodies in the Ecoregion that are relatively undisturbed. The 75th percentile of the frequency distribution of these relatively pristine reference water bodies could be used to develop the criteria. When pristine reference water bodies are not identified, the 25th percentile of the frequency distribution of the entire population of water bodies is used. The 25th percentile method was used in this evaluation. The Guadalupe-Blanco River Authority (GBRA), the Upper Guadalupe River Authority (UGRA) and the Texas Natural Resource Conservation Commission (TNRCC) recognize that the issue of numerical nutrient criteria is very complex and variable. This study was designed and supported by the Texas Clean Rivers Program (CRP) to evaluate the techniques proposed by EPA to establish numeric nutrient criteria and to assess other approaches that may have greater utility for waters in the Guadalupe River basin.

In addition to the national recommendations from EPA, the U.S. Geological Survey (USGS), with EPA support has applied the percentile methodology to a more detailed set of Ecoregions in Texas (Hornig, 2000). In this study the same method was also applied to the waters of the Guadalupe Basin. The results of this work, together with the EPA recommendations and USGS findings were reviewed and discussed. The basic finding is that the percentile methodology yields results that differ substantially depending on the study area being considered. This variability does not inspire confidence in the result.

Another major limitation of the percentile method noted and discussed is that there is no technical tie between the percentile values and the uses that have been established for the waters. Water

quality standards consist of two elements: designated uses (the goal of the standard) and criteria that can be measured to determine if the use is being achieved. The National Research Council's (NRC) report to EPA on the Total Maximum Daily Load (TMDL) program (NRC, 2001) argues that to avoid confusion the use statement should be as specific as possible. They note that statements like "aquatic life use support" are too vague for proper quantification and suggest language like support for a specific type of fishery and the biological communities necessary to support that fishery. The NRC report also notes that it is desirable for the criteria to be as closely related to the use being protected as possible. The lack of any technical relation between designated use and the criteria used to judge attainment of the use was considered by the NRC team to be a serious problem.

Another problem is that when the national and state-based percentile criteria are compared with actual data from the Guadalupe Basin, most of the lakes/reservoirs would not attain the criteria. In theory, this would mean that they are not supporting their designated aquatic life support uses and a TMDL study would have to determine the needed reductions in nutrient loads. While this may be the case at some locations, it is hard to imagine this is true for most basin waters.

The main study recommendation is that effort is needed to work with the TNRCC and EPA in developing site-specific standards for the key waterways in the basin. Following on the NRC (2001) recommendations, these standards should include a more specific definition of the uses for each reservoir, and numerical criteria that have a quantitative tie to attainment of these uses. The GBRA and associated water quality programs would be well suited to supervise this effort.

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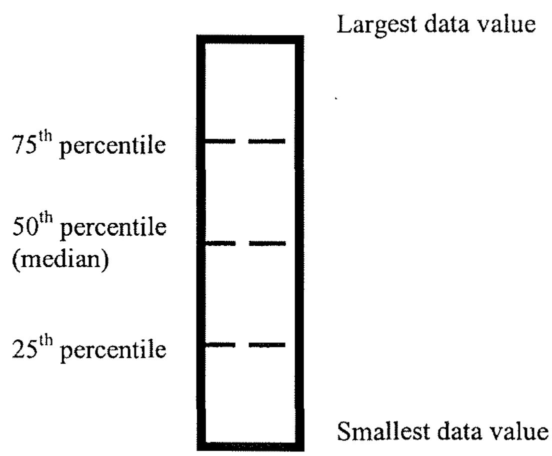
1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has set a national goal of establishing numerical nutrient standards. Their National Strategy for the Development of Regional Nutrient Criteria, published in June 1998, defines a goal to have numeric nutrient criteria for all U.S. waters. The target date to have criteria in place is now 2004. Technical guidance manuals (Guidance Manuals) for the development of nutrient criteria have been published by the EPA for lakes/reservoirs (EPA, 2000a), streams/rivers (EPA, 2000b), and estuarine/coastal marine waters (EPA, 2001).

Nutrients, primarily nitrogen and phosphorus, are a water quality concern because in excess supply they can stimulate high concentrations of aquatic plants and degrade the quality of a water body. At the same time, a certain amount of nutrients are necessary to support the base of the aquatic life food web. There are many unique conditions that can affect the levels that actually result in degraded water quality. The challenge of setting numerical criteria is to define amounts that protect the designated uses such as aquatic life support and public water supply, without making unreasonable demands on sources of nutrients such as agricultural runoff, wastewater discharges, and atmospheric deposition.

The methodology in the Guidance Manuals is essentially empirical in that it recommends establishing criteria based on a percentile of existing data for systems that share some type of geographic similarity. The common geographical similarity in their method is being in one of 14 Ecoregions defined for the continental U.S. Briefly for background, a percentile is obtained by arranging available data in order from largest to the smallest values. The 75th percentile of the data would be the value obtained by going 75% of the way up the list.



The Guidance Manuals suggest two ways to establish criteria. The first is to identify reference water bodies in the Ecoregion that are relatively undisturbed. The 75th percentile of the frequency distribution of these relatively pristine reference water bodies would be one way that could be

used to develop the criteria. When pristine reference water bodies are not identified, another method offered is to use the 25th percentile of the frequency distribution of the entire population of water bodies. The 25th percentile was chosen by EPA to represent a surrogate for an actual reference population. Note that for parameters such as Secchi depth that have higher readings associated with better water quality, the criterion is developed from either the 25th percentile of reference water bodies or 75th percentile of the entire population.

Water quality standards consist of two elements: designated uses (the goal of the standard) and criteria that can be measured to determine if the use is being achieved. The National Research Council's (NRC) report on the Total Maximum Daily Load (TMDL) program (NRC, 2001) argues that to avoid confusion the use statement should be as specific as possible. They note that statements like "aquatic life use support" are too vague for proper quantification and suggest language like support for a specific type of fishery and the biological communities necessary to support that fishery for particular conditions. The report also notes that it is desirable for the criteria to be as closely related to the use being protected as possible.

The purpose of numerical criteria is to quantify and support protection of the designated water uses. For example, dissolved oxygen (DO) criteria exist as a quantitative measure to support aquatic life uses, and indicator bacteria criteria are established to support contact recreation uses. While recognizing that the percentile method does not establish a tie between the numerical values (criteria) needed to allow a given use, and that the ecological or scientific basis behind the recommended percentile methods is not robust, EPA has expressed the intent that criteria of some sort be adopted by the year 2004. Texas has indicated that it intends to focus initially on lakes and reservoirs and have some numerical values in place by 2004.

Once criteria have been incorporated into the Surface Water Quality Standards, failure to attain the criteria is equivalent to a finding that the associated water uses are not being supported, which can lead directly to a TMDL study designed to attain the criteria by allocating nutrient loads to various dischargers. To avoid misunderstandings and incorrect actions, it is critical to have as clear an understanding as possible of the specific uses and the relation of the criteria to these uses. An analogy might be a use like safe highway transportation, where a criterion is a posted speed limit. A fair amount of work has gone into developing speed limits, and there is a measure of consensus that exceeding that criterion by a significant degree means that the use (safe transportation) is not supported.

Currently, nutrients are assessed in Texas by a combination of narrative criteria and by using statewide screening levels statistically derived from long-term monitoring data. Typically these screening levels are set at the 85th percentile of the statewide data pool, and are not intended as criteria but rather as a means to flag potential problems. Because there are no criteria for nutrients, exceeding the screening level is only a cause for water quality concern and further study.

The Guadalupe-Blanco River Authority (GBRA), the Upper Guadalupe River Authority (UGRA) and the Texas Natural Resource Conservation Commission (TNRCC) recognize that the issue of numerical nutrient criteria is very complex and variable. This study was designed and supported by the Texas Clean Rivers Program (CRP) to evaluate the techniques proposed by EPA to establish numeric nutrient criteria and to assess other approaches that may have greater utility for waters in the Guadalupe River basin. GBRA, with its management responsibility of both the quantity and quality of the waters, has a strong interest in seeing that this issue is addressed properly.

Over the last several decades Texas has established and revised numerical criteria for each water quality segment that quantify support for uses such as domestic water supply, aquatic life protection, and contact recreation. For example, water supply uses are generally protected with criteria for dissolved solids, chlorides and sulfates; aquatic life with DO and also with toxicity-based criteria; while contact recreation uses are addressed with indicator bacteria criteria. This document can be considered as an intermediate step along the way to having numerical criteria for each segment that are needed to support designated uses that might be affected by nutrients. We believe these uses need to be refined for each body of water, but until that can be done we expect these uses to be the general statements like aquatic life support and in the case of water supply reservoirs, the public water supply use. The first step in the process was taken by EPA in establishing a broad policy goal and suggesting a relatively simple method for selecting numerical values. The 14 Ecoregions employed by EPA cover vast expanses of the country, within which individual waters exhibit very large differences in characteristics. EPA officials (Gibson, 2001) have expressed the view that the broad Ecoregion-based criteria are not necessarily the final answer but a default if no better answer can be obtained. EPA has encouraged states to develop better answers. One step along the way has been for the TNRCC, with EPA funding, to have the U.S. Geological Survey (USGS) apply the method using Level III Ecoregions specific to Texas (Hornig, 2002).

Both the EPA and USGS documents are reviewed in this study. Both employ a common statistical approach grouping and analyzing data from many waterbodies in broad geographic areas. This study further narrows the analytical focus to a particular river basin. While the Ecoregion approach is employed, the study goes further to address ways that criteria might be developed for specific segments. Ultimately, we would expect that some measure of detailed study will be needed to develop a consensus on the specific parameters and levels needed to support the designated uses of each segment.

Another point in this introduction is that while Texas does not have numerical nutrient criteria, it has long had narrative nutrient criteria. Section 307.4(e) states that:

> "Nutrients from permitted discharges or other controllable sources shall not cause excessive growth of aquatic vegetation which impairs an existing, attainable, or designated use."

This narrative criteria language has been the basis for establishing nutrient effluent limitations on a number of wastewater dischargers. In the Guadalupe River, nutrient limitations on the wastewater discharges from Kerrville (to Flat Rock Lake), GBRA (to Canyon Lake) and the City of San Marcos (to the San Marcos River) have been implemented.

While the narrative criteria have been effective in addressing specific problems, they are difficult to apply before a problem is encountered. There is little doubt that when specific numbers are assigned to criteria, the level of measurement, concern, and expenditures will tend to increase. Most would view an increase in the level of attention to a water quality issue as a social good.

The study has five major parts. The first, presented in Section 2, is a summary of the EPA method and the values that EPA has recommended for application to major waters of the Guadalupe River basin. It also includes the results of the USGS effort specific to Texas waters. Section 3 draws on the specific data that have been collected in the basin and applies the EPA percentile method to these basin data. This section also includes an examination of different percentile approaches. Section 4 presents an assessment of the results of different means of computing criteria. Section 5 includes a discussion of possible future approaches to developing criteria, and recommendations for future actions.

2.0 NUTRIENT CRITERIA RECOMMENDED BY EPA

When considering numerical criteria to quantify support for the existing uses, there are many alternative approaches. This section reviews the parameters selected by the EPA and the technical approach to criteria development. The results of the national approach, along with Texas results obtained by the USGS (Hornig, 2002) are also presented.

2.1 PARAMETER SELECTION

In the case of lakes and reservoirs, the main concern is generally excess phytoplankton, single-celled aquatic organisms. High levels of phytoplankton can degrade water quality and limit its ability to support the aquatic life use. A typical measure of the phytoplankton concentration is one based on the amount of plant pigment, chlorophyll *a*, found in a water sample. While there are limitations on the accuracy and reliability of this measure, it is employed far more widely than collecting and identifying algal cells. Another measure of phytoplankton density is water clarity, frequently measured with a simple device called a Secchi disk. The deeper the disk can be observed the clearer the water. If the primary cause of decreased water clarity is phytoplankton, and not runoff or wind wave induced turbidity, the Secchi disk depth is a good measure of phytoplankton levels. The EPA employed both chlorophyll *a* and Secchi disk depth as direct measures of excess phytoplankton levels in lakes and reservoirs. In River and Stream waters, EPA includes water turbidity in place of Secchi depth.

If temperature, light and nutrient supplies are sufficient, phytoplankton are capable of rapid growth rates, potentially doubling in density in a day. Factors that can limit the growth of phytoplankton include colder temperature, lack of light, lack of one or more key nutrients, or predation. In most cases, the only parameter over which man has some control in dealing with excess phytoplankton growth is nutrient levels. Many measures of nutrient concentrations could be employed. The form of nutrients that are actually available for use by phytoplankton is the dissolved inorganic state. For example, phytoplankton can use dissolved ortho-phosphate (PO_4^--P), ammonium nitrogen (NH_4^+-N) and nitrate-N (NO_3^--N). Primarily because there are very little data of this type collected at meaningful analytical reporting levels, the EPA Guidance Manuals require that numeric criteria be developed for only total nitrogen (TN) and total phosphorus (TP). By definition, TN and TP include the phytoplankton itself as well as the nutrients in the water that might be available for plankton use, but are generally correlated with high levels of phytoplankton. More importantly, there are much larger data sets of TN and TP available for statistical analysis.

2.2 ECOREGION APPROACH FOR CRITERIA SELECTION

The EPA adopted an ecoregional approach in the criteria development process. Ecoregions are regions with relatively homogeneous ecological characteristics. The delineation of ecoregions is based on geographic conditions that cause or reflect differences in ecosystem patterns.

These conditions include geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology. EPA has developed maps of ecoregions of the United States at various levels of resolution and aggregation. There are 79 Level III Ecoregions in the conterminous United States.

The Level III Ecoregions were aggregated by EPA into 14 nutrient Ecoregions in the conterminous United States. As shown in Figure 2-1, the EPA aggregate Ecoregions extend over large areas of the country.

The Level III Ecoregions for Texas also cover substantial areas. Figure 2-2 shows the Level III Ecoregions in Texas. The Guadalupe River Basin and the Lavaca-Guadalupe Coastal Basin are located within four of these Ecoregions. The following table shows the correspondence between the Aggregate Ecoregions used by the EPA and the Level III Ecoregions in the two basins.

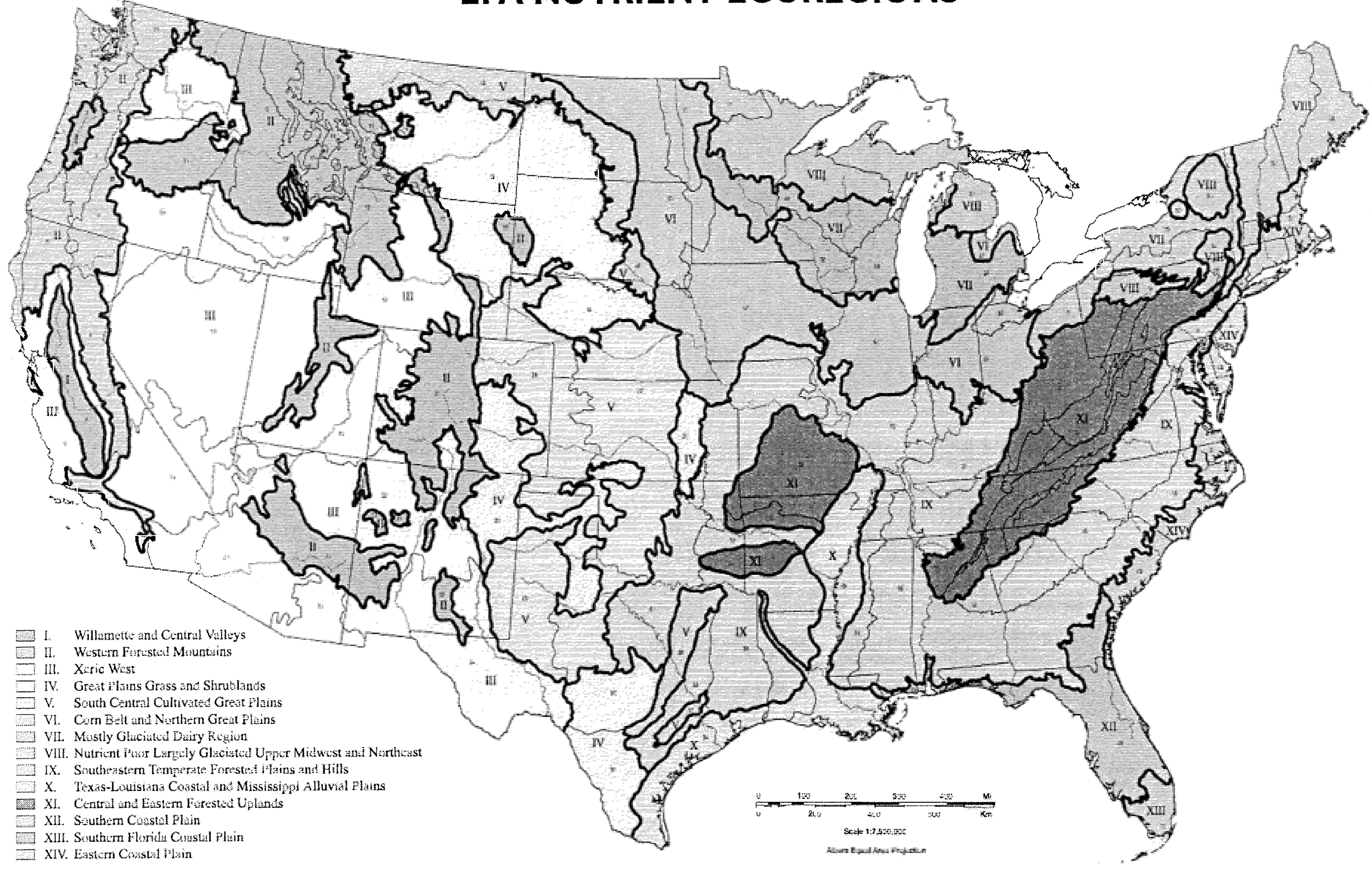
EPA Aggregate Nutrient Ecoregions		Level III Ecoregions	
IV	Great Plains Grass and Shrublands	30	Edwards Plateau
V	South Central Cultivated Great Plains	32	Texas Blackland Prairies
IX	Southeastern Temperate Forested Plains and Hills	33	East Central Texas Plains
X	Texas-Louisiana Coastal and Mississippi Alluvial Plains	34	Western Gulf Coastal Plain

2.3 RECOMMENDED CRITERIA

The criteria recommended by EPA for the above Aggregate Ecoregions for lakes/ reservoirs and rivers/streams are shown in Table 2-1. As noted above, these Ecoregions extend over much of the continental U.S. and cannot be said to be representative of Guadalupe River conditions. If these were applied as criteria, most of the Guadalupe River basin waters would be out of compliance most of the time.

Table 2-2 presents the values obtained by the USGS for the Level III Ecoregions using only Texas data. It can be seen that the values differ substantially but do not seem to have a consistent pattern of difference. For some parameters and locations, the EPA values are higher while for others the difference is in the other direction.

FIGURE 2-1
EPA NUTRIENT ECOREGIONS



Adapted from Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion IV.
EPA 822-B-01-013

FIGURE 2-2
LEVEL III ECOREGIONS IN TEXAS

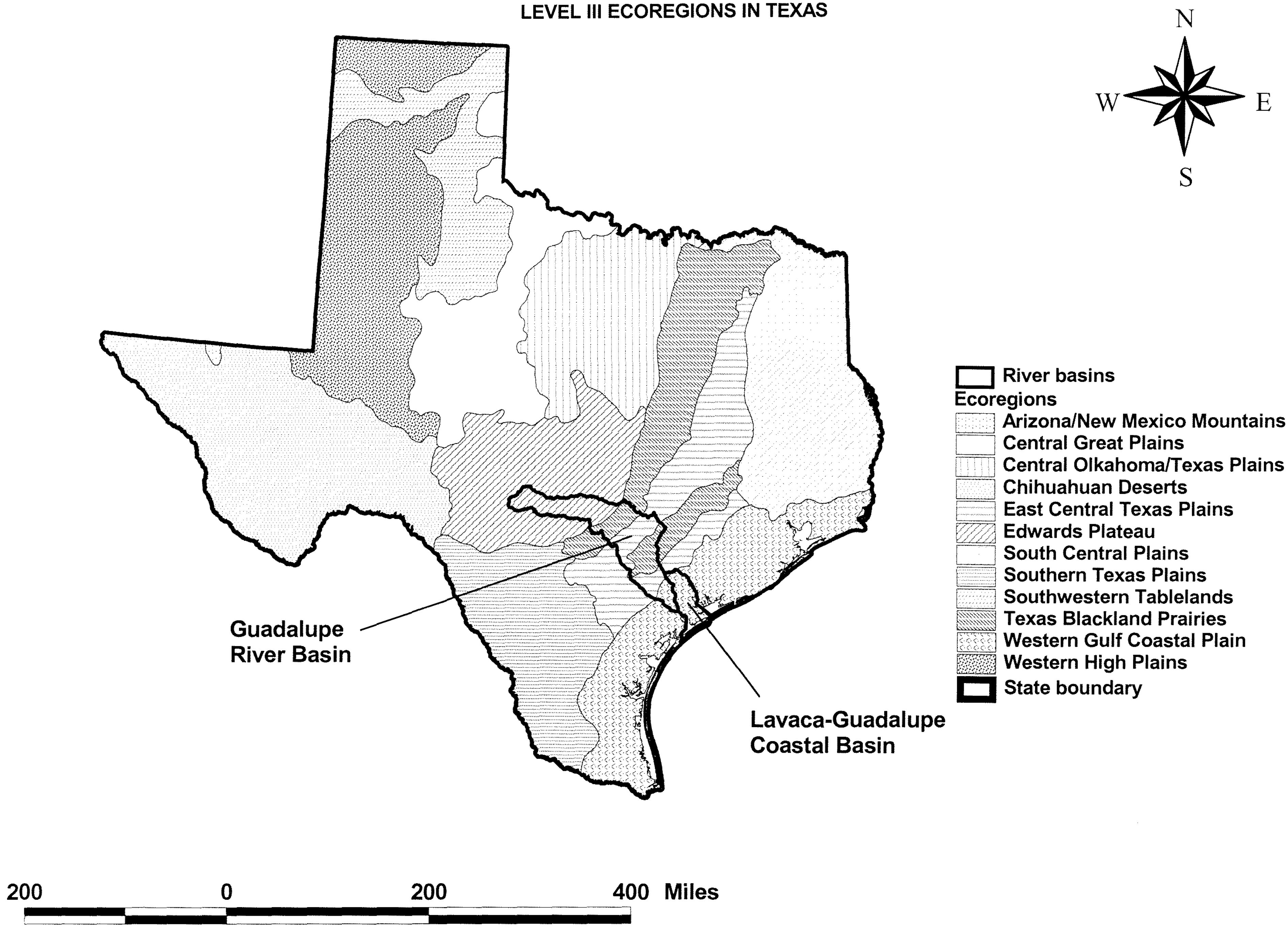


TABLE 2-1

EPA RECOMMENDED NUTRIENT CRITERIA

Parameter	Lakes and Reservoirs[2]			Rivers and Streams			
	IV	V	IX	IV	V	IX	X
TP (μg/L)	20	33	20	23	67	37	128
TN (μg/L)	440	560	360	560	880	700	760
Chl *a* (μg/L)	2.00	2.30	5.18	2.40	3.00	0.93	2.10
Secchi depth (m)	2.00	1.30	1.53				
Turbidity[1]				4.21	7.83	7.02	17.50

[1] Unit for turbidity is NTU for Ecoregion IX and FTU for others.

[2] No criterion has been published for Ecoregion X for Lakes and Reservoirs.

TABLE 2-2

USGS RESULTS (25TH PERCENTILES) USING EPA METHODOLOGY

Ecoregion		Lakes and Reservoirs			Rivers and Streams		
		TP (µg/L)	TN (µg/L)	Chl *a* (µg/L)	TP (µg/L)	TN (µg/L)	Chl *a* (µg/L)
24	Chihuahuan Deserts	21			25	743	1.00
25	Western High Plains	20			145		3.15
26	Southwestern Tablelands	12			16	469	1.00
27	Central Great Plains	26	456	1.41	32	673	1.80
29	Central Oklahoma/Texas Plains	40	538	4.13	53	743	1.99
30	Edwards Plateau	34	430	1.69	8	401	1.00
31	Southern Texas Plains	50			30	1008	1.00
32	Texas Blackland Prairies	16	728	3.69	55	1268	1.15
33	East Central Texas Plains	60	858	9.17	107	1082	1.23
34	Western Gulf Coastal Plain	147			144	1008	1.84
35	South Central Plains	40	566	2.65	63	707	1.27

3.0 STATISTICAL ANALYSIS OF DATA

This section describes the statistical analyses performed on the Guadalupe Basin data. The first part employs the basic EPA methodology and the second deals with other statistical approaches.

3.1 ANALYSIS USING EPA METHOD

Data of the Guadalupe River Basin (Basin 18) and Lavaca-Guadalupe Coastal Basin (Basin 17) were downloaded from the TNRCC Surface Water Quality Monitoring program. The period of the data is from January 1993 to January 2002. These data are characterized in Table 3-1 and include observations from the TNRCC, USGS, GBRA and UGRA. Figure 3-1 shows the location of the sampling stations in each Ecoregion.

Total nitrogen is a derived parameter. It is the sum of TKN (which includes both NH_3-N and Organic-N), NO_2-N and NO_3-N. Routinely, these parameters are not measured at the same time. One reason is that the TKN test is relatively expensive and the concentrations tend to be low in some waters. With that, it is easy to justify foregoing these analyses. Therefore, total nitrogen has the smallest amount of data. The analysis was also performed for TKN as an alternative variable.

Secchi depth is generally measured on lakes and reservoirs. However, there are very few observations for the run-of-river lakes.

Significant percentages of TKN, TP and chlorophyll *a* data are reported as below detection limits. Both TKN and TP have 14% of the data below detection limits, whereas one third of the chlorophyll *a* data are below detection limits. This study applied half the reporting limit concentration for values reported below the detection limit, as did EPA and the USGS (Hornig, 2002). For example, this approach is also used by TNRCC in data assessment (TNRCC, 2002).

3.1.1 Method Description

Using the EPA method, the analysis we did is described below.

1. The data were grouped according to Ecoregions and water body types. The following water body types were considered in this analysis:

   Rivers/Streams
   Lakes/Reservoirs
   Run-of-River Lakes
   Estuaries

TABLE 3-1

DATA FROM JANUARY 1993 TO JANUARY 2002

Level III Ecoregion	Type of water bodies	Number of water bodies	Number of stations	Number of observations							
				TN [2]	NO_3-N [3]	TKN	TP	Chl *a*	Secchi depth	TSS	Turbidity
30 Edwards Plateau	Lakes/Reservoirs	1	12	3	80	22	134	89	46	134	108
	Run-of-River Lakes	5	5	0	106	0	14	94	0	131	184
	Rivers/Streams	16	58	66	763	190	527	839	56	1081	1085
32 Texas Blackland Prairies	Run-of-River Lakes	4	6	2	89	5	164	119	4	164	159
	Rivers/Streams	15	30	50	331	143	678	604	42	681	544
33 East Central Texas Plains	Rivers/Streams	5	9	26	136	53	225	188	26	236	176
34 Western Gulf Coastal Plain	Estuaries	3	3	38	38	59	59	59	53	58	0
	Rivers/Streams	2	7	10	160	38	279	182	27	271	239
TOTAL		51	130	195	1703	510	2080	2174	254	2756	2495
Number of non-detects				2	26	73	283	748	9	75	1
% of data non-detect				1.0%	1.5%	14.3%	13.6%	34.4%	3.5%	2.7%	0.0%

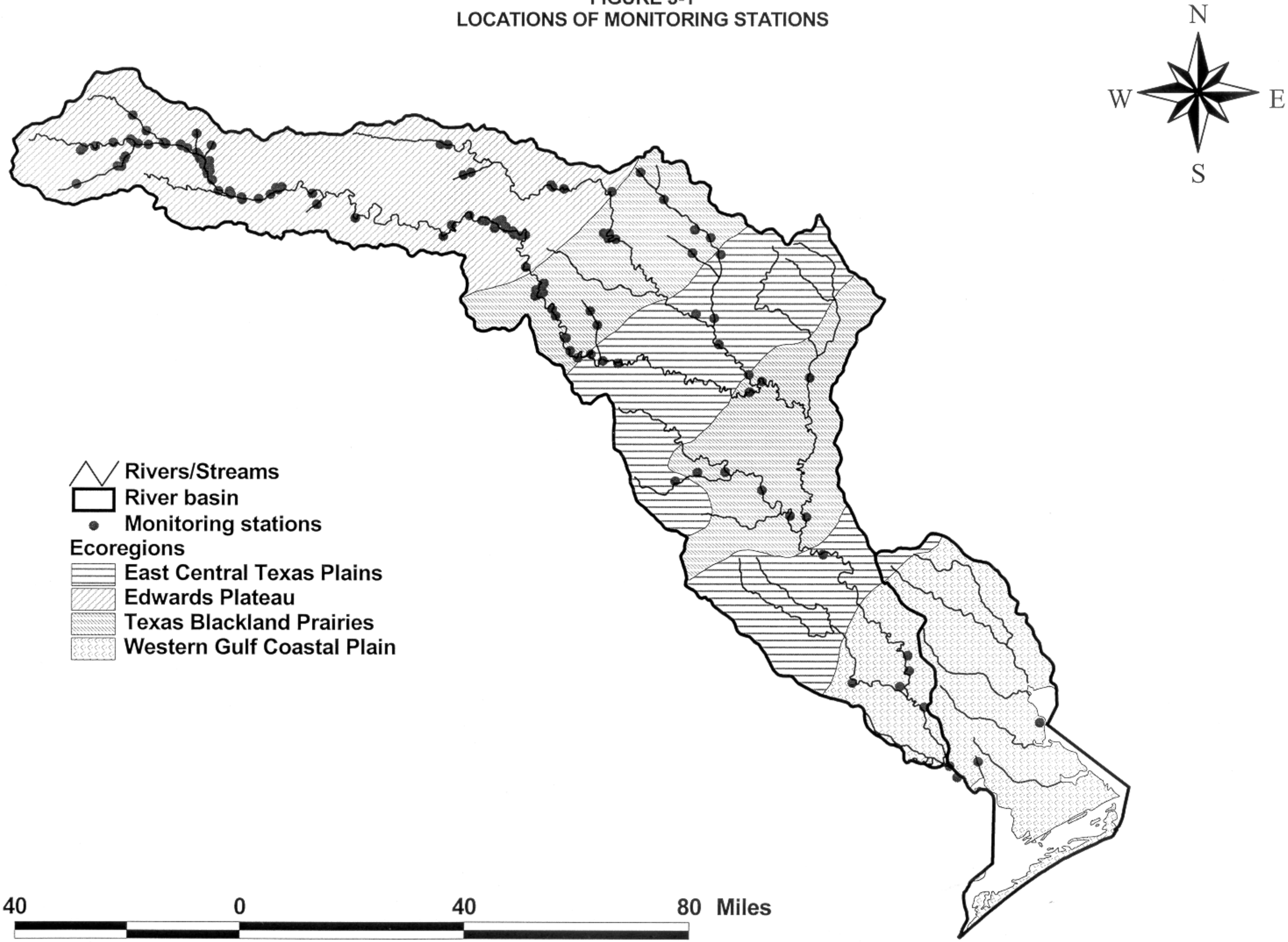
[1] Storet code of parameters:

00625 TKN
00665 TP
32211 Chl *a*
00078 Secchi depth
00530 TSS
82079 Turbidity

[2] TN is calculated as the sum of TKN (00625), nitrite nitrogen (00615) and nitrate nitrogen (00620), or the sum of TKN (00625) and nitrite-nitrate nitrogen (00630).

[3] Nitrate nitrogen (00620) or nitrite-nitrate nitrogen (00630).

FIGURE 3-1
LOCATIONS OF MONITORING STATIONS



Because the physical characteristics of the run-of-river lakes are intermediate between rivers and lakes, they were considered as a separate type of water bodies.

2. The data were grouped by season of collection, with the seasons defined as follows:

Spring	March to May
Summer	June to August
Fall	September to November
Winter	December to February

3. For each water body, the median of the data for each parameter and each season was obtained.

4. The 25^{th} percentile for a season is derived from the medians of the same type of water bodies in an Ecoregion.

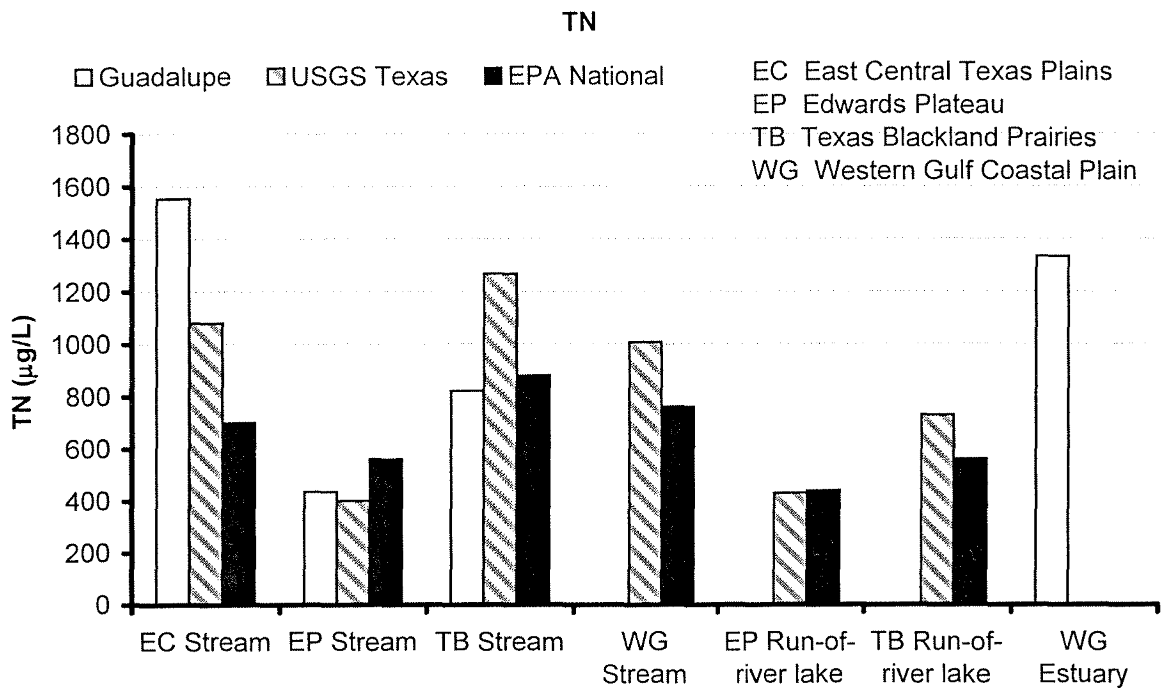
5. The 25^{th} percentile for all seasons was calculated by taking the median of the four seasonal 25^{th} percentiles.

Canyon Lake is the only lake in Ecoregion 30 (Edwards Plateau), and with only one water body the above procedure (step 4) cannot be applied. A more complicated situation is when data exist for only one water body in some seasons but for more than one water body in other seasons. As a practical matter, USGS personnel (Hornig, 2002) have observed that the percentiles of all the data yields results that are usually close to those obtained with the more detailed seasonal procedure. This would be the case where the data tend to be uniformly distributed over seasons, but might not be the case where the record was dominated by a few short-term studies. In this study, the EPA procedure was still used to obtain the 25^{th} percentile.

3.1.2 Results Presentation

Figure 3-2 presents the 25^{th} percentile of each water body type for each Ecoregion. The criteria recommended by EPA for the Aggregate Nutrient Ecoregions are also shown in the figure for comparison. The USGS has calculated the 25^{th} percentile for TN, TP and chlorophyll *a* for Ecoregions in Texas. Their results are also shown in the figure for comparison. The results by EPA and USGS do not have the run-of-river lakes category. Their lake results are used for comparison with run-of-river lake results in this study.

FIGURE 3-2
25TH PERCENTILES USING EPA METHODOLOGY



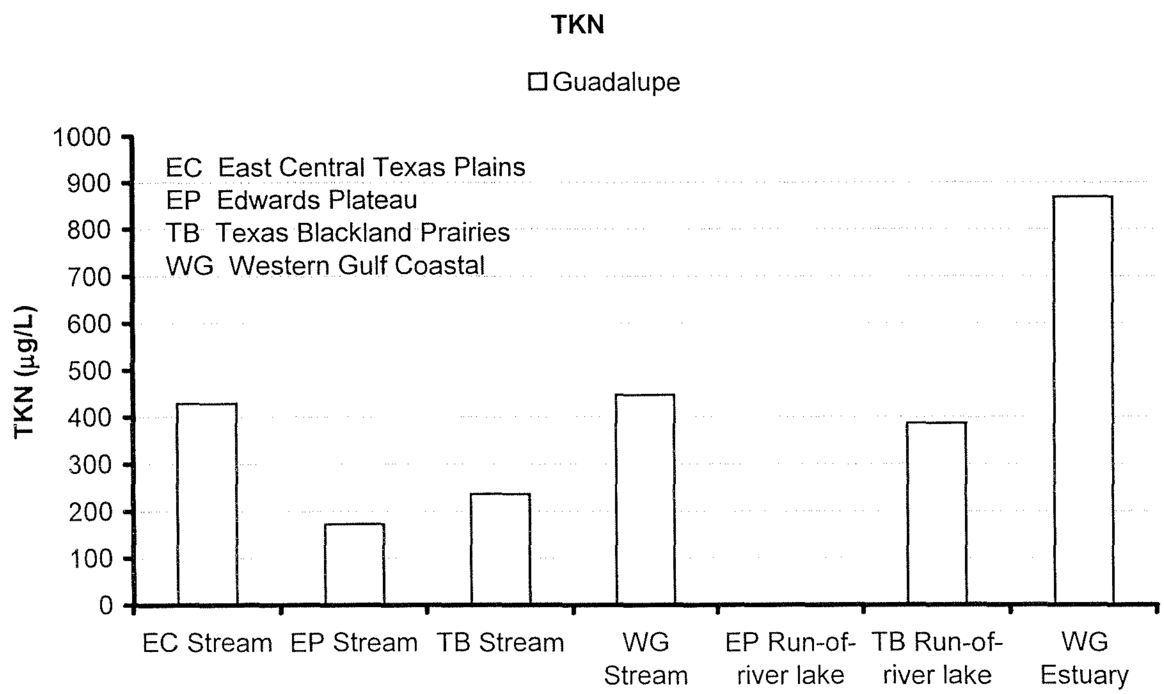
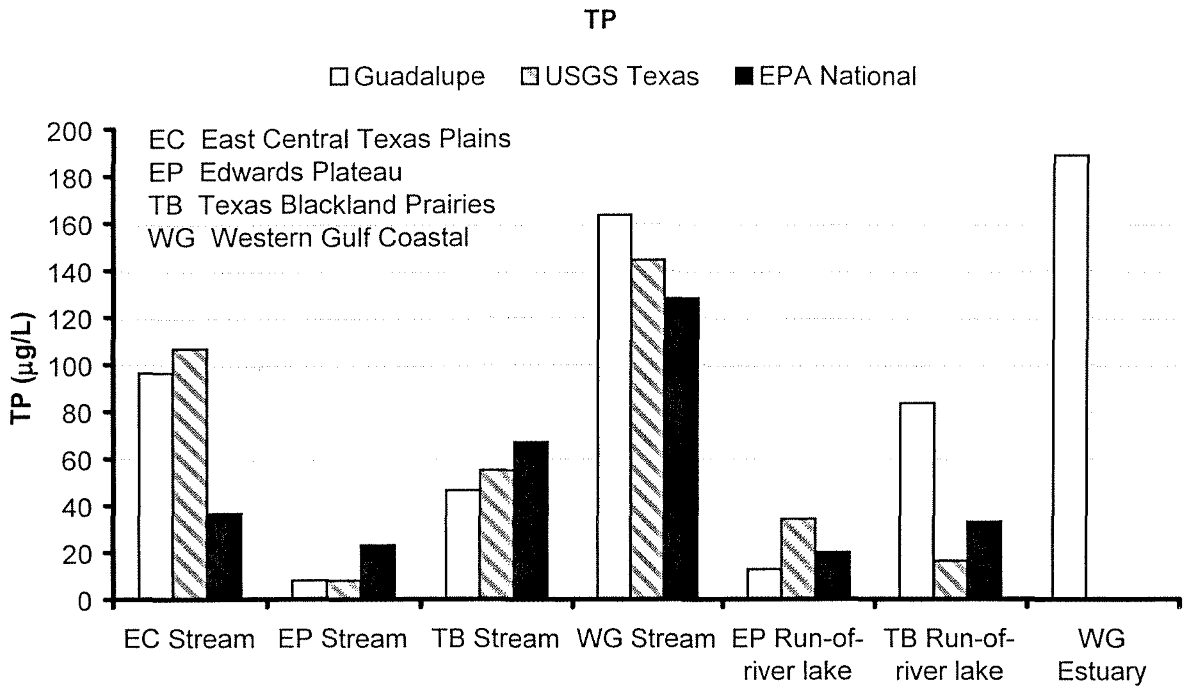


FIGURE 3-2 (CONTINUED)
25TH PERCENTILES USING EPA METHODOLOGY



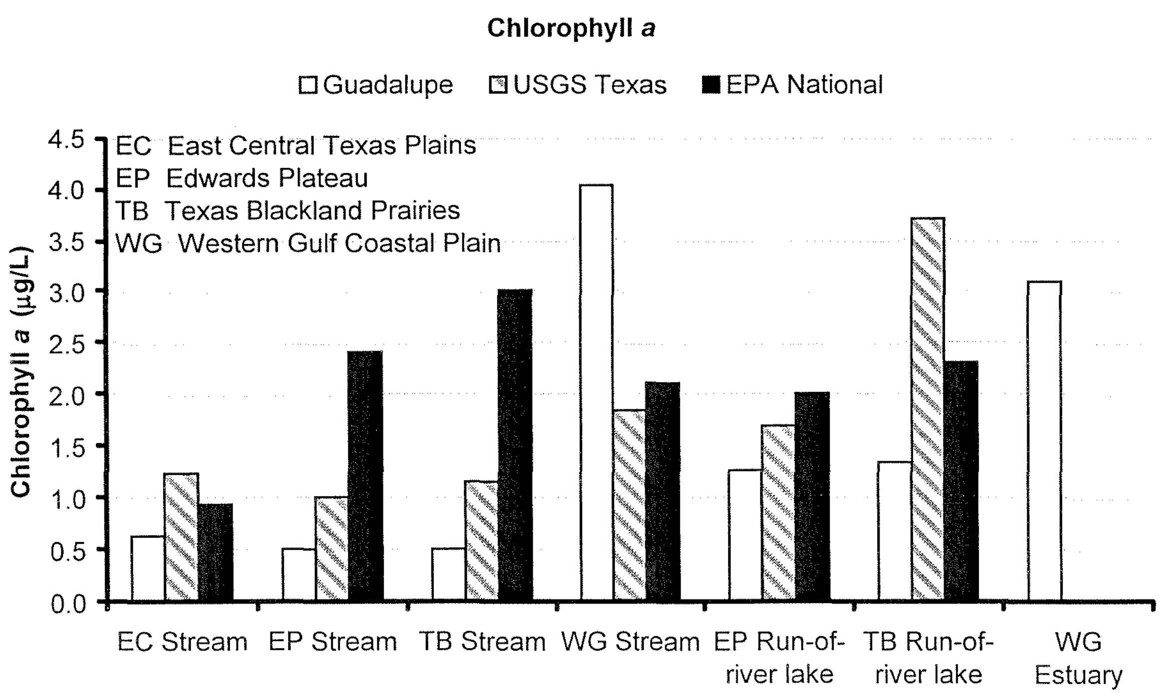
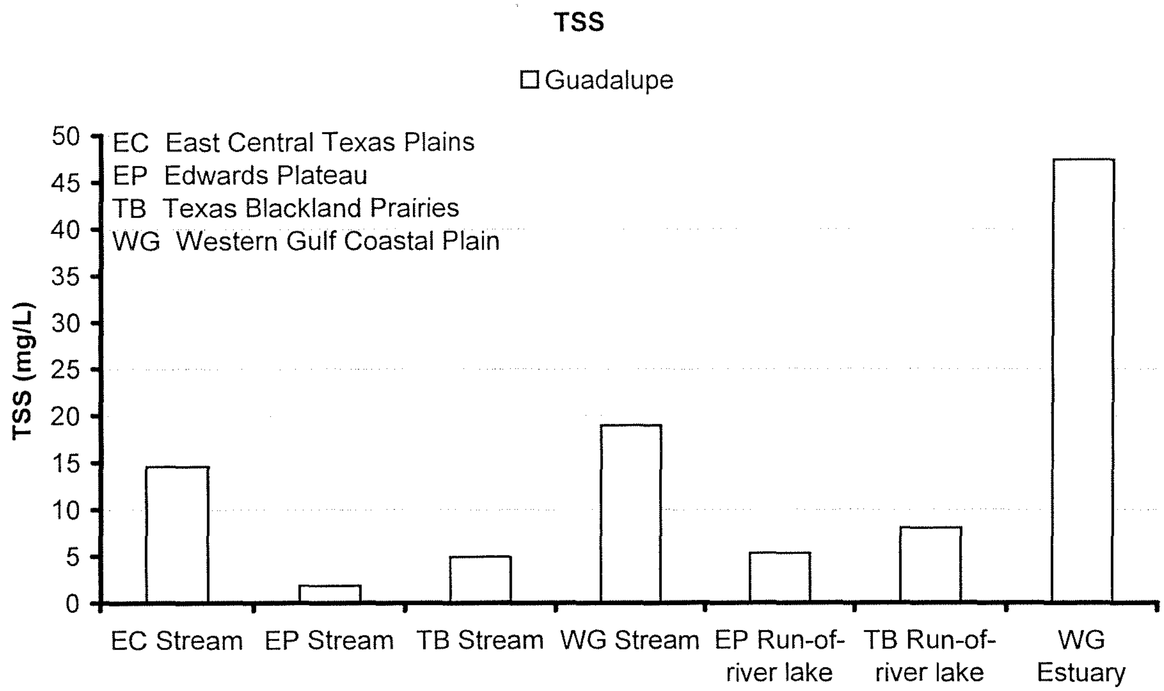
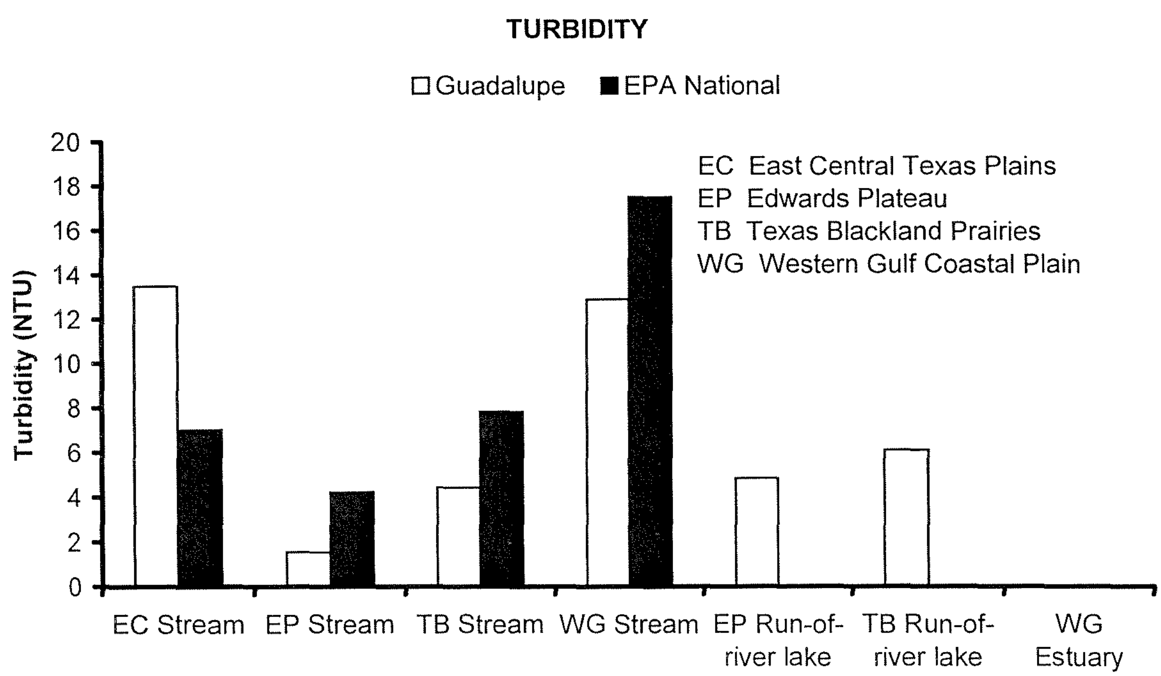


FIGURE 3-2 (CONCLUDED)
25TH PERCENTILES USING EPA METHODOLOGY





Unit in FTU for EP, TB, WG of EPA, but basically equivalent to NTU.

3.1.3 Results Discussion

Although there appears to be some correlation between results of the three studies, there are significant differences. The following table shows the average absolute percentage difference between results of this study and those of EPA and USGS for TN, TP and chlorophyll *a*.

	Comparing USGS with this study	Comparing EPA with this study
TN	31%	30%
TP	48%	72%
Chlorophyll *a*	98%	185%

The results of EPA, USGS, and this study correspond to progressively smaller regions. Discrepancies between the results suggest that it may not be appropriate to select a single criterion and apply it to a large geographic area. Variability between water bodies will likely require specific criteria to be developed for each segment. While water bodies in a small region may have more similarities, the number of water bodies is likely to be few. This poses a problem with the EPA methodology that the calculation of the quartiles may not be meaningful with a small number of water bodies.

Another problem with the methodology is that all the data of each water body are reduced to a median. This approach avoids over-representation of a water body that has many more observations than others. On the other hand, if one water body has significantly more observations than another, we should have more confidence in the data from that water body compared with the one with fewer observations. However, the EPA method gives equal weight to the medians derived for each water body.

3.2 ANALYSIS OF INDIVIDUAL RESERVOIR DATA

TNRCC's initial focus is on criteria development for reservoirs. Table 3-2 shows the number of data for Canyon Lake and the run-of-river impoundments. Nutrient data are relatively sparse and a few of the run-of-river impoundments have no data at all.

At the beginning of the Clean Rivers Program in 1992, data in the Guadalupe River Basin collected from the early 1980s to early 1990s were compiled. These older data were retrieved and the numbers of observations are shown in Table 3-3. Besides Canyon Lake and Lake Dunlap, the older database also has very few observations for the other run-of-river lakes. However, the database provides significant numbers of TN observations for Lake Dunlap. For this analysis, the older Canyon Lake and Lake Dunlap data were added to the TNRCC database.

TABLE 3-2

DATA FROM JANUARY 1993 TO JANUARY 2002 FOR LAKES AND RESERVOIRS

		Number of observations							
Level III Ecoregion	Water body	TN	NO_3-N [3]	TKN	TP	Chl *a*	Secchi depth	TSS	Turbidity
Edwards Plateau	Canyon Lake	3	80	22	134	89	46	134	108
Edwards Plateau	Center Point Lake	0	38	0	10	35	0	44	53
Edwards Plateau	Flat Rock Lake	0	1	0	0	0	0	1	1
Edwards Plateau	Lake at Louise Hays Park	0	0	0	0	0	0	0	41
Edwards Plateau	Lake at Ingram	0	39	0	2	35	0	52	45
Edwards Plateau	UGRA Lake	0	28	0	2	24	0	34	44
Texas Blackland Prairies	Lake Dunlap	2	75	2	111	67	2	111	108
Texas Blackland Prairies	Lake McQueeney	0	14	3	53	52	2	53	49
Texas Blackland Prairies	Lake Placid	0	0	0	0	0	0	0	1
Texas Blackland Prairies	Lake Wood	0	0	0	0	0	0	0	1

[1] Storet code of parameters:
- 00625 TKN
- 00665 TP
- 32211 Chl *a*
- 00078 Secchi depth
- 00530 TSS
- 82079 Turbidity

[2] TN is calculated as the sum of TKN (00625), nitrite nitrogen (00615) and nitrate nitrogen (00620), or the sum of TKN (00625) and nitrite-nitrate nitrogen (00630).

[3] Nitrate nitrogen (00620) or nitrite-nitrate nitrogen (00630).

TABLE 3-3

ADDITIONAL DATA FROM 1981 TO 1992 FOR LAKES AND RESERVOIRS

		Number of observations							
Level III Ecoregion	Water body	TN	NO_3-N [3]	TKN	TP	Chl *a*	Secchi depth	TSS	Turbidity
Edwards Plateau	Canyon Lake	2	102	12	103	32	5	33	70
Edwards Plateau	Center Point Lake	0	77	0	0	0	0	7	0
Edwards Plateau	Flat Rock Lake	2	94	2	2	1	0	9	0
Edwards Plateau	UGRA Lake	0	79	0	0	0	0	7	0
Edwards Plateau	Lake at Ingram	0	72	0	0	0	0	1	0
Texas Blackland Prairies	Lake Dunlap	60	107	60	161	32	2	32	70

[1] Storet code of parameters:

- 00625 TKN
- 00665 TP
- 32211 Chl *a*
- 00078 Secchi depth
- 00530 TSS
- 82079 Turbidity

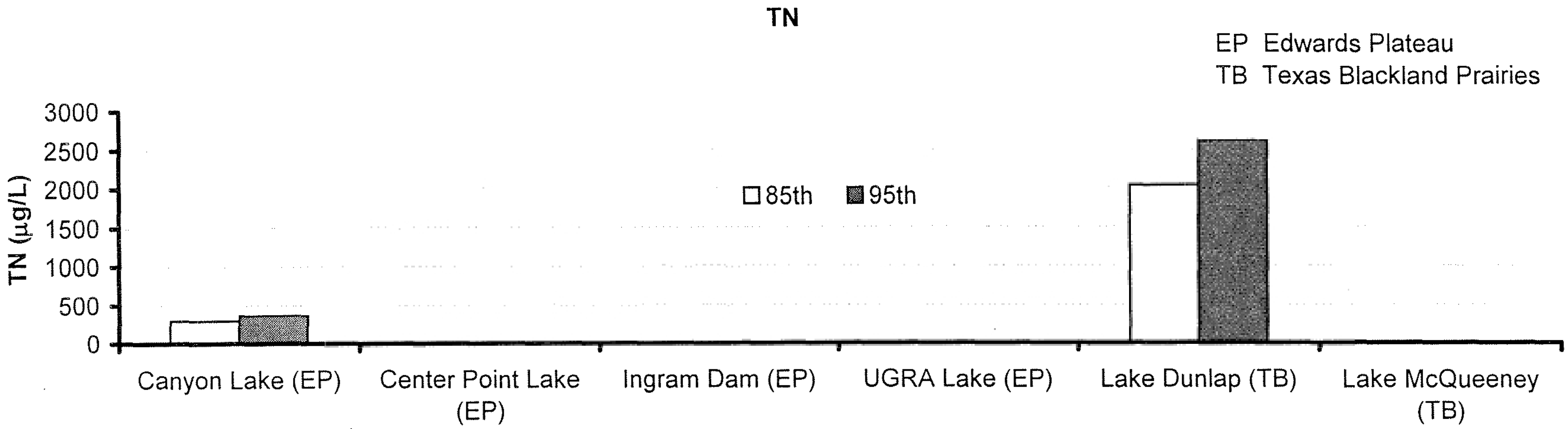
[2] TN is calculated as the sum of TKN (00625), nitrite nitrogen (00615) and nitrate nitrogen (00620), or the sum of TKN (00625) and nitrite-nitrate nitrogen (00630).

[3] Nitrate nitrogen (00620) or nitrite-nitrate nitrogen (00630).

The 85th and 95th percentiles for each parameter for the lakes are shown in Figure 3-3. TNRCC has long used 85th percentile values in screening of parameters for which there are no established criteria. The 95th percentile values were included to approximate one of the ways in which numerical water quality criteria have been established, in this case, for total dissolved solids, chlorides and sulfates. These criteria were some of the first to be set in Texas to protect the most basic of surface waters uses, public drinking water and crop irrigation. The procedure used to establish these criteria was similar to that employed by the EPA, in that it was based on a percentile of existing data and had no direct relationship to values needed to support a specific use. By basing criteria on existing data, there was implicit recognition that waters in the western part of the state tended to be saltier than waters in the east, but within limits were still suitable for their existing uses. The main value of these criteria was in providing a means of insuring that dissolved salts would not increase in concentration due to an action of man.

While the procedures are similar, the selection of very different percentile values implies a fundamentally different worldview. Use of the 95th percentile of the data for each segment and comparing the criteria obtained with the year-long average of data for the segment implies that existing conditions are acceptable and the criteria would be attained unless some major change takes place. These criteria function as a means to prevent major increases in dissolved salts. In contrast, EPA's use of the 25th percentile implies that three-fourths of the waters in each Ecoregion have been unacceptably impacted and some corrective action is needed throughout most of the state. In this case the criteria can be viewed as a mechanism to produce major changes. While it is clear that Texas has constructed many reservoirs, and perhaps most receive some amount of higher nutrient content wastewater return flows, it is not yet widely accepted that three-fourths of the state's reservoirs are impacted by nutrients to an unacceptable degree.

FIGURE 3-3
85TH & 95TH PERCENTILES FOR LAKES



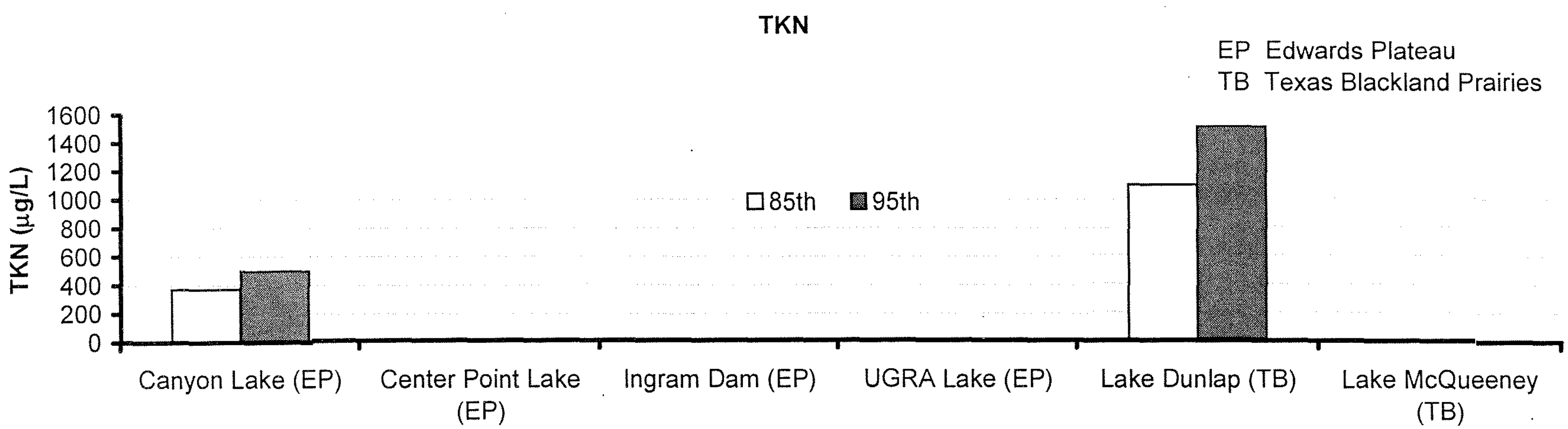
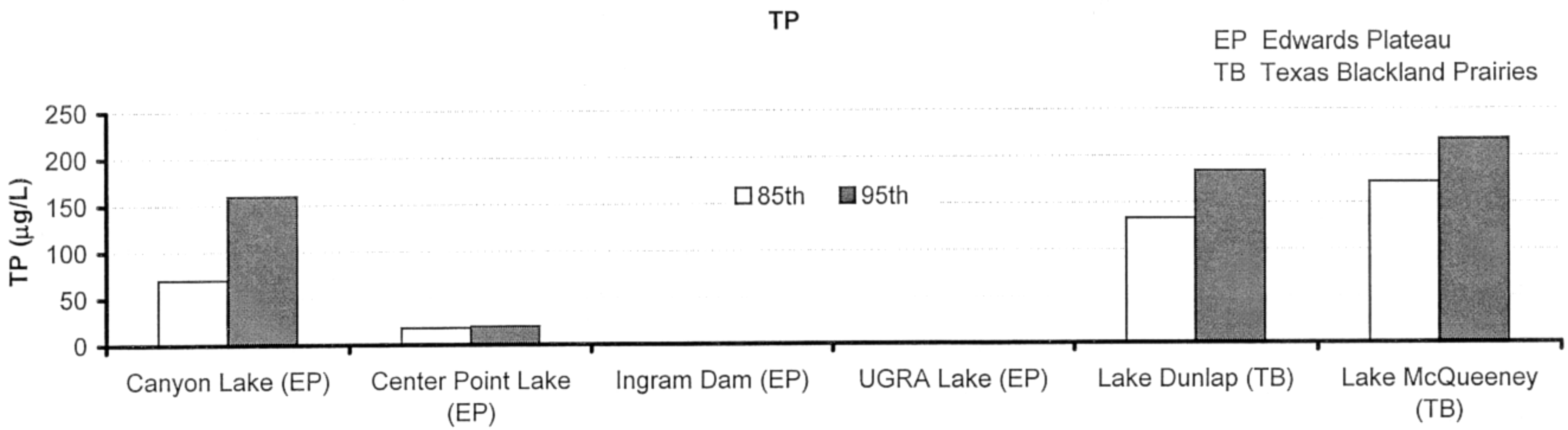


FIGURE 3-3 (CONTINUED)
85TH & 95TH PERCENTILES FOR LAKES



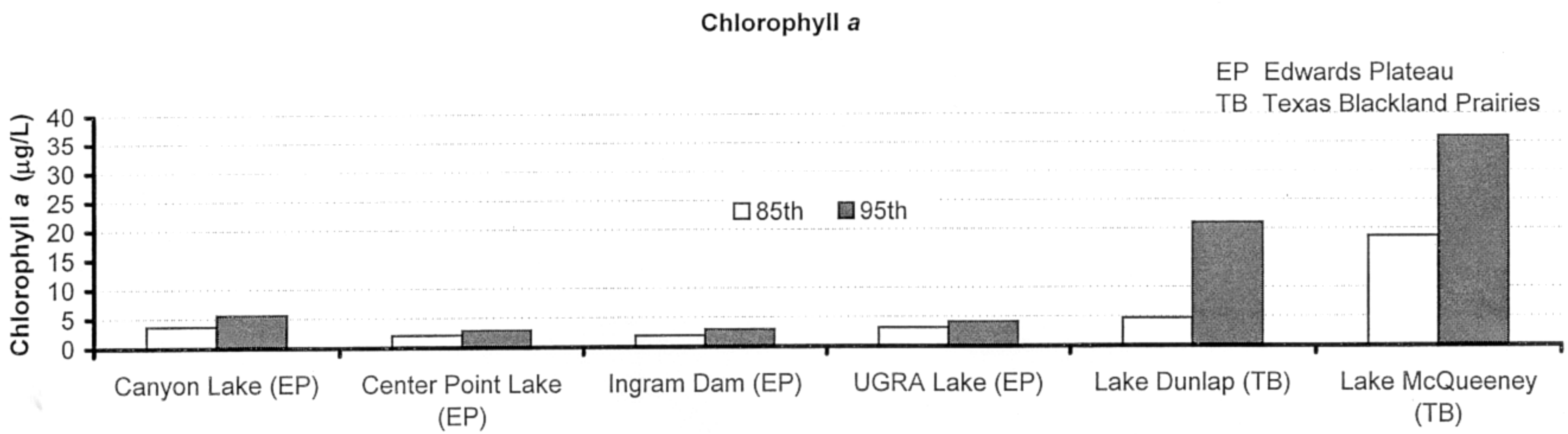
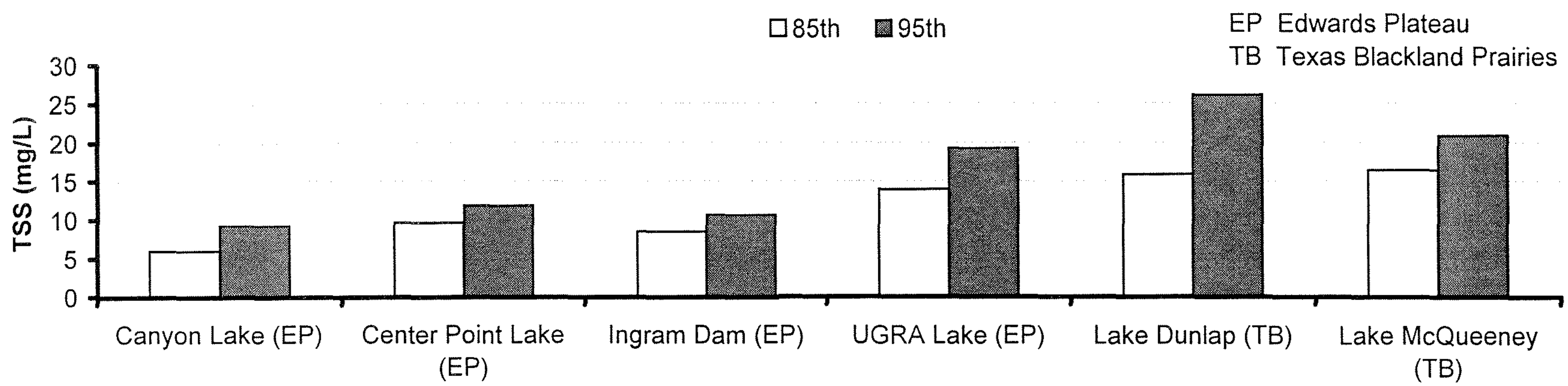
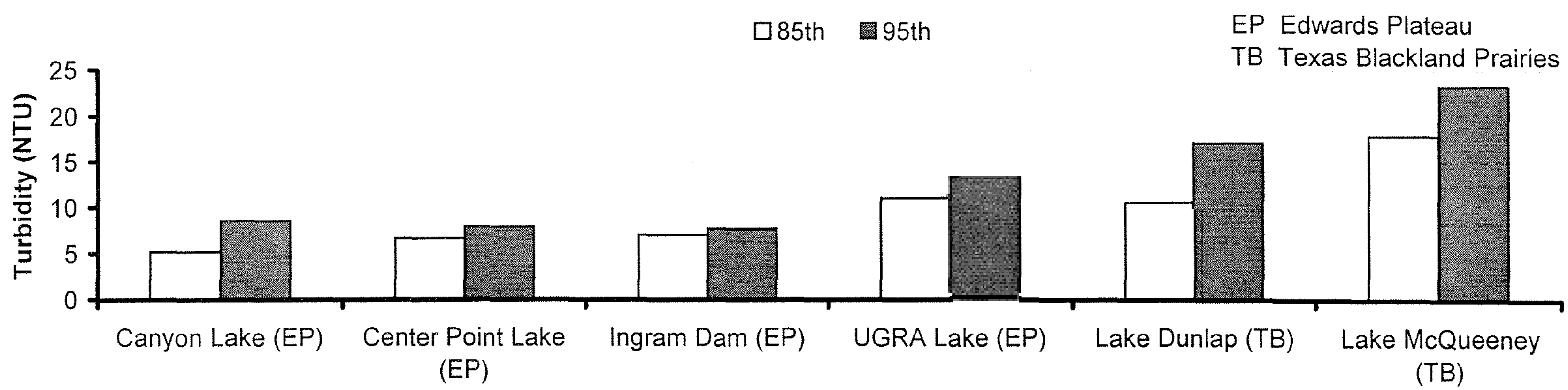


FIGURE 3-3 (CONCLUDED)
85TH & 95TH PERCENTILES FOR LAKES

TSS



Turbidity



4.0 ASSESSMENT OF POSSIBLE CRITERIA WITH BASIN DATA

The 25th percentile levels shown in the previous section represent three calculations of proposed nutrient criteria using the same methodology in progressively smaller and more specific geographic areas. This section compares these possible criteria with the actual data from basin waters and assesses, if these criteria were adopted, the likelihood of listing for failure to attain the criteria and by definition fail to support aquatic life uses. The results suggest that for most waters, criteria developed specifically to quantify support for the specific uses in each reservoir would be more appropriate.

Table 4-1 presents for most reservoirs in the basin a comparison of the criteria values proposed by the EPA and the percent of observations where the criteria would be exceeded. Similar results are shown in Table 4-2 using the USGS calculated values for the Level III Ecoregions. In reviewing these tables, note that the TNRCC has historically concluded that a designated use is not supported if more than 25% of the observations fail to meet the criterion. By this measure, UGRA Lake, one of the most pristine in the basin, would fail to meet the chlorophyll *a* criterion. Canyon Lake would fail all criteria except those with limited data, as would lakes Dunlap and McQueeney. The older data from Canyon and Dunlap show very similar results to the more recent data. The basic message of these tables is that many of the waters in the basin either have little data or if they have data, would have a high percentage of the data exceeding the proposed criteria.

Another way to assess the criteria alternatives is to simply compare the values for each reservoir. Table 4-3 presents this comparison for each reservoir. The table shows for each lake the national and Texas-based Ecoregion values, the statewide 85th percentile, and for the particular lake, the 95th and 50th percentiles along with the number of observations available.

Also shown in the table are possible criteria based on a method proposed by the TNRCC. This method is similar to that used for the development of chloride, sulfate and total dissolved solids criteria (see Attachment 1). The criteria are derived by a formula that uses the arithmetic mean, standard deviation and Student's t value for the number of data used in the calculation. The TNRCC has indicated that only data collected from the main pool of the reservoir in summer would be used for nutrient criteria development, and the number of samples used to calculate the annual mean (n_2 in Attachment 1) should be 10. Data from April to October have been used to calculate the criteria with this approach in Table 4-3. With this method, a larger number of samples in the baseline data set (n_1 in Attachment 1) would give a lower value of the criterion for the same mean and standard deviation. However, based on a few trials on actual data, the change does not seem to be significant. Reducing n_1 by half only changes the criteria by a few percent.

As shown in Table 4-3, Canyon Lake, that has been characterized as having the best water quality of any major reservoir in the state (Groeger, 2001) would not meet a TP or chlorophyll *a*

TABLE 4-1

PERCENTAGE EXCEEDANCE OF EPA CRITERIA

	Chl *a* (µg/L)	Secchi depth (m)	TN (µg/L)	TP (µg/L)
UGRA Lake				
EPA criteria	2	2	440	20
Number of observations	24	0	0	2
Percent of values exceeding criteria [1]	37.5%			0.0%
Canyon Lake				
EPA criteria	2	2	440	20
Number of observations	89	46	3	134
Percent of values exceeding criteria [1]	39.3%	43.5%	0.0%	60.4%
Lake Dunlap				
EPA criteria	2.3	1.3	560	33
Number of observations	67	2	2	111
Percent of values exceeding criteria [1]	10.4%	100.0%	100.0%	89.2%
Lake McQueeney				
EPA criteria	2.3	1.3	560	33
Number of observations	52	2	0	53
Percent of values exceeding criteria [1]	59.6%	0.0%		86.8%
Canyon Lake (include 1981 to 1992 data)				
EPA criteria	2	2	440	20
Number of observations	121	51	5	237
Percent of values exceeding criteria [1]	28.9%	39.2%	0.0%	34.2%
Lake Dunlap (include 1981 to 1992 data)				
EPA criteria	2.3	1.3	560	33
Number of observations	99	4	62	272
Percent of values exceeding criteria [1]	21.2%	50.0%	98.4%	90.1%

[1] Below criteria in case of Secchi depth.

[2] Data from 1993 to 2002.

TABLE 4-2

PERCENTAGE EXCEEDANCE OF USGS CRITERIA

	Chl *a* (µg/L)	TN (µg/L)	TP (µg/L)
UGRA Lake			
USGS criteria	1.69	430	34
Number of observations	24	0	2
Percent of values exceeding criteria [1]	41.7%		0.0%
Canyon Lake			
USGS criteria	1.69	430	34
Number of observations	89	3	134
Percent of values exceeding criteria [1]	50.6%	0.0%	50.7%
Lake Dunlap			
USGS criteria	3.69	728	16
Number of observations	67	2	111
Percent of values exceeding criteria [1]	6.0%	100.0%	95.5%
Lake McQueeney			
USGS criteria	3.69	728	16
Number of observations	52	0	53
Percent of values exceeding criteria [1]	51.9%		94.3%
Canyon Lake (include 1981 to 1992 data)			
USGS criteria	1.69	430	34
Number of observations	121	5	237
Percent of values exceeding criteria [1]	37.2%	0.0%	28.7%
Lake Dunlap (include 1981 to 1992 data)			
USGS criteria	3.69	728	16
Number of observations	99	62	272
Percent of values exceeding criteria [1]	18.2%	98.4%	97.1%

[1] Data from 1993 to 2002.

TABLE 4-3

COMPARISON OF CRITERIA FOR RESERVOIRS

	Chl *a* (µg/L)	Secchi depth (m)	TN (µg/L)	TP (µg/L)
UGRA Lake				
EPA - National	2.00	2.00	440	20
USGS - State	1.69		430	34
85th Statewide	21.40			180
TNRCC proposed method [3]	2.83			
95th percentile [4]	4.10			11
50th percentile (median)	1.39			10
Number of observations	24	0	0	2
Center Point Lake				
EPA - National	2.00	2.00	440	20
USGS - State	1.69		430	34
85th Statewide	21.40			180
TNRCC proposed method [3]	2.27			18
95th percentile [4]	2.90			20
50th percentile (median)	1.32			13
Number of observations	35	0	0	10
Lake at Ingram				
EPA - National	2.00	2.00	440	20
USGS - State	1.69		430	34
85th Statewide	21.40			180
TNRCC proposed method [3]	2.36			
95th percentile [4]	2.93			12
50th percentile (median)	0.99			9
Number of observations	35	0	0	2
Canyon Lake				
EPA - National	2.00	2.00	440	20
USGS - State	1.69		430	34
85th Statewide	21.40			180
TNRCC proposed method [3]	2.99	3.34		78
95th percentile [4]	4.74	0.90	381	154
50th percentile (median)	1.70	1.94	210	40
Number of observations	89	46	3	134
Lake Dunlap				
EPA - National	2.30	1.30	560	33
USGS - State	3.69		728	16
85th Statewide	21.40			180
TNRCC proposed method [3]	16.05			145
95th percentile [4]	4.78	2.00	1347	190
50th percentile (median)	0.50	2.00	1320	90
Number of observations	67	2	2	111
Lake McQueeney				
EPA - National	2.30	1.30	560	33
USGS - State	3.69		728	16
85th Statewide	21.40			180
TNRCC proposed method [3]	22.19	0.39		129
95th percentile [4]	36.00	0.47		218
50th percentile (median)	4.20	0.60		80
Number of observations	52	2	0	53

TABLE 4-3 (CONCLUDED)

COMPARISON OF CRITERIA FOR RESERVOIRS

	Chl *a* (μg/L)	Secchi depth (m)	TN (μg/L)	TP (μg/L)
Canyon Lake (include 1981 to 1992 data)				
EPA - National	2.00	2.00	440	20
USGS - State	1.69		430	34
85th Statewide	21.40			180
TNRCC proposed method [3]	3.42	3.25	228	116
95th percentile [4]	5.60	0.88	365	160
50th percentile (median)	2.00	1.98	215	30
Number of observations	121	51	5	237
Lake Dunlap (include 1981 to 1992 data)				
EPA - National	2.30	1.30	560	33
USGS - State	3.69		728	16
85th Statewide	21.40			180
TNRCC proposed method [3]	23.26	0.63	2015	156
95th percentile [4]	21.03	0.87	2590	185
50th percentile (median)	0.67	1.50	1400	90
Number of observations	99	4	62	272

[1] 85th percentile statewide screening levels for nitrogen are 106 μg/L for NH_3-N and 320 μg/L for NO_2+NO_3-N.

[2] Data from 1993 to 2002.

[3] For Secchi depth, criterion is the mean minus t times standard error (refer to Attachment 1).

[4] 5th percentile in case of Secchi depth.

criteria that was based on the ecoregional approach. However, the 95th percentile chlorophyll *a* value of 4.7 μg/L is much lower than the statewide 85th percentile and only marginally higher than the national and state 25th percentile values. The chlorophyll *a* data for Lake McQueeney are higher than for Lake Dunlap immediately upstream. The older data for Canyon and Dunlap appear very consistent with the newer data. It appears that the TNRCC proposed method that considers actual reservoir data is less likely to result in an inappropriate or unattainable criterion.

Table 4-4 presents a similar comparison for rivers and streams. Since there are many more distinct streams, the table is organized in a more compact form. For each major Ecoregion the national and state values are presented followed by a listing of the number of observations and the median and 95th percentile values for each individual stream. The streams in each Ecoregion include both the main stem of the Guadalupe and the smaller tributaries that have some data but are not designated segments.

Most of the streams have very low chlorophyll *a* values. A common 50th percentile value is 0.5 μg/L, which stems from the high number of observations at the reporting limit of <1. The Blackland Prairies and East Central Plains streams have higher levels than the Edwards Plateau streams.

For turbidity, a high proportion of the streams have median values that exceed the proposed criteria, particularly in the lower basin. The same basic observation can be made for the TN and TP criteria in basin streams.

A key point with rivers and streams is that the main measure of excess nutrients is not planktonic chlorophyll *a*, but attached algae and larger aquatic plants. At present there are very limited data on these types of aquatic plants upon which to base an assessment of use support and criteria needed.

A basic finding of the comparisons is that there does not appear to be a consistent pattern with the Ecoregion-based criteria. It is difficult to justify using these percentile results as a basis for stating that the aquatic life use is not supported and a TMDL is needed to establish and allocate a reduced load of nutrients. Rather, these percentile approaches appear to be primarily useful as a starting point, prompting efforts at developing criteria for particular waters that may have some degree of stress and that might reasonably benefit from nutrient management. In this role it is clear that the proposed criteria have enjoyed a measure of success.

TABLE 4-4

COMPARISON OF CRITERIA FOR RIVERS AND STREAMS

Water body	Chlorophyll a (μg/L)			Turbidity (NTU)			TN (μg/L)			TP (μg/L)		
	Number of obs	50th percentile	95th percentile	Number of obs	50th percentile	95th percentile	Number of obs	50th percentile	95th percentile	Number of obs	50th percentile	95th percentile
EDWARDS PLATEAU												
EPA - National		2.40			4.21 [2]			560			23	
USGS - State		1.00						401			8	
85th Statewide [1]		11.60									800	
BLANCO RIVER	96	0.50	7.82	58	2.00	4.97	19	510	964	122	20	140
CAMP MEETING CREEK	34	0.97	3.41	4	1.65	14.72	0			4	13	19
CYPRESS CREEK	61	0.50	2.67	15	1.50	3.75	12	315	524	35	10	186
GOAT CREEK	17	0.50	1.44	0			0			0		
GUADALUPE RIVER	338	0.70	3.62	624	5.30	11.00	8	660	3216	274	25	170
INDIAN CREEK	1	0.60	0.60	2	2.30	2.75	0			2	12	18
JOHNSON CREEK	52	0.50	2.85	53	6.10	16.00	8	585	1373	24	10	29
BIG JOSHUA CREEK	1	2.20	2.20	1	0.50	0.50	0			1	5	5
LITTLE BLANCO RIVER	2	0.96	1.37	0			3	140	239	3	10	19
NORTH FORK GUADALUPE RIVER	68	0.44	1.48	142	1.60	3.00	8	570	1628	28	10	37
QUINLAN CREEK	23	1.01	2.19	2	9.80	14.48	0			2	27	41
SOUTH FORK GUADALUPE	78	0.50	2.05	182	2.60	5.70	8	555	844	28	10	30
THIRD CREEK	2	0.03	0.05	0			0			0		
TOWN CREEK	21	0.46	2.18	0			0			0		
TURTLE CREEK	19	0.40	1.68	0			0			0		
VERDE CREEK	26	0.64	1.75	2	0.95	1.09	0			4	7	10
TEXAS BLACKLAND PRAIRIES												
EPA - National		3.00			7.83 [2]			880			67	
USGS - State		1.15						1268			55	
85th Statewide [1]												
ANDREWS BRANCH OF PORTER CREEK	1	7.40	7.40	0			0			1	200	200
BLANCO RIVER AT HAYS	11	1.39	3.48	0			6	605	840	10	20	97
CLEAR FORK OF PLUM CREEK	4	0.50	0.50	0			4	4965	8486	2	45	59
COMAL RIVER	87	0.50	1.61	87	1.40	4.76	10	1775	1961	137	25	102
DRY COMAL CREEK	63	2.30	8.11	62	3.85	26.48	0			63	80	219
ELM CREEK	9	8.00	54.90	3	36.00	197.10	0			0		
GERONIMO CREEK	65	0.50	2.38	65	10.00	21.80	0			65	70	148
GUADALUPE RIVER	167	1.70	9.49	175	13.00	84.30	10	590	3243	212	110	425
LOWER SAN MARCOS RIVER	15	0.50	2.79	0			9	1200	1616	15	70	140
PEACH CREEK	65	2.70	12.80	66	25.00	87.00	0			65	330	556
PLUM CREEK	7	0.50	25.52	2	25.50	27.75	0			6	425	1165
SANDIES CREEK	64	2.30	19.90	58	30.00	76.35	0			56	405	903
SAN MARCOS RIVER	10	1.25	4.79	10	18.50	69.40	0			10	135	501
UPPER SAN MARCOS RIVER	36	0.50	2.94	16	1.75	2.95	11	1240	1610	36	23	203
EAST CENTRAL TEXAS PLAINS												
EPA - National		0.93			7.02			700			37	
USGS - State		1.23						1082		127	107	
85th Statewide [1]												
ELM CREEK	9	0.50	6.20	3	37.00	188.20	0			0		
GUADALUPE RIVER	21	0.50	9.24	0			7	1340	2012	21	60	260
LOWER SAN MARCOS RIVER	77	0.50	5.00	110	12.70	50.75	10	1395	1980	124	100	317
PLUM CREEK	78	1.80	10.72	63	16.20	106.00	8	3440	4770	77	510	1344
WALNUT CREEK	3	12.40	14.74	0			1	13720	13720	3	2620	2818
WESTERN GULF COASTAL PLAIN												
EPA - National		2.10			17.5 [2]			760			128	
USGS - State		1.84						1008			144	
85th Statewide [1]												
COLETO CREEK	94	3.37	12.54	109	6.80	21.00	8	480	1701	139	80	160
GUADALUPE RIVER	88	4.64	16.72	130	36.50	151.00	2	1955	2068	140	428	1111

[1] 85th percentile statewide screening levels for nitrogen are 170 μg/L for NH_3-N and 2760 μg/L for NO_2+NO_3-N.

[2] Unit in FTU, but basically equivalent to NTU.

5.0 DISCUSSION AND RECOMMENDATIONS

The previous sections have presented an evaluation of nutrient criteria that have been proposed by the EPA. The agency has stated its intent to impose their proposed criteria unless states provide suitable alternatives. Texas has agreed to address nutrient criteria for reservoirs by the end of 2004.

In evaluating these criteria and calculating the values using the proposed methods on national, state and only basin data, the basic conclusion is that there is a great deal of variability depending on the geographic area employed. Furthermore, there does not appear to be a technical basis behind the criteria. It is not clear that if those criteria were attained the use would be supported or vice versa. If they were applied, the result would be that a high proportion of the waters in the basin would be found to not support the aquatic life use. This conclusion would theoretically lead to a TMDL study to allocate reduced nutrients to the waters of the basin. Leaving aside the question of whether there may or may not be a need to reduce nutrients to a particular waterway to maintain a specific use, any decision on this point is likely to involve significant public costs and should have a technically defensible basis.

Late in this study process, the TNRCC announced its intent to not employ the ecoregion approach but rather to move to an approach based on data for each reservoir. The alternatives evaluated in Section 4 include this new approach now being considered. This would seem to be a major improvement as it will greatly reduce the likelihood of an inappropriate or unattainable criterion being imposed. As the process evolves it is still important that interests in the basin stay in close touch with the process and work to insure that both the uses and the criteria are appropriate to each water body.

We recommend that the key entities in the basin work with the TNRCC in the development of new standards that are appropriate to the major waters of the basin. These new standards should have expanded and more specific definitions of expected uses, and specific criteria established that are technically tied to the support of these uses. The recent project supported by the Water Environment Research Foundation (WERF, 2002) to define methods for establishing site-specific nutrient standards would be one source of information among many.

A major element and consideration in development of numerical criteria are the data employed in the process. With the data there are a number of issues that need to be recognized and ultimately addressed. These include the reliability and reporting limits of the historical data, recent trends in reporting limits for new data, and actions needed to improve the utility of all data.

As noted in the preceding sections that are based on the existing data, a substantial part of the available nutrient and chlorophyll *a* data are reported as less than, “<” values. This is a consequence of using analytical methods that were originally developed to characterize water such as wastewater that tend to have higher concentrations, and applied to ambient waters that tend to have low concentrations,

particularly in the Guadalupe River Basin. The "less than" means the actual value of the parameter is lower than the ability of the test measure with acceptable accuracy. With this result all the user of the data knows is that the true result is somewhere between the reporting limit and zero. In these cases, the convention of using one half of the reporting limit in the analysis is followed. This provides a value to use in the statistical analysis, but it is not a value that can be accorded a high degree of confidence.

In recent years the TNRCC has increased efforts to be sure that the data that are produced are accurate and reliable. They have specified detailed procedures to establish Ambient Water Reporting Levels (AWRLs) that are intended to insure that the reported data are technically valid. As a practical matter, this sometimes means that the reporting levels using the same sampling and analysis procedures have to increase. An example is chlorophyll *a*, where a typical reporting level in the existing database is 1 μg/L, is now increased to 10 μg/L. This higher level means that a higher proportion of the routine monitoring data will join the ranks of the "less than". Also, the higher the AWRL, the less validity that can be placed on the half-reporting limit assumption. Perhaps most importantly, with a reporting level of 10 μg/L, most of the criteria values considered in this report could not be measured and would thus have no utility.

Note that this is not intended as an argument against accuracy. However, there is a balance that must be achieved that considers the intended use of the data. Where the intended use is an enforcement or legal proceeding, accuracy must take priority. However, in cases involving developing understanding of biochemical processes, it is often more useful to report the best estimate value that is at the ragged edge of the equipment capabilities, than it is to merely say the value is less than some much larger number. To the extent that the AWRL procedures reduce the relevance of the results, the improved accuracy may not be a true benefit.

Both the high proportion of non-detects in the historical record, and the increasing number on non-detects expected in the future record, highlight the need for improved analytical methods to address nutrients in the Guadalupe River Basin. This will involve increased cost for the application of equipment and procedures that already exist, and increased cost for participation in the development of new procedures that are appropriate to the unique situations in the basin. This will be a process that can be expected to take a number of years, but ultimately yield data that will be appropriate to the challenge of managing nutrients in the waters of the Guadalupe River Basin.

6.0 REFERENCES

Gibson, G. 2001. EPA Headquarters. Nutrient Criteria presentation in Dallas August 29-30, 2001.

Groeger, A. 2001. Presentation to Canyon Regional Steering Committee, December 4, 2001.

Hornig, E. 2002. Presentation to TNRCC Nutrient Criteria Development Advisory Work Group meeting, May 20, 2002.

National Research Council. 2001. Assessing the TMDL Approach to Water Quality Management.

U.S. Environmental Protection Agency (EPA). 2000a. Nutrient Criteria Technical Guidance Manual – Lakes and Reservoirs.

———. 2000b. Nutrient Criteria Technical Guidance Manual – Rivers and Streams.

———. 2001. Nutrient Criteria Technical Guidance Manual – Estuarine and Coastal Marine Waters.

Texas Natural Resource Conservation Commission. 2001. Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data, 2002.

Water Environment Research Federation. 2002. Summary of project 99-WSM-3, Develop Technically-Based Site-Specific Measures for Identifying the Ecological Impacts Associated with Nutrients.

ATTACHMENT I

ATTACHMENT I

Development of Chloride, Sulfate and Total Dissolved Solids Criteria in the Texas Surface Water Quality Standards
(provided by the Texas Natural Resource Conservation Commission)

Currently these criteria are developed from ambient data for each individual segment within a river basin. From time to time the criteria may be recalculated to reflect the expanding data base. If recalculations are performed care must be taken to ensure that a pollution source is not responsible for increased concentrations of these parameters. The actual criteria are derived by a formula which utilizes the arithmetic mean, standard deviation and Student's t value for the number of data values used for each calculation. Water quality standards attainment is evaluated as an annual mean of at least four samples taken on different dates not to exceed the derived criterion.

The calculation is based on the minimum value for the annual mean TDS, chloride or sulfate would have to attain such that a Student's t test would reject the null hypothesis that the annual mean and the mean of the baseline data were drawn from the same population with a probability of 0.05 (one-tailed). Assumes annual mean is based on at least four samples and the variances of the baseline data set and data used for calculating the annual mean are the same.

Calculated as follows:

Criterion = $\bar{x}_1 + t_{(1)(0.05)}(s_{\bar{x}1 - \bar{x}2})$

Where: criterion = the value the annual mean should not exceed

$\bar{x}_1$ = mean of the baseline data set

$t_{(1)(0.05)}$ = critical value of the t distribution where $\propto = 0.05$ one tailed at $n_1 + 4$ degrees of freedom

$s_{\bar{x}1 - \bar{x}2}$ = standard error for the difference of two means

$= \sqrt{(s_p^2/n_1 + s_p^2/n_2)}$

Where: n_1 = number of samples in baseline data set

$n_2 = 4$ = number of samples used to calculate annual mean

$s_p^2 = 2(s^2(n_1 - 1))/(n_1 + 2)$

s = standard deviation of the baseline data

Reference: Moore, D. S. and G. P. McCabe. 1993. The pooled two-sample t procedures. pp 542-549. In *Introduction to the practice of statistics*. W. H. Freeman and Company, New York.